Technical University of Denmark

Technical University of Denmark

Proceedings of the

24th European Conference on e-Learning

Technical University of Denmark (DTU), Denmark

23-24 October 2025



Dr MD Saifuddin Khalid

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Proceedings of the
24th European Conference on e-Learning

ECEL 2025

A Conference
Hosted By
Technical University of Denmark
(DTU),Denmark

23-24 October 2025

Edited by Dr MD Saifuddin Khalid

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About the 24th European Conference on e-Learning, 2025

The European Conference on e-Learning (ECEL) is a prominent academic conference that serves as a platform for researchers, educators, and practitioners in the field of e-learning to share and discuss their findings and insights. With a history spanning 24 years, the conference has established itself as a vital forum for exploring advancements and innovations in e-learning. The Proceedings of the 24th European Conference on e-Learning, 2025 includes academic research papers, PhD research papers, Master's Research papers and work-in-progress papers, which have been presented and discussed at the ECEL 2025 conference. The proceedings are of an academic level appropriate to a professional research audience including graduates, post graduates, doctoral and post-doctoral researchers. All papers have been double-blind peer reviewed by members of the Review Committee.

Aims and Scope

The primary aim of ECEL is to foster collaboration and knowledge exchange among those involved in e-learning. It seeks to advance the field by providing a space where latest research, technologies, and pedagogical strategies can be presented. The conference encourages participation from a diverse group of attendees, including academics, industry experts, and policy-makers, reflecting the multifaceted nature of e-learning.

Topics Covered

The call for papers for the ECEL conference asked for contributions that considered the following topic. In addition, the committee welcomed papers on a number of specialist mini-tracks which can be seen at the end of this list.

- **Educational Technologies**: Innovations in digital tools and platforms designed to enhance learning experiences.
- **Blended Learning:** Strategies for effective teaching and learning in online and hybrid environments.
- **Distance Education**: Best practices and challenges in implementing distance learning programs.
- **Learning Analytics**: Use of data to improve educational outcomes and personalize learning experiences.
- **Inclusive Education**: Addressing accessibility and inclusivity in e-learning environments.
- **Mobile Learning**: Exploring the impact of mobile technology on education.
- **Game-Based Learning**: Integration of games and gamification in educational contexts to encourage engagement and motivation.

Experts in the field proposed mini tracks on the following topics. Papers accepted on these topics after the double-blind peer review process were presented as mini tracks at the conference and are also published in these proceedings.

- Artificial Intelligence in Education, a Lifelong Learning Challenge

The programme from the 2024 conference can be downloaded from here and full details about the conference can be seen from the conference website: https://www.academic-conferences.org/conferences/ecel/

ECEL Preface

These proceedings represent the work of contributors to the 24th European Conference on e-Learning (ECEL 2025), hosted by ACI and the Technical University of Denmark (DTU), Denmark on 23-24 October 2025. The Conference Chair is Dr. Md Saifuddin Khalid from the Department of Applied Mathematics and Computer Science, DTU, Denmark and the Programme Chair Dr. Tobias Tretow-Fish from Department of Culture and Learning Aalborg University (AAU), Denmark.

ECEL is now a well-established event on the academic research calendar and in its 24th year the key aim remains the opportunity for participants to share ideas and meet the people who hold them. The scope of papers will ensure an interesting two days. The subjects covered illustrate the wide range of topics that fall into this important and ever-growing area of research.

The opening keynote presentation is given by Prof. Christian Stöhr from Chalmers University of Technology, Gothenburg, Sweden, who will discuss *From Learning to AI to AI for Learning: Navigating Hype and Hope of Generative AI in Higher Education*. We will also have a keynote speech from Prof. Iza Marfisi from Le Mans University, France who will discuss *If You build It… Will Teachers Use It? Bridging the Gap Between TEL Research and Real Classrooms*. The second day of the conference will begin with an address by Prof. Thomas Ryberg from Aalborg University, Denmark on the topic of *Expanding Digital Learning Spaces*.

With an initial submission of 114 abstracts, after the double blind, peer review process there are 49 Academic research papers, 5 PhD research papers and 5 work-in-progress papers published in these Conference Proceedings. These papers represent research from, Bulgaria, Canada, Czech Republic, Denmark, El Salvador, Finland, France, Germany, Greece, Hong Kong, China, Hungary, Ireland, Japan, Malaysia, Malta, Morrocco, Norway, Oman, Pakistan, Palestine, Serbia, Singapore, Slovakia, South Africa, Sri Lanka, Sweden, Switzerland, Thailand, Turkey, UK and USA.

We hope you enjoy the conference.

Dr Md Saifuddin Khalid
Associate Professor
Leader of LearnT -Centre for Digital Learning Technology
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Technical University of Denmark (DTU)
Denmark

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University of Florida, Gainesville, USA, Prof Stephen Alstrup, Department of Computer Science, University of Copenhagen, Denmark, Prof Susana Silva, School of Hospitality and Tourism, Institute Polytechnic of Porto, Portugal, Prof Vitor Santos, New University of Lisbon, Portugal, ramakanth evani, Independent Technoly Researcher, US, René Holm Andersen, University College of Northern Denmark, Aalborg, Denmark, Runa Jesmin, Global Heart Forum, UK, Satyadhyan Chickerur, B V Bhoomaraddi College of Engineering and Technology, Hubli, India, Sumowalt Roosevelt, Liberia Initiatives For Fostering Empowerment, Inc., Liberia, Susannah Quinsee, City University, London, UK, Thomas Goetz, Hokusei Gakuen University, Sapporo, Japan, Tobi Mark, The Michener Institute of Education at UHN, Toronto, Canada, Vasileios Paliktzoglou, University of eastern Finland, Finland, Veerabhadram Paduri, Namibia University of Science and Technology, Namibia

Conference and Programme Chairs



Dr. Md Saifuddin Khalid, is an Associate Professor at the Technical University of Denmark (DTU) with expertise in digital learning technologies, user experience, and human-centered design. Leading the LearnT – Centre for Digital Learning Technology, Dr. Khalid teaches courses in digital learning and statistics, mentors Ph.D. students, and supervises projects in adaptive learning, e-learning, and innovation in education and workplace training technologies. His research spans diverse areas, including evaluating EdTech platforms, integrating generative AI, adaptive technologies, and enhancing usability in digital education and training. With extensive academic experience in Denmark and a commitment to bridging digital divides, Dr. Khalid actively contributes to interdisciplinary R&D projects, funded by Erasmus+, Novo Nordisk, and Innovation Fund Denmark. He has an established record of publications in educational technology and human-computer interaction, aiming to foster inclusive, impactful digital solutions for education and training.



Dr. Tobias Tretow-Fish, is an Assistant Professor at University College Absalon's School and Learning research group 'DigiLær'. His research focuses on leveraging AI technologies to enhance educational outcomes, particularly in the health and vocational sectors. In Danish nursing education, Tobias has extensively evaluated the implementation of adaptive learning platforms, developing methodologies to assess their impact on student learning and teacher integration. Currently, he is part of a national project exploring the potential of Generative AI in STEM education within vocational training. As an academic and researcher, Tobias is dedicated to using AI and learning analytics to transform educational practices, aiming to foster deeper engagement and personalized learning experiences

Keynote Speakers



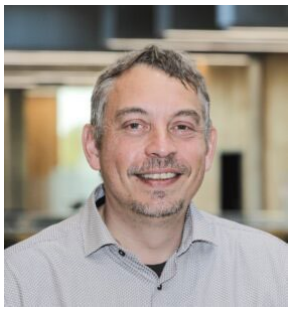
Prof. Christian Stöhr leads the Digital Learning and Teaching research theme within the Department of Communication and Learning in Science at Chalmers University of Technology, Gothenburg, Sweden. His work focuses on developing and evaluating evidence-based strategies to enhance learning in engineering education, with particular expertise in flipped and hybrid pedagogies, AI-assisted teaching and learning, online course design, and Massive Open Online Courses (MOOCs). Professor Stöhr's publications highlight the impact of digital technology on STEM learning, teacher development, and educational practices



Prof. Iza Marfisi is a Full Professor at the LIUM lab, which hosts one of the largest research teams in France focused on Technology-Enhanced Learning (TEL). Her primary research interests revolve around the development of authoring tools designed to assist educators in creating personalized educational environments. Specifically, she is dedicated to supporting teachers in the creation of custom Serious Games and using innovative Human-Computer Interaction technologies, such as Mixed Reality, Virtual Reality, and tangible objects, to enhance teaching and learning experiences. Her projects consistently involve pioneering educators who collaborate in the co-design and testing of these tools within real classroom settings. In her keynote talk, Professor Marfisi will discuss the critical importance of working directly with teachers to ensure the validity of research outcomes. She will also address the challenges that lie ahead in transforming today's educational practices based on research results.

Prof. Thomas Ryberg is Professor of PBL and digital learning and director of Institute for Advanced Study in PBL (IAS PBL). His primary research interests are within the fields of Networked Learning and Problem Based Learning (PBL). In particular, he is interested in Problem Based Learning, and how new media and technologies transform our ways of thinking about and designing for networked and hybrid Learning. He is co-chair of the International Networked Learning Conference and co-editor of the Springer book series 'Research in Networked Learning'. He has participated in European and international research projects and networks (EQUEL, Kaledioscope, COMBLE, PlaceMe, EATrain2, ODEdu), and in development projects in Southeast Asia and Latin America (VISCA, VO@NET, ELAC). He was recently engaged in the PBL future project which developed new directions for PBL in a digital age.

Mini Track Chairs



Associate Prof. Peter Mozelius is an Associate Professor and Researcher, working at the Department of Education at the Mid Sweden University in Sundsvall, Sweden. His research interests are in the fields of Technology enhanced learning, Game-based learning, Lifelong learning, AI in education and Programming education. Peter teaches in programming courses that are given as professional development for STEM teachers, in courses on scientific writing and in courses on artificial intelligence.

Prof. Martha Cleveland-Innes is an Open, Digital, and Distance Education Professor at Athabasca University. She is Editor-in-Chief of the bilingual *Canadian Journal of Learning and Technology*, and the co-author of open-source publications *The Guide to Blended Learning* (2018), *Participant Experience in an Inquiry-Based Massive Open Online Course* (2022), and *Principles of Blended Learning* (2024). *The Design of Digital Learning Environments: Online and Blended Applications of the Community of Inquiry* was recently co-edited by Dr. Cleveland-Innes (Taylor& Francis, 2024). As a principal investigator, Martha received funding from SSHRC's Canada First Research Excellence Fund to study *Wellness outcomes and education participation for sick children from marginalized*

populations (2024-2026). She is currently a Visiting Professor of Pedagogy at Mid-Sweden University (2018-present)



Prof. Marcia Håkansson Lindqvist holds a PhD in Education, in Learning and Information and Communication Technology (ICT). As an associate professor, her research interests involve teaching, learning, and leading with digital technologies, One to One (1:1), and Technology Enhanced Learning (TEL) as well as the practical implications of teaching and learning with technology in practice and school development. At present, she is a senior lecturer, distinguished for teaching excellence, and the Department Head at the Department of Education at Mid Sweden University, Campus Sundsvall. Her teaching responsibilities are found in the Swedish National Principal Training Programme, The Collaboration for Best School (SBS) and teacher education. Other projects involve Teacher Shortage, Work-integrated Learning and Reflection as a tool for learning.

Prof. Jimmy Jaldemark is a Professor at the Department of Education, Mid Sweden University, Sundsvall, Sweden. He has worked with the digitalisation of learning in Swedish higher education and working life for nearly 30 years, including administration, research, teaching, and assessment of educational settings. His current research interest concerns collaborative, lifelong, mobile, and networked aspects of learning. his interest is usually applied in higher education or professional development settings and embraces the impact of digitalisation (for example, AI) on society.

Co-Designing Gamified Learning for Soft Skills: A Participatory Future Workshop

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Abstract: Rapidly evolving academic and professional environments require essential skills such as communication, collaboration, creativity and critical thinking, which are not typically learned and assessed explicitly in formal education. These skills encompass a significant part of the competencies and are increasingly valued in an AI-driven workforce because they cannot be easily replicated by machines. However, despite their growing relevance, students often lack awareness of the role and value of soft skills, and higher education institutions frequently address them only indirectly through content-focused, lecture-based instruction. This study responds to both the pedagogical gap and the challenges posed by the upskilling need within higher education by exploring how gamification can support the development of soft skills in academic settings. Using a participatory design approach, we conducted a Future Workshop with 52 master's students in informatics at a university in southern Sweden. The workshop facilitated structured engagement in critique, ideation, and prototyping phases, during which seven student groups identified barriers to soft skills development and proposed gamified, digitally mediated solutions to enhance learning and engagement. A short questionnaire administered at the outset captured students' baseline understanding of soft skills. The workshop produced several low-fidelity prototypes that illustrate how gamification can be integrated into curricula to develop soft skills through active, real-time application. The findings demonstrate how, in a participatory setting, students co-design meaningful learning environments and inform new directions for teaching practice. Furthermore, this study exemplifies the potential of the Future Workshop methodology to support students in developing interpersonal competencies and soft skills as part of their formal education, while also enhancing their ability to demonstrate knowledge and hard skills in a more GAI-resilient examination format.

Keywords: Soft Skills, Higher Education, Future Workshop, Participatory Design, Gamification.

1. Introduction

In today's rapidly evolving academic and professional environments, soft skills, such as communication, teamwork, adaptability, and problem-solving, are increasingly recognised as essential to academic success, professional growth, and societal resilience (Marin-Zapata et al., 2022). These competencies enable individuals to navigate complex, collaborative, and increasingly digital workspaces and are considered foundational to lifelong learning and employability (Schislyaeva & Saychenko, 2022). Despite their growing significance, higher education systems have traditionally emphasised technical and disciplinary knowledge, often at the expense of structured soft skills development (Módné Takács et al., 2022). This disconnect has contributed to a widening gap between the skills higher education institutions cultivate and the competencies demanded by the contemporary labour market (Succi & and Canovi, 2020). Absence of well-defined pedagogical frameworks (Ngang et al., 2015) limited awareness and recognition of the importance of soft skills among key stakeholder groups, including educators, students, and institutional leaders, (Dell'Aquila et al., 2017) insufficient integration of soft skills into curricula (Egalite et al., 2016), and a lack of appropriate assessment methods to measure their development meaningfully are further widening the gap.

The nature of soft skills and how they can be acquired inevitably demands new pedagogies; students perceive game-based learning as a promising approach for promoting active learning and supporting the development of soft skills through increased engagement (Módné Takács et al., 2022). Interactive and experiential game-based approaches can support both cognitive and soft skill development, making them valuable tools in contemporary education (Aghaee & Karunaratne, 2023). However, limited research has examined how, and under what conditions, gamification effectively supports their development (Aghaee & Karunaratne, 2023). This study explores the challenges and opportunities for learning and assessing soft skills in higher education. By directly involving students in the design process, the study contributes to a deeper understanding of how gamification can be integrated into higher education, extending beyond engagement to support essential interpersonal skills, thereby preparing students for both academic and professional success.

Hence, by involving students as active participants in the design process, this research aims to conceptualise the complex and innovative assessment models that integrate gamification into formal academic learning. Furthermore, it seeks to contribute to the ongoing discussion on adapting educational practices in response to technological advancements. A key focus is also on enhancing the overall student learning experience, making it more engaging, participatory, and relevant to real-world contexts. This includes creating conditions for students to experience collaboration, creativity, and feedback through playful and authentic learning environments. Two research questions guide this study: 1) What are the perceptions of higher education students regarding the development of soft skills within their education, and what solutions do they envision for upskilling? and 2) What gamified learning experiences for soft skills learning and assessment can the students envision through participatory co-design approaches?

2. Background - Soft Skills Demand and Supply Implications

Across the European Union, a soft skills mismatch is well-documented. Employers across EU Member States consistently report difficulty finding graduates equipped with the soft skills necessary to thrive in dynamic and team-oriented work environments (EU, n.d.). At the same time, graduates often underestimate the importance of these skills or lack opportunities to develop them within traditional academic settings (Aghaee & Karunaratne, 2023). Strong, quantifiable performance and traditional assessment methods are limiting the integration of soft skills learning and assessment in higher education programs (Dell'Aquila et al., 2017). The focus on measurable outcomes and a learning culture dominated by a fear of failure, risk avoidance, and extrinsic motivation hinders the development of essential soft skills, such as collaboration, creative problem-solving, and adaptability (Nørgård et al., 2017). Traditional instructional methods, characterised by passive learning, often involve passive acceptance, rote memorisation, and mechanical repetition. These methods are frequently reinforced by traditional instructional approaches, such as lectures, which limit student engagement and lack interactive learning experiences (Qiong et al., 2025). In contrast, active learning approaches develop soft skills improvement, since it provides more effective conditions for developing these critical interpersonal skills, as (Freeman et al., 2014) shows: Active learning significantly enhances student performance, engagement, and the depth of learning, thus offering a promising alternative to traditional lecturing in addressing the soft skills gap (Brieven et al., 2025).

The rise of Generative Artificial Intelligence (GAI) complicates this educational landscape by significantly disrupting traditional assessment practices of basic knowledge. Assessments that primarily emphasise conceptual understanding, content reproduction, and typical continuous assessment types, such as lab reports, home assignments, and reports including theses, are becoming increasingly problematic in the presence of GAI tools. These technologies can now generate high-quality responses to common assessment tasks, such as essays, reports, and factual summaries, raising significant concerns about the validity and integrity of traditional measures of student achievement (Xia et al., 2024). Consequently, the needed shift toward dynamic, practice-oriented evaluation methods, such as oral exams, demonstrations, and problem-based learning, directly measures the achievement of intended learning goals and indirectly measures associated human competencies, including collaboration, creative thinking, critical analysis, and effective communication. Hence, such soft skills are becoming essential for students to navigate and contribute to an AI-driven workforce successfully (Xia et al., 2024). Consequently, as GAI increasingly automates content reproduction, uniquely human competencies, such as collaboration, adaptability, and creative problem-solving, become even more central to students' future employability.

To navigate an increasingly complex higher education environment, shaping higher education into dynamic labour market profiles, gamification, game-based learning, and playful approaches have emerged as promising strategies (Módné Takács et al., 2022). Gamification approaches have the potential to develop active engagement, collaboration, and problem-solving, creating dynamic learning environments that actively promote the development of essential interpersonal skills. Notably, they bridge the gap between experiential and instrumental learning, mainly when designed with an understanding of learner motivation and contextual factors (Deterding et al., 2011; Kim et al., 2018; Koivisto & Hamari, 2019; Liu et al., 2017). Role-playing games (RPGs), for instance, enable students to assume different roles, negotiate complex scenarios, and solve problems, enhancing situated learning and overall engagement (Ruiz-Ezquerro, 2021). Similarly, educational escape rooms have proven effective in improving teamwork and problem-solving abilities through immersive, challenge-based learning experiences (Clarke et al., 2017; Warmelink et al., 2018). Further supporting the value of these approaches, Nørgård et al. (2017) and Whitton, (2018) emphasise the role of playful learning in higher education, illustrating how game mechanics and cooperative play can cultivate creativity, risk-taking, and

intrinsic motivation. This approach not only enhances soft skills but also reframes failure as an opportunity for learning, encouraging persistence and resilience. In addition, Plass et al., (2015) argue that game-based learning develops deeper cognitive development by integrating complex game mechanics with educational content. This combination helps students develop critical problem-solving and decision-making skills. In line with the growing body of evidence supporting the effectiveness of active learning strategies (Freeman et al., 2014), this study explores the use of gamification, co-designed with students through participatory methods, to find innovative pathways for embedding soft skills development into higher education curricula.

Although gamification, serious games, and playful learning approaches have demonstrated potential in various educational contexts, most existing studies primarily explore general outcomes such as engagement, motivation, or task performance. A notable lack of targeted research remains, exploring how these methods can explicitly support the development of soft skills, particularly when students are actively involved in the design process. Therefore, this study also examines how participatory co-design methods such as the Future Workshop leverage student insights to develop gamified learning experiences explicitly aimed at enhancing critical soft skills.

3. Methodological Approach

In exploring students' perspectives on how they can develop their soft skills through gamified learning environments, the study adopted a qualitative, participatory approach. The methodological design combined preparatory background data collection with a short survey, followed by a Future Workshop (FW) that developed creative collaboration, critical reflection, and the co-design of potential solutions. This study employed FW methodology, following the structure outlined by Vidal, (2006) and based on the original model developed by Jungk & Müllert, (1987). The approach was selected for its alignment with democratic problem-solving and participatory design principles, particularly its capacity to create collaborative ideation and critical engagement among participants with shared learning contexts.

3.1 Data Subjects (Study Sample)

The participant group for the future workshop consisted of 53 master's students in informatics, all enrolled in a course that integrated design thinking into digital transformation at a higher education institution in southern Sweden. This cohort was selected due to their dual exposure to technical and social aspects of digitalisation. The Future Workshop was conducted in seven groups of students. Although the gender proportion was 32 male and 21 female participants, no demographic information, such as age or gender, was directly collected to preserve anonymity. All participants had prior familiarity with key concepts such as gamification, co-design, and collaborative learning, which enabled them to engage meaningfully with the workshop content.

3.2 Pre-workshop Survey

The pre-workshop survey is a short questionnaire administered to 53 students using the interactive digital tool Mentimeter. This instrument included two closed-ended and one open-ended question. The questions assessed students' self-reported familiarity with gamification and soft skills and explored their knowledge and understanding of these skills in the context of higher education. The data collected served to contextualise the upcoming workshop activities by revealing the participants' conceptual entry points and general orientation toward the topic. While the questionnaire serves as a basis for understanding the perception of soft skills, it also sensitises facilitators to themes that might emerge during the participatory phases.

3.3 Future Workshop for Participatory Co-design

The Future Workshop followed the classical three-stage structure as outlined by Vidal. Preparatory activities were an official initial phase to start the workshop, serving as a warm-up and providing information to the participants. The short survey was also conducted as part of the preparation phase. During this stage, students were also asked to identify key stakeholders relevant to the topic. In the second phase, the critique phase, participants formed small groups to collectively identify the challenges and shortcomings in current models of soft skills training and assessments in higher education. These reflections, grounded in students' academic experiences, enabled them to critically examine prevailing practices in higher education. The moderator additionally introduced and facilitated brief discussions on the role of generative AI and the growing importance of soft skills in the context of ongoing educational transformation.

In the third phase, the fantasy phase, participants generated speculative ideas for gamified interventions that could address the previously identified problems and develop solutions connected to gamification and the use of AI. In line with the FW model, this phase encouraged participants to suspend constraints of realism and explore aspirational, creative design directions. The emphasis was placed on open-ended thinking rather than immediate feasibility, creating space for imaginative alternatives to conventional learning strategies. The fourth and final phase in this workshop, referred to as the implementation phase, required groups to refine and consolidate their concepts into more concrete forms. This was done using the MoSCoW prioritisation framework, which helped participants distinguish between essential and non-essential features of their proposed solutions. Each group created low-fidelity prototypes to illustrate their gamification concepts, using digital tools such as Padlet, Canva, and Miro, or traditional tools like pen and paper, to visualize interaction flows, motivational elements, and intended learning outcomes.

The workshop phases marked a transition from problem and abstract ideation to grounded design work, allowing students to articulate how their ideas might be realised in practice. As there was no direct prototype or product resulting from this workshop, the follow-up phase was not included in the workshop, and participants were informed accordingly. Throughout all phases of the workshop, the process was designed to encourage democratic participation, mutual learning, and the negotiation of meaning among group members. These elements are central to both participatory design and the pedagogical goals of developing soft skills.

3.4 Ethical Consideration

The study adhered to ethical standards appropriate for pedagogical research within a university setting. Participants were informed that their involvement was voluntary and that their contributions could be used for research purposes, including publication. Anonymity was ensured by collecting all questionnaire responses and workshop outputs without personal identifiers. Students could withhold their submissions or explicitly indicate if they did not wish their material to be included in the study. Because the research was embedded within an educational context and did not involve the collection of sensitive personal data, no additional ethical approval was required beyond compliance with institutional research integrity guidelines.

4. Results and Discussion

4.1 Pre-workshop Survey - Student Perceptions About Soft Skills

The pre-workshop questionnaire offered valuable insights into students' perceptions and prior exposure to soft skills training. This stage included three key questions. First, students were asked whether they had heard of the concept of soft skills (also referred to as non-cognitive skills). As shown in Figure 1, participants were familiar with the term; however, most reported that they had not yet received formal instruction on soft skills within their academic programmes. Notably, 16 students indicated both a clear understanding of soft skills and prior learning experiences related to them through coursework; however, the majority of students felt that current academic programs do not adequately prepare them for applying real-world soft skills.

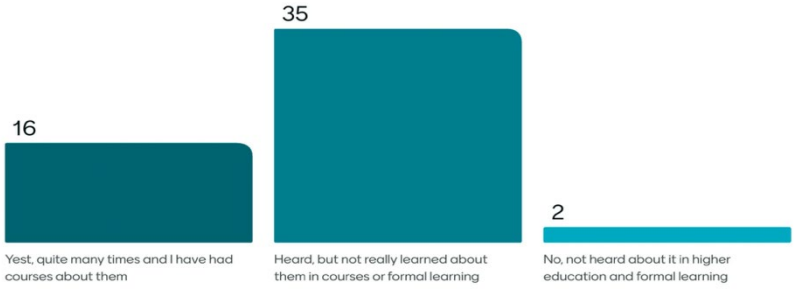


Figure 1: The distribution of students based on their familiarity with the soft skills

The second research question focused on exploring students' awareness of soft skills. To assess this, students were asked to identify up to five skills they had heard about or learned concerning the concept of soft skills. Their responses provided insights into the range and depth of their understanding. The results are summarised in Figure 2.



Figure 2: The most commonly mentioned soft skills by respondents

Communication emerged as the most widely recognised soft skill among students, followed closely by leadership, critical thinking, presentation skills, problem-solving, and time management. These skills align closely with the competencies typically required of master's students in academic and research contexts. For example, communication and presentation skills are essential for effectively articulating research findings, both in written and oral forms. Leadership and collaboration often come into play during group-based project work, while critical thinking and problem-solving are integral to designing and executing thesis research and laboratory experiments. Time management, likewise, is crucial for balancing multiple academic responsibilities and meeting project deadlines. The prominence of these skills in student responses suggests that their awareness is shaped, at least in part, by the demands of their advanced academic tasks and experiential learning contexts.

The final question was open-ended and aimed at assessing students' understanding of the concept of soft skills. Responses highlighted a strong interest in interactive and gamified learning approaches as a means to improve engagement and skill acquisition. The outcomes varied from "*skills to survive in the society*" to "*interpersonal skills that allow for effective communication and collaboration but are learned through experience*". Most students described soft skills as abilities gained through experience, interaction, and collaboration rather than formal instruction. Responses included phrases such as *"skills that are not taught in school," "not taught using books,"* and *"skills we use in our everyday life, such as in social gatherings, the workplace, or society."* Some also described them as *"inbuilt"* capabilities that enable effective interaction and teamwork.

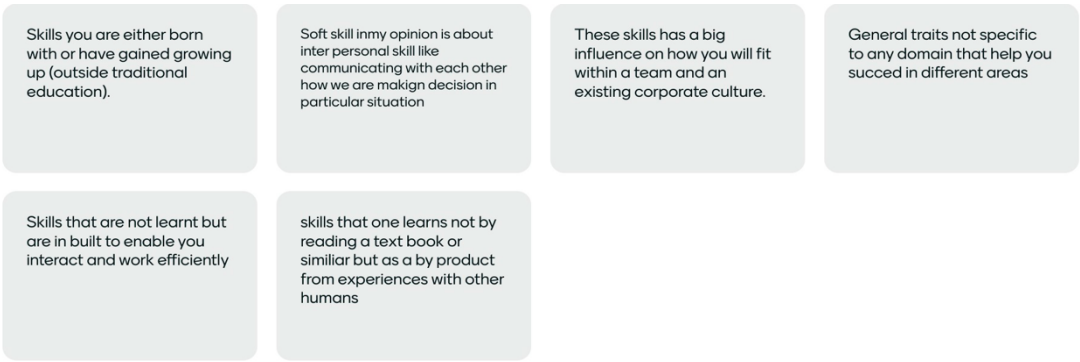


Figure 3: Segment of snippets about "define soft skills according to your understanding"

The responses demonstrate a strong alignment with the commonly cited skills in question 2, primarily those related to effective social interaction, including communication, teamwork, and leadership. This suggests that students tend to associate soft skills predominantly with interpersonal competencies. However, other equally essential soft skills, such as resilience, empathy, and tenacity, were notably absent from the responses. This can indicate a limited understanding of the broader scope of soft skills, highlighting a potential gap in students' awareness of the full range of non-cognitive competencies necessary for both academic and professional success.

A key takeaway from the pre-workshop questionnaire was that it enabled the researchers to design the structure of the Future Workshop holistically and constructively by identifying and addressing existing gaps in students' knowledge of soft skills. This preparatory insight was crucial for shaping the initial stages of the co-design process as well. By understanding students' baseline awareness and misconceptions, the facilitators were able to tailor the introductory phase of the workshop to clarify the concept of soft skills, broaden students' perspectives, and establish a shared understanding among participants.

This strategic alignment ensured that knowledge gaps would not hinder the creativity or relevance of the ideas generated during the co-design phase. In other words, the Future Workshop could focus on envisioning meaningful and contextually grounded solutions for soft skills training, rather than spending time compensating for fundamental misunderstandings. The advantage of this pre-assessment was that it positioned students not merely as participants but as informed contributors, better equipped to co-create learning experiences that are both pedagogically sound and practically applicable.

4.2 Future Workshop Outcome - the Grand Designs of Skills Training

Each of the seven groups collaboratively explored the challenges and the co-design of the skills learning solutions. Figure 4 shows two examples of selected group outcomes.

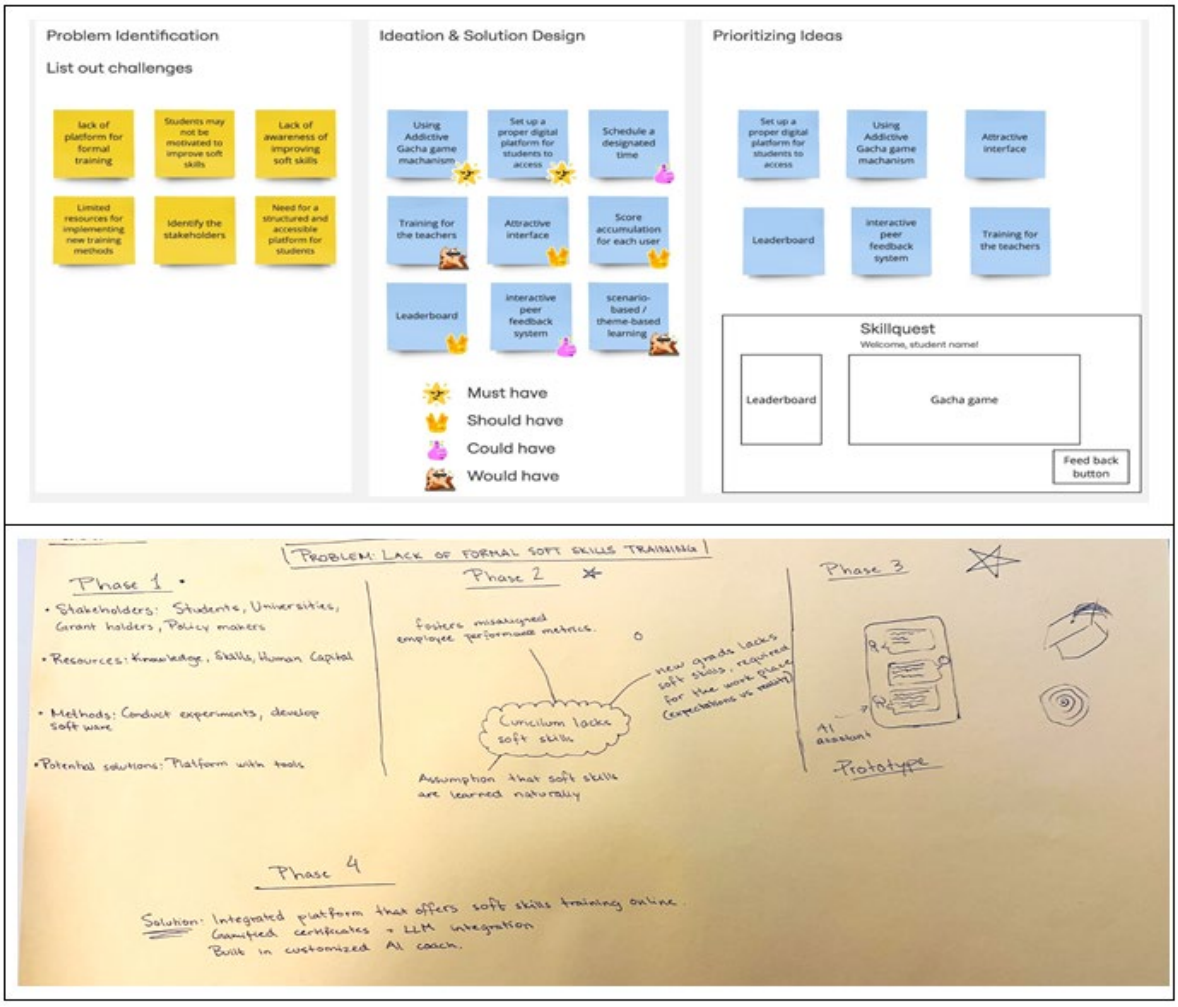


Figure 4: Example deliverable from groups of the Future Workshop on a gamified soft skills learning framework/methodology (digital-Top, paper-bottom).

The outcomes showed that students perceive gamification as an effective way to develop soft skills. The group's diversity, across academic backgrounds and international representation, added valuable perspectives and enriched the collaborative process. Their solutions emphasised real-time skill application, interactive learning, and integration with academic assessments. Table 1 illustrates a summary of the low-fidelity prototypes, a range of gamified learning systems from role-playing scenarios to digital simulations.

Table 1: The summary of the eight scenarios.

Group	Challenges (Problems) Identified	Solution Design	Implementation
1	• Lack of a platform for formal training • Students may not be motivated to improve soft skills • Lack of awareness for improving soft skills • Limited resources for implementing new training • Identify stakeholders • Need for a structured and accessible platform	• Using the Addictive Gacha game mechanism • Set up a proper digital platform for students to access • Schedule a designated time • Training for teachers • Attractive Interface • Score accumulation for each user • Leaderboard • Interactive peer-feedback system • Scenario-based/theme-based learning	Skillquest Gacha game - leaderboard - Game GUI - Feedback button
2	• Mismatched learning objectives with current technology • Not an effective teaching • Lack of preparation for future employment • Lack of soft skills can lead to a worse presentation of hard skills	• A school-wide app that awards users with badges if they complete a soft skills quiz or exercise in the app. • These quizzes are optional but completing them will enrol you in a form of lottery with rewards. • Exercises with abstract situations that include soft skills lessons, increasing complexity with age. • *Kobayashi Maru* style situations where you can fail	Develop a quiz platform with badges within LMS (should not be discouraged or punished for not enrolling /not using GPT)
3	• Not having soft skills is a problem • (Skills gap) between academia and industry	• Gamification business case presentation	Presentation material and rewards scheme
4	• Communication and collaboration problems • Social inclusion is lagging	• Bonus credit points for participating in workshops, seminars and presentations and exhibiting soft skills. • Guest lectures on the importance of soft skills	An app similar to Canvas App. The credit points will be added there
5	• The curriculum lacks soft skills • The assumption that soft skills are learnt naturally • New graduates lack the skills needed by the workplace • Misalignment of performance metrics	• Integrated platform offering soft skills training online • Gamified certificates/LLM integration • Built-in customised AI coach	An AI assistant prototype
6	• Students lack skills in how to solve a case • (You need to collaborate, communicate, present, and be analytical)	• Application for solving cases together with other students • Practice presenting and collaborating with others • Collecting points and doing quizzes.	- User network for practice - Challenges - industry onboard for headhunting

Group	Challenges (Problems) Identified	Solution Design	Implementation
7	• Over-reliance on AI • Lack of collaboration, teamwork, cooperation, and critical thinking • Social media, social inclusion	• "Captain" in charge of keeping the organisation of various tasks • A new team of 4 is designated every month, where a new captain is designated every week. • Teams gather points, and a winner is presented at the end of each month. • Prizes are awarded to the top 3.	- Assistant robots to teach presenting - Gamification - Examinations on-site

4.3 Strategic Suggestions and Recommendations Resulting From the Future Workshop

Although the proposed solutions from the student groups remain at the conceptual design stage and lack empirical validation, many of the ideas reflect principles and features commonly identified in the literature on soft skills development. Solutions 1 and 2 (cf. Table 1) take the form of digital platform-based interventions. Notably, Solution 1 aligns closely with existing proposals in contemporary research that advocate for digital environments to support the learning of soft skills (Adhiatma et al., 2019; Aghaee & Karunaratne, 2023).

Interestingly, the students also suggested non-digital approaches (Solutions 4 and 6), which are equally noteworthy. These designs emphasise real-world projects and problem-solving activities that develop soft skills, such as collaboration, leadership, and adaptability, through experiential learning. Several groups also incorporated the use of artificial intelligence, particularly generative AI tools, into their designs. For instance, large language models like GPT were envisioned as the backbone of gamified learning environments or as engines for narrative-driven, case-based learning, as illustrated in Solution 6. These approaches demonstrate an emerging understanding of how AI can be leveraged not just for content generation but also as interactive, adaptive learning companions.

Using badges as a reward system is not new in skills training programs (Mobini & Karunaratne, 2019), yet it has not been systematically integrated into formal pedagogical approaches for upskilling. The use of quizzes to assess soft skills is also being discussed and prototyped (Mobini & Karunaratne, 2019). However, integrating these innovative features into mainstream pedagogical frameworks remains a significant methodological and institutional challenge.

5. Conclusion and Future Work

This study explored how students perceive the need for and approaches to learning soft skills. Based on a participatory design approach to explore potential ways forward in addressing the growing need for soft skills development in higher education, this approach not only develops innovative learning solutions but also contributes to more authentic, engaging, and contextually relevant educational experiences by engaging students as co-creators. The Future Workshop methodology proved effective in surfacing student perspectives and generating actionable ideas that align with both pedagogical and technological shifts. This work contributes to the discourse on digital learning design by demonstrating how student-driven processes can inform the development of gamified interventions aimed at real-world skill application.

Future research should focus on translating these prototypes into functional learning environments and empirically evaluating their effectiveness in improving student engagement, collaboration, and skill acquisition over time.

Ethics Declaration

In collecting empirical data, this study followed the ethical requirements of the respective university. As described in section 3.4, this research study has not collected any sensitive data from the data subjects and, hence, did not require ethical approvals from the university. However, information about the study and the possibility of publication was provided to all workshop participants, and informed consent was obtained prior to data collection.

AI Declaration

No AI tools were directly used in conducting the research. Language correction tools were employed during the development of the workshop and the writing of the manuscript to proofread and correct language errors.

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From the Implications of Open Education for Teachers to the Design of A Self-evaluation Tool for Open-Only Blended Instruction

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Abstract: Integrating open educational resources into blended learning courses or online instruction poses considerable challenges for teachers, particularly when using open-only resources. These include navigating through a multitude of resources, incorporating them into the curriculum, addressing copyright concerns, or collaborating with librarians or IT professionals. This becomes especially important in cases of teachers' collaboration across multiple organizations, whether for legal, technological, cultural, or pedagogical reasons. To address this challenge, we have developed an instrument to help teachers engage in designing open-only blended learning instruction. A five-phase process is proposed. It starts with a comprehensive inventory of scientific knowledge and ends with validation of an instrument. To begin, extensive reviews of the literature were conducted, specifically focusing on the impact of open educational resources (OER) on teachers in blended learning environments. This allowed us to precisely outline the roles and responsibilities of teachers who adopt OER. Subsequently, advanced artificial intelligence was used to facilitate the development of a self-evaluation tool. To ensure its theoretical soundness, all these findings are cross-referenced to create the instrument. A Delphi method and future ecological tests will be performed to validate the instrument before proper dissemination. The instrument—we called SATOB (Self-Assessment Tool for Teachers in Open-resource-only Blended Learning), consists of four parts: planning and preparation; blending instructional strategies; open education; reflection, improvement and sharing. It contains twenty self-evaluation questions and a scoring system with recommendations for professional development. The instrument was created to facilitate the process of teacher self-regulation to assess the extent to which a course is open resources only and well integrated into a blended instruction design. In the long term, once the tool becomes empirically validated, teachers and institutions committed to open science and open education can use it. However, further research is still necessary.

Keywords: OER, Blended Learning, Self-evaluation, SLR, DELPHI Method

1. Introduction

With the promotion of Open Science, open access and open data have policies and practices usually in place. Despite this, open educational resources (OER) are not as widely used as they could be due to various barriers (Gutnecht et al., 2020), such as a lack of knowledge that holds teachers back (Otto, 2021), institutional and legal issues regarding rights to the resources created (Mishra, 2017), and a lack of incentives (Belikov et al., 2016). Open education is propelled by two interconnected and complementary goals: sharing and quality (Leonelli, 2023). The former embodies a horizontal dynamic that contributes to the latter. Indeed, sharing promotes exposure, which facilitates constructive feedback. Nevertheless, these two purposes raise substantial challenges for teachers. For example, sharing involves copyright management and clarifying the target audience of the developed resource. Therefore, it can be difficult to include OER in teaching, especially within a blended learning design where sharing resources is done alongside teaching.

One of the authors experienced the challenges of designing open-blended courses firsthand. As colleagues from different universities offered similar courses, we decided to collaborate. However, practical constraints made this very difficult. Some colleagues had not taken care to include only royalty-free resources, legally limiting sharing between universities. Others had failed to consider the technical limitations of their colleagues, such as the absence of certain features in one of the learning management systems, which made incorporating OER technically complicated. Finally, once other colleagues complied with the technical and legal frameworks for inter-university collaboration, the resource was perceived as not sufficiently attractive to students. This highlights the complexity of committing to open resources and inter-institutional sharing. To facilitate interinstitutional teaching collaboration, it was deemed essential to develop tools to support instructors in designing open-only blended learning.

To achieve this objective, we have thoughtfully crafted a three-step strategy. First, we undertook a systematic literature review (SLR) to pinpoint the challenges that teachers face when using and creating OER. Next, using generative AI, we developed a suite of self-evaluation tools for teachers to evaluate their instructional design, their creation/use of open resources, and the integration of these resources into blended learning. We then confronted the results to design the self-evaluation instrument. Ultimately, we present a brief description of the Delphi technique that will be employed before ecological tests to evaluate, regulate and validate the self-evaluation instrument.

2. Literature Review

As Otto (2022) states, the concept of OER is generally well understood in academia. However, their implementation is often inconsistent. While some studies have examined the connection between open resources and the quality of education, their underutilization remains a concern (Ofoegbu et al., 2021). Certainly, policies, financial or technical barriers at the institutional level may be at play. However, the additional workload and tasks for teaching staff may also be contributing factors. Nevertheless, open resources are a relevant lever that can help promote the sustainability of education (Zaid & Alabi, 2021). Studies show that OER facilitates connections between teachers from different institutions, generating a new "space for learning" (Baas et al., 2023, p. 6053). This leads to collaboration, debate, and mutual assistance. Proper use of OER can also improve learning quality (Luo et al., 2020). Ultimately, when coupled with open educational pedagogy, it contributes to enhancing the students' learning journey (Miller et al., 2021) by encouraging them to be more proactive learners.

OER are resources for teaching and learning that offer a wide range of possibilities for use (Wiley et al., 2018, p. 134): retain, reuse, revise, remix, and redistribute. The development of OER is possible with a variety of funding models (Zaid & Alabi, 2021), for example membership, donations, contributor-pay, or sponsorship. It certainly requires skills (Robert & Youga Dieng, 2016). Finally, teachers' familiarity with open resources was structured from simple exposure to deliberate selection (Cox & Trotter, 2017).

When integrated into a blended learning design, OER brings new obstacles. For instance, there is the need to define the instructional design before distributing the open materials and allowing other teachers to reuse them (Mullens & Hoffman, 2023). Yet another example is the essential partnership with fellow professionals, such as librarians and IT experts (Moore & Reinsfelder, 2020). While this task certainly brings professional satisfaction and quality in the resources created, it requires a significant amount of work time. Could we develop a more comprehensive inventory of the consequences for teachers of committing to embracing open education? The objective of this study is to compile a comprehensive list of the consequences that open-resources-only blended learning design would have on the teaching profession.

3. Implications for Teachers Committed to OER—Materials and Methods

To document the implications for teachers when committing to OER, a rather innovative systematic literature review (SLR) was conducted that combined the classic PRISMA flow diagram (Page et al., 2021) with an AI-supported process (via *SciSpace* https://scispace.com/). This approach was selected due to the complementary nature of the methods (one is transparent, the other generative) and the fact that the initial article extractions reveled distinct lists. One could no longer ignore the two parallel processes.

3.1 A Systematic Literature Review

The SLR was conducted through a comprehensive search of relevant articles in *Web of Sciences*, *ERIC* (via *Ovid SP*), and *PsycINFO* (via *EBSCOhost*). The search terms—via the thesaurus—used to extract articles included "open educational resources," "OER," "teach*," and "methods" (see Figure 1). On the left, the identification and extraction process, which complies with the PRISMA statement, shows the transition from 147 scientific articles identified in the databases to 10 scientific articles selected. The removal of duplicates, then of articles whose title and abstract explicitly indicated another subject of study, and finally the retention of only those that meet the eligibility criteria, transparently explains the reduction in the number of articles selected. On the right, the transition from the first 200 articles proposed by *SciSpace* to the 130 articles selected for analysis by generative AI is explained (13 duplicates with SLR, 10 in foreign languages, and 45 not retrieved because of paywall or other motives). Subsequently, the visual guide demonstrates that the 130 articles were scrutinized by generative AI.

Notably, the same articles seldom recur in both instances. This suggests that the selection of the tow complementary methods (PRISMA and AI) was judicious, instilling trust in the thoroughness of the article selection.

3.2 Results From AI-Supported SLR

After extracting the first 200 SciSpace articles (prompt: "What are teachers really doing with OER and what are the tasks they are doing to make proper use of these resources?") and following the process described in Figure 1—column B, the 130 remaining articles were submitted to *DeepSeek-R1-Distill-Llama-8B* via *GPT4ALL* v3.10.0, with the following prompt: "Based on these 130 documents, what are teachers actually doing with OER? Provide a comprehensive inventory of all the tasks identified in these 130 documents. The DeepSeek output has listed 11 tasks (Figure 2, which is now presented without the lengthy introduction that preceded the list).

If DeepSeek's tasks 3 and 11 are similar, it makes 10 propositions based on the 130 articles. For example, teachers involved in open education must identify and modify resources, create new materials, select and organize them, incorporate them into their instruction, and disseminate and share these lessons. Moreover, they should participate in training on OER, engage in professional networks, evaluate the impact of open resources on teaching and learning quality, and stay up to date with the latest developments in open education. Some of these tasks may be subject to debate. Integrating resources into teaching is not exclusively the domain of OER. Similarly, participating in learning communities is primarily a matter of professional growth rather than a requirement of open education. However, this collection of articles highlights the additional effort required to engage with open resources, which should not be underestimated.

3.3 Open Resources and Teachers' Workload

After examining the two SLRs, we were able to clearly define the responsibilities related to the use of OER. We compared the list presented in Figure 2 with the practices documented in Table 1, to produce Table 2. This table has been divided into three sections that reflect the impact of open education on teachers: "cross-cutting implications," "implications when reusing OER," and "implications when creating OER." These three categories are practical and enable actions to be considered.

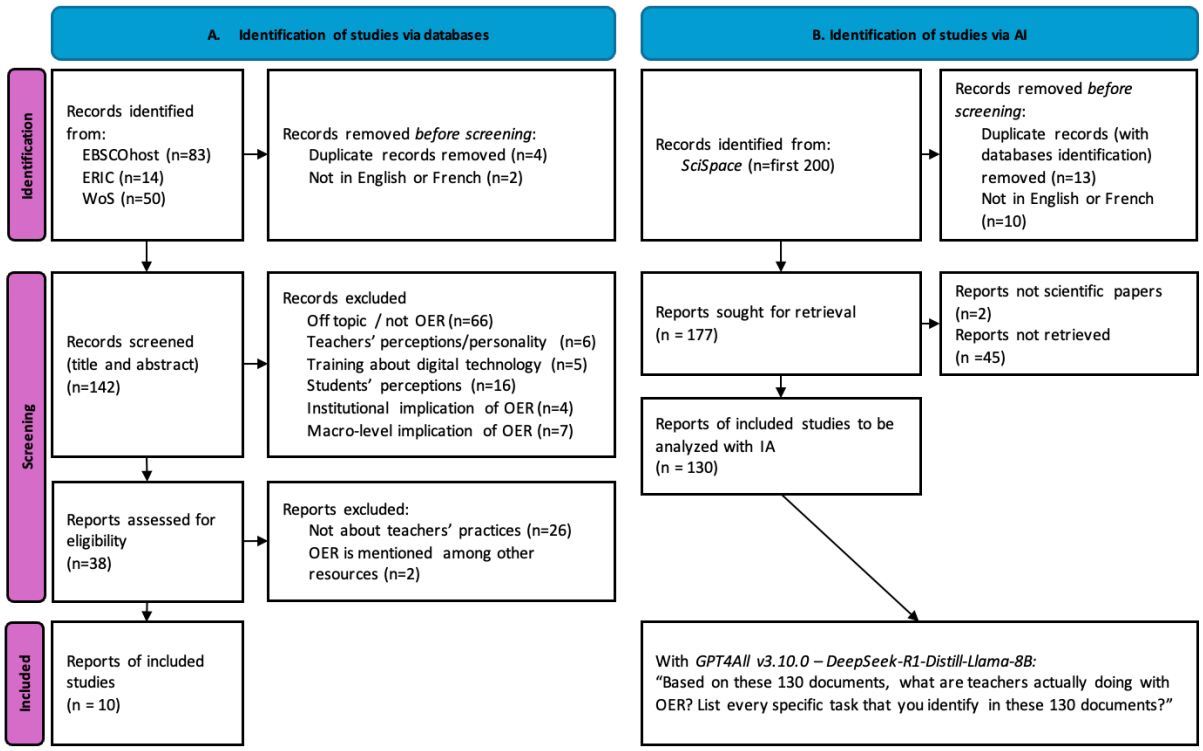


Figure 1: Adapted PRISMA diagram to include a double literature review (classical + AI-supported)

Table 1: Included studies documenting teachers' practices and requirements when using OER.

Author, Date	Context (Country)	Methods	Documented Teachers' Practices
(Al-Zahrani, 2024)	Faculty members of the University (Saudi Arabia)	Online survey	- Use of various technologies - Request support
(Bradshaw et al., 2024)	Human rights course using OER for young adults (Ghana)	Qualitative interviews	- Adopt new concepts (e.g., openness) - Search for OERs - Collaborate with other teachers
(Dashtestani & Suhrawardi, 2023)	English as a foreign language for adults (Iran)	Mixed-method approach (survey and semi-structured interviews)	- Deal with uncertainty (e.g., copyright) - Control equality, assess credibility, improve and update OERs - Develop digital literacy and OERs - Get training (quality, copyright, repositories, implementation…)
(Helton, 2024)	Cross-disciplinary science for K–12 teachers (USA-WV)	Design-based research (pre-, peri-, & post-interview, observations, & discussing outputs with participants)	- Sharing resources publicly - Deal with various concerns (e.g., exit the comfort zone, assume the perceptions of others, assess technical-pedagogical knowledge…)
(Gerard et al., 2022)	Science learning for secondary school (USA-CA)	Interviews and logged data	- Review instructional approach - Review OER (connect to students' lives, additional content, academic language help, clarify instructions, technical challenge reduction, …)
(Lo et al., 2023)	Mathematics for secondary school (Hong Kong)	Qualitative (semi-structured interviews and written feedback) and quantitative (evaluative survey)	- Review OER (accuracy and visual appeal, alignment to standards, ease of use and support, ability to meet students' needs)
(Miller et al., 2021)	Calculus for university students (USA-OH)	Case study of institutional initiatives over 10 years	- Review of the whole instructional approach - Professional development for instructors - Large team collaboration
(Pulker & Kukulska-Hulme, 2020)	University Language teachers (UK)	Online questionnaire and interviews	- Reappropriation (gain ownership, adapt OER…) - Reflection (question the quality of OER and the instructional design) - Sharing in close spaces (gain confidence, identify specific students…)
(Love & Blankstein, 2024)	Various disciplines with college and university teachers (USA)	Survey across disciplines: humanities, social sciences, sciences, area studies, and medicine	- Examine and update instructional approach - Consult instructional designers, IT, or other support - Promote academic integrity - Collaborate with librarians - Understand copyright, intellectual property…
(Tlili et al., 2023)	Teachers from various University disciplines (Ghana)	Mixed methods (questionnaire and semi-structured interviews)	- Integrate technology - Search for, evaluate and modify OER - Develop and share OER

(1) Accessing & Identifying: seek out OER that aligns with teaching subjects & student needs.
(2) Adapting Resources: modify existing materials to suit individual lesson plans, curriculum requirements, or specific learning objectives.
(3) Creating New Resources: develop original content using OER as a foundation, which may include creating lesson plans or multimedia elements.
(4) Curating Collections: organize and select the available resources to compile collections judged useful for both students and colleagues.
(5) Using OER in Teaching: incorporate OER into lessons to enhance learning experiences.
(6) Recording & Sharing: create class recordings, share with students as study materials.
(7) Attending Training: participate in workshops focused on the use of OER and its production.
(8) Discussing Practices: engage in professional chats about practices associated with OER.
(9) Researching Impact: conduct studies to evaluate how OER enhances teaching methods and improves student performance or engagement levels.
(10) Continuous Learning: maintain knowledge by staying informed about new developments in OER.
(11) Producing OER: create original content, lesson plans, interactive activities, videos, or other digital tools designed to meet specific educational needs.

Figure 2: Output of *DeepSeek* when prompted about teachers' additional tasks, based on the 130 retained documents

Table 2: Additional work for teachers resulting from their involvement in OER.

Categories	Additional Tasks
Cross-cutting implications	- Professional development and new concept adoption (e.g., copyright, intellectual property) - Collaborate with Librarians, IT, other teachers, or instructional designer - Integrate technology - Deal with pedagogical concerns (uncertainty, perceptions of others…) - Review instructional approach
Implications when reappropriating OER	- Search for and modifying open resources - Analyze the relevance of the resource for reappropriation (alignment with standards, suitability for students' needs, adjustment to location, modification of the vocabulary, assessment of integrity and credibility…)
Implication when creating OER	- Develop specific digital literacy - Clarify targeted student and learning goals - Gain confidence to sharing resources - Curate collection or work with institutional partners

4. Discussion

According to the literature, OER has barriers (Gutnecht et al., 2020), and one of these may be the increase in teachers' workload. With the SRL we conducted, an extensive list of additional tasks resulting from engagement with open education has been proposed. Its content might be of interest to universities or schools that are considering implementing an institutional policy on OER. They should not overlook the impact on teachers' daily activities, nor engage in open washing (Farrow, 2017).

Since our findings are based on SLR, every subsequent task was previously documented in scholarly articles. Due to the research approach, no novel findings could arise. For instance, the importance of teamwork with other professionals had already highlighted (Moore & Reinsfelder, 2020), as was the need for developing abilities crucial for involvement in open education (Robert & Youga Dieng, 2016). However, by integrating these elements, we can offer a comprehensive perspective on open science and the OER movement.

Therefore, the act of teaching with open educational materials can be classified into three distinct categories. The first—cross-cutting implications—encourages training institutions and teachers to familiarize themselves with the implications of open education: mastering new concepts such as copyright (Love & Blankstein, 2024),

facilitating interprofessional collaboration (Miller et al., 2021), reevaluating teaching methods (Gerard et al., 2022), and managing pedagogical instability (Dashtestani & Suhrawardi, 2023; Helton, 2024). The second aspect—implications when reappropriating open resources—is that universities and instructors must allocate time to locate and organize teaching materials (Tlili et al., 2023). They must also carefully examine these resources to determine their suitability for the educational context (Love & Blankstein, 2024). Modifying or adjusting them requires additional time and skills (Lo et al., 2023). The third aspect—implication when creating OER—highlights the important issues that teachers and institutions need to address when they want to participate in the dissemination of open resources. By taking part in training courses and engaging with communities of practice, individuals can acquire the essential skills (Miller et al., 2021). Resources should be made available to a targeted audience with clear learning objectives so that other people, whether teachers or students, can use them. Developing skills then becomes a lever for gaining confidence in sharing (Pulker & Kukulska-Hulme, 2020). Finally, everything related to content curation requires a significant amount of work. The framework in which OER can be made available must be delineated by negotiations between the institution and teachers (Love & Blankstein, 2024), to define the conditions under which OER can be made available.

Belikov et al. (2016) suggested that a lack of incentives might explain some teachers' hesitation towards open education. However, making OER mandatory has been documented as not preferred by the teaching staff (Otto, 2022). Therefore, we suggest an alternative incentive based on pedagogical values: the quality of education made possible thanks to self-evaluation. This approach to instrumental support is certainly of interest to teachers, since education quality is generally valued (Baas et al., 2023). Lack of involvement in OER could be due to a lack of skills (Bossu & Willems, 2024), whereas engagement for openness in education is often driven by quality (Pulker & Kukulska-Hulme, 2020). A self-positioning tool, which has been used to support teachers (Alvarez et al., 2021; López-Angulo, et coll., 2024), could help increase familiarity with OER, from awareness to willingness (Cox & Trotter, 2017).

5. Toward a Self-evaluation Instrument

No self-evaluation tool for teachers was identified during the search for scientific literature on open, blended learning. OBTRA (Los et al., 2021) offers a good starting point, but its objective is not self-positioning after instruction design, but rather measuring general readiness. Since no identified instruments, we chose AI-generated solutions to start designing the self-evaluation tool after some preliminary tests that seemed convincing. We keep in mind that this work is not sufficient on its own and must be tested and verified.

5.1 Consequently, we (1) Generated 3 Tools With AI, (2) Compared the 3 Propositions to Build a First Version, and (3) Compared This First Version With the Results Found in OER Implications for Teachers (Table 2) to Make a Theoretically Sound First Draft.

Using *Llama 3 8B Instruct*, 3 different instruments were generated using the following prompts:

1. "Imagine a teacher that designs a blended learning course using only open educational resources or creating open educational resources. Generate a self-evaluation tool that the teacher can use to analyze the quality of the open-resource-only blended learning design,"
2. "Imagine a teacher working in a university and wanting to offer blended learning to her students. In addition to that, she wants to use and generate open educational resources only so she can share her blended learning course. Can you generate a self-evaluation tool to help her analyze the quality of the blended learning design and the adequacy of the open educational resources use?"
3. "I am a teacher. I design a blended learning course. I want to create open educational resources and only use open resources for this blended learning course. Can you help me assess what I have done?"

Confronting the three outputs, two of the co-authors have prepared an initial version of the self-evaluation instrument following steps 1 to 6 proposed by DeVellis (2017) to examine the operationalization of the tool. The first version is available online (here: https://www.doi.org/10.5281/zenodo.15431354), but should not be used in its current form, as it is only a preliminary draft that requires further work.

5.2 Confronting First Instrument with OER Implications for Teachers

The first version of the document was confronted with the outcomes of the OER implications. Regarding the open education section, several elements identified were already given by the AI-supported development process and have been estimated as fully equivalent. For instance, "Integrate technology" (see Table 2) is

explicitly stated in B2 “Have I used a variety of digital tools and resources […]” (see first draft), “Review instructional approach” is evident in B3 “Are my instructional strategies flexible enough […]”, or “Clarify targeted students and learning goals” is specified in A1 “Have I clearly defined the learning objectives and outcomes […]”.

However, four very important additional tasks for teachers when choosing OER (see Table 2) were estimated as being missing or insufficiently developed. For example, “Search for and modify OER” is absent from the first draft of the self-evaluation tool; an item needs to be added. It is similar for “Collaborate with librarians, IT, other teachers, or instructional designers,” for the “alignment with standards” in “Analyze the relevance of resources for reappropriation,” for “Curate a collection of work with institutional partners,” for “Gain confidence to sharing resources” and for “Professional development and new concept adoption.” Therefore, the following items have been added (see Figure 3).

In *Section A*.
- Am I fully qualified and confident for OER-only blended learning design, thanks to professional development or other forms of training?
- Have I established a network of partners (e.g., librarians, IT, other teachers, instructional designers) to ensure that I have all the necessary skills to design OER-only blended learning?

In *Section C*.
- Have I done appropriate research and evaluation (e.g., quality, alignment with standards) of the OERs available for the design of my blended learning course?

In *Section D*.
- Is the curating work properly organized with my institutional partners so that my OER-only blended learning course can be shared?

Figure 3: Items added to the self-evaluation instrument, based on the results of the SLR

The second draft of the Self-Assessment tool for Teachers when designing Open-resource-only Blended learning (we call it SATOB, for a nod to satellite observation and the notion of monitoring one’s own practice as a teacher), is available here: https://doi.org/10.5281/zenodo.15490129. With a strong theoretical foundation, it is now crucial to put it to the test in practice.

6. Next Steps—Confront the SATOB

The instrument, as it is emerging from SLR, AI, and five researchers’ work, seems theoretically sound. However, it still needs validation. Since the tool is intended for self-evaluation, several methods are conceivable, from questionnaires to assess the clarity of items (Borg & Edmett, 2019), statistical tests to document the link with measured variables (Calancie et al., 2017), or a Delphi study (Lim & Antony, 2016). We intend to conduct the latter because “One of the major premises underlying the whole approach [Delphi technique] is the assumption that a large number of ‘experts’ judgments are required to ‘treat adequately’ any issue” (Linstone & Turoff, 1975, p. 22). Its application can serve concepts and framework development (Okoli & Pawlowski, 2004). In our case, it is especially interesting because of the Delphi technique “helps gauge the generalizability (external validity) or transferability of the findings” (Hasson & Keeney, 2011, p. 1701). Indeed, the self-evaluation instrument that has been created deserves scrutiny by experts, with the goal of refining it until a consensus is reached on its substance and form.

7. Conclusion

The primary objective of this research was twofold. Firstly, it aimed to explore the implications of OER for teachers. Secondly, it sought to create a tool to help teachers self-regulating after designing blended instruction with OER. Two SLRs were conducted to document teachers’ implications when using OER (one traditional, following the PRISMA process, and the other using generative AI). Three self-evaluation tools were generated using AI. The findings were compared to create an instrument that teachers can use. However, before introducing it to real-world scenarios, it must first be evaluated by experts using the Delphi method.

Our study aligns with previous findings (Otto, 2022) that suggest that educators do not favor mandatory OER. Instead, they prefer incentives and assistance to participate in this initiative of open education, which appears to be broadly supported. Moreover, OER may align more closely with open pedagogy, facilitating its adoption (Tang et al., 2021)—even if open resources are necessary for implementing open pedagogy (Arispe et al., 2023)—but that would require a clear and explicit policy that promotes openness in teaching, as well as

professional development and dedicated time for redesigning instruction (Miller et al., 2021). This is particularly important when designing and creating OER for online or blended learning rather than for face-to-face instruction (Ofoegbu et al., 2021).

The two parallel and complementary extractions from scientific literature indicated that teachers' work is undergoing change because of their commitment to open education. The aforementioned factors have been classified as "cross-cutting implications," "implications when reappropriating OER," and "implications when creating OER."

Open education is a political project in the field of education to which teachers generally agree. However, they may require guidance in incorporating this openness-centric approach into university settings and other educational institutions. The self-evaluation instrument that is currently being designed has the potential to contribute to this support.

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Evaluating A Skill Management Platform: Towards an Upskilling System for Large and Small Companies

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Abstract: As industry navigates the transition towards Industry 5.0, the need for human-centric workforce development becomes more pressing than ever. This shift highlights not only technological implementations but also employee empowerment through lifelong learning. Digital platforms for learning and skill management rapidly emerge, to align individuals' skills with changing organisational needs. However, how these platforms are perceived and integrated across different companies is greatly underexplored. This study describes a mixed-methods evaluation of a digital skill management platform implemented in two industrial contexts: large Swedish companies and small and medium-sized enterprises (SMEs) in Germany. The platform offers individual skill gap assessments, recommending suitable training for users. In the study, two main dimensions were investigated, i.e. the platform's perceived effectiveness for users and the organisational integration of the platform. Results show a range of challenges in said dimensions. Users report varying platform usability and relevance of recommended learning. Results also reveal challenges in organisational integration and in aligning the platform with existing company-internal skill, task, and job taxonomies, including learning management systems (LMS). Other identified issues were user engagement and the visibility of learning progress for managers. Our conclusions emphasise the importance of adapting solutions to organisational contexts when implementing skill management systems. Based on insights from the study, recommendations for supporting successful implementation of such platforms, including the need to accommodate different stakeholder needs, are outlined. Our recommendations include enabling conditions, organisational integration and platform design. The presented results contribute to ongoing discussions on how digital learning solutions can support efficient workforce transformation towards Industry 5.0. Our findings have clear value for the university and research institution context, where researchers, teachers, and leaders are exploring ways to deliver lifelong learning opportunities in industry. Skill management platforms have potential to serve as bridges between university courses and workplace learning demands, enabling universities to play important roles in their employees' lifelong learning.

Keywords: Upskilling; Skill gap; Skill matching; Learning Management Systems; Industry 5.0

1. Introduction

Increasing demands for a strong, well-skilled European workforce has put pressure on organisations' learning and human resources departments. Industry needs to become resilient and sustainable while putting humans at the centre (Breque et al., 2021). People working in industry are key drivers for this transformation and need to be supported in their well-being and skill development. Upskilling initiatives have been implemented to train employees and prepare them for new tasks and ways of working. According to the World Economic Forum (World Economic Forum, 2025), 39% of employees' skills will soon be outdated and new skills will need to be learned. To meet this demand for training, education providers need to adapt their curricula and create training to bridge the industry's skill gaps.

Clearly, companies and their employees today struggle with job changes. One reason is the challenge of identifying new skills needed, finding relevant training for each employee (Rikala et al., 2024, Fareri et al., 2023). The speed of change is increasing, and individuals require support in assessing their skill gaps. To meet this need, attempts to perform digital skill gap assessment and matching to training have been made by e.g. leveraging artificial intelligence (Braun et al., 2024a) or patent analysis (Fareri et al., 2023). However, such solutions are underexplored, there is a lack of research on the impact of the solutions on people and their skill gaps.

In approaching this research gap, this study evaluates implementations of one digital skill management platform in two contexts, i.e. 1) at four large companies in Sweden and 2) at two small companies in Germany. The study evaluates the outcome of implementing a skill-matching solution, including different stakeholders' perspectives,

and provides insights into the challenges. By analysing participant activity in the platform, their feedback during focus group settings, and surveys, common key outcomes could be identified and were mapped as recommendations. To guide this study, the following research questions were formulated: *How was the skill management platform perceived within large companies in Sweden and SMEs in Germany, especially regarding organisational and technological aspects? How should scalable skill management ecosystems be built?*

2. Theoretical Background

To provide the context for this paper, this chapter outlines the significance of continuous skill development within the workforce during the industry's digital transformation towards Industry 5.0 and provides an overview of assessing skill gaps.

2.1 Skill Development in a Changing Industrial Scenario

In an increasingly digitalised industrial environment, where sustainability, resilience, and human-centricity become more important, work is changing too, i.e. changing skills, leadership, collaboration, communication, corporate culture, occupational health and wellbeing, and more (Singer-Coudoux et al., 2023). At the same time, fewer young people are entering the job market due to demographic changes in Europe and other parts of the world (Statista, 2025). Recruiting talent will therefore be challenging. Employees need to adapt the way they work and train new skills to meet the new requirements, managers need to give the resources and right motivations, and education providers need to find new ways to deliver training opportunities to the industry (Braun et al., 2024b). Lifelong learning is becoming crucial for being valuable in the job market, and digital learning platforms are one important option to bring training to employees (Braun et al., 2022a). However, it is challenging for managers and their employees to know what should be learned in connection with the way the business is transforming. In the current industrial scenario, skill gaps arise when employees don't match the skill needs of their employer, hence not having the right skills with the right person at the right time, hindering the business from transforming (Rikala et al., 2024, McGuinness and Ortiz, 2016). Therefore, there are solutions to support understanding how job roles are changing and what new skills should be learned, and what could be suitable training to bridge the person's skill gap.

2.2 Identifying and Bridging Skill Gaps

This section summarises research about identifying and bridging skill gaps in industrial contexts.

2.2.1 Identifying Skill Needs for an Individual

The need to adapt training to an individual's needs is more important than ever, but tools that recommend new skills and training to employees are still underexplored (Braun et al., 2022b). There are some examples for skill-matching solutions, e.g. (Fareri et al., 2023) propose a tool to map a worker's current skills and the skills that meet current and future business needs by analysing patents. This patent analysis gives insights into technologies impacting the work humans do and provides implications for how jobs and skill needs are changing (Fareri et al., 2023). In a recent publication (Braun et al., 2024a), an AI-based skill gap assessment tool uses data from LinkedIn and other databases to make conclusions about a person's skill needs and recommends them to suitable learning, just by asking for their current job role and industry. Different attempts have been made to match skill needs, job roles, tasks, and relevant learning to people (Braun et al., 2022b). Some challenges have been noticed so far, including the content specificity related to the specific industry of the recommendation and the continuously changing industry, requiring the skill matching to be updated continuously to stay relevant. From a technological perspective, it is challenging to handle company-specific skill taxonomies and the integration with existing systems (Braun et al., 2024a).

2.2.2 Assessing Skill Gaps

To bridge skill gaps, one first needs to understand and measure the skill gap. Skill gaps can be measured in various ways through data collection from stakeholders, such as employers, employees, but also from databases containing job information like LinkedIn or the ESCO database by the European Commission (European Commission, 2024). In some cases, companies define a skill framework for a certain job role and a set of skills that this job role contains. In the skill assessment step, employees can use the skill framework to do a self-assessment and find out their skill gap (Rikala et al., 2024). However, self-assessment of skills can be biased. The famous Dunning-Kruger effect describes how humans often assess their skill level lower after training a certain

skill (Dunning, 2011). Another way of reflecting people's assessment of their skills is by using the Johari window, which describes the self-awareness and others' perception of oneself (Luft and Ingham, 1961).

3. Methodology

This study used a mixed-methods approach to evaluate a skill management platform across two distinct organisational contexts: large corporations in Sweden and small to medium-sized enterprises (SMEs) in Germany. While both groups used the same digital platform, the evaluation strategies were tailored to suit the respective context and research access. The sample was purposively chosen to include large companies and SMEs to identify needs for both user groups.

3.1 Overview of the Skill-matching Platform

The skill-matching platform has been implemented in the contexts of large companies and SMES to determine whether it meets the need to assist employees and organisations in identifying their skill gaps and determining what to learn. The platform leverages AI to assess participants' job roles and companies, identifying the current skills required for their roles. Users view the identified skills and can select some to focus on. In the subsequent step, the platform allows users to self-assess their current levels in these skills and identify their skill gaps. Ideally, the users' managers also assess their employees' skill levels concurrently. Based on these assessments, users receive personalised recommendations for learning modules, based on the AI's suggestions. The concept and functionality of the skill-matching platform are detailed in two prior publications, see (Braun et al., 2024a, Orth et al., 2023).

3.2 Sample A: Large Company Context

In Sweden, the study involved 40 participants from four large industrial companies in the automotive, manufacturing, and energy sectors. Participants completed a survey before their profiles on the skill-matching platform were set up. This survey was necessary to gather their job profiles and company details. For each individual, the platform team established a profile on the platform and identified the skills required for their job role at the respective company. Participants accessed the platform, completed a self-assessment, and received information on their identified skill gaps along with recommendations for future learning. The matched learning opportunities were focused on modules from a Swedish online learning platform created by 13 Swedish universities (Braun et al., 2023).

After the platform-based assessment, the participants were invited to semi-structured focus groups. These were organised separately for learners and managers, facilitating an understanding of different stakeholder needs. The topics discussed during the focus group meetings included self-assessment, trust in AI, the relevance of the recommended learning content, platform usability, and the benefits and challenges associated with integration into the organisation.

The sample was assembled from four different companies. Company 1 is an automotive company, Company 2 is in the manufacturing sector, Company 3 is an energy company, and Company 4 is also within the automotive sector. Participants' job roles range from engineering and technical roles to leadership and management roles. Some participants are learning leaders in their companies, or have roles related to data, digital factory, operations, and business. Some participants have roles related to customer service.

3.3 Sample B: SME Context

The German part of the study was conducted in collaboration with two SMEs, both medium-sized manufacturing firms (sheet-metal fabrication and welding technology, respectively). A total of 7 participants from these companies took part in the pilot: this included technical specialists and team leaders (as end-user learners), as well as staff involved in HR and development roles (as managers overseeing training).

We employed a mixed-methods approach combining an online survey with qualitative focus group discussions. The online survey was administered in Q1 2024. In parallel, two structured focus group discussions were conducted: the first in Q4 2023 after initial platform use and the second in Q1 2024 after further use and platform updates to gather in-depth feedback. This design allowed us to track changes over time and to triangulate numerical ratings with rich qualitative insights.

The evaluation instruments were structured around four key indicator clusters reflecting the project's objectives: 1) Technology: Focusing on platform usability and functionality, 2) Organisational Integration: The degree of platform implementation in company processes and support from leadership, 3) Accompanying Workshops: On the topics of corporate strategy and systematic competency development and, 4) Overall Platform Impact: Overall effectiveness of the platform for learning (including satisfaction and perceived benefit). Participants rated the platform's usability and user interface, reported on their learning outcomes and skill development progress, assessed the career relevance of the content, and noted their frequency of use (e.g. typical hours per week).

The survey also collected overall satisfaction ratings and self-assessments of knowledge gain. The focus groups (with 3–4 participants each) were guided by the same themes, using open-ended questions to prompt discussion about learning experiences, perceived benefits or obstacles, and suggestions for improvement. The longitudinal approach provided insights into changes in the users' perception and potential impact over time, with rich qualitative feedback on platform value and limitations.

4. Results

This section presents findings from the Swedish and German sample, based on self-assessments, platform activity, and feedback from focus groups.

4.1 Results From Sample A

The results are organised according to the two participant groups: end-user learners and managers managing the learners.

4.1.1 Learners' Perspectives

Some reflections of learners were made regarding their experiences with the skill assessment. Several learners, particularly from Company SE1 and Company SE4, reported **difficulty in evaluating their own skills**, especially those with a lot of experience. Respondents reported a difficulty in knowing what to refer to when assessing their own skills, for instance, what does a "2" mean on the scale? Participants from Company SE1 and Company SE2 expressed **frustration with the interaction** with the platform, e.g. that they couldn't return to revise previous skill choices, revisit content recommendations, and some functionalities were not found intuitively. Some learners from Company SE2 and Company SE3 expressed that they received **irrelevant content** after selecting the skills. However, learners from Company SE4 expressed that the articles recommended as learning content were very useful for them. But there were mixed answers about the satisfaction with the recommended content. Users from Company SE2 appreciated recommended courses like the one in data science, but others felt the results were too generic. A user from Company SE4 was also sceptical about how well the suggested skills align with their current job role. They also requested a way to give feedback to the system immediately, to e.g. suggest skills perceived as missing.

One common point was that learners from all companies noted **difficulty in finding time** for self-assessment and learning activities. This was particularly emphasised in Company SE3. The participants also highlighted that a session facilitated by the platform provider or the project team as a workshop would have helped to improve the engagement of learners with the platform.

4.1.2 Managers' Perspectives

Regarding the integration of the skill management platform into existing systems, managers from Company SE3 and Company SE4 expressed concern about the platform being "yet another tool" in already quite **fragmented learning management systems**. A manager from Company SE3 explained that they use a learning management system from an external provider and also have their own internal platforms. At Company SE1 and Company SE4, managers explored the **possibilities of integrating** the platform with existing HR processes, such as annual employee development meetings.

Several managers, particularly from Company SE3, express a **hesitation towards AI-generated skill assessments and recommendations**, and expressed that they will use it alongside human interaction. As the manager from Company SE3 put it, that the platform "can be used as a tool to reflect, but we still need to talk with our employees". In addition, managers from Company SE2 and Company SE4 noted that the **skill definitions**

generated by the platform were often too broad and unspecific, and that they could be improved by connecting the platform to the company's internal definitions of job roles and skills.

Some challenges were raised regarding the engagement of their employees. Managers from all four companies acknowledged the **difficulty in engaging users** and explained that the employees' time constraints were the reason for less engagement. Managers from Company SE1 and Company SE3 proposed a walk-through session to show employees how to use the platform and limit the hurdles to start. A manager in Company SE2 suggested applying the platform for recruitment to assess candidates' skill profiles.

4.2 Results From Sample B

The following section presents selected findings based on the method described. The results are organised across four core dimensions:

4.2.1 Technology-Level Evaluation

The two focus group sessions conducted between Q4 2023 and Q1 2024 revealed significant changes in users' perception of the platform's usability. In the first session, participants from Company DE1 and Company DE2 reported challenges with registration and basic functionality. By the second session, users highlighted improvements such as smoother scrolling and a clearer interface, although some issues remained with newly added features and overall navigation.

While usability was increasingly rated positively, participants identified areas for further improvement. Suggestions included implementing filters by skill level, visually marking completed content, integrating company-specific materials, and adding gamification features to increase user engagement. These qualitative insights aligned with survey responses, which showed overall positive answers in the perceived user-friendliness of the platform among both learners and managers.

4.2.2 Organisational-Level Evaluation

Organisational integration of the platform also showed noticeable developments over the evaluation period. In the first focus group, participants described limited influence on team processes and reported low satisfaction with learning outcomes. Without formal structures or time allocations, employees found it difficult to engage in self-directed learning during work hours.

In contrast, the second focus group reported more flexible use of the platform, leading to greater satisfaction and improved learning outcomes. Survey data supported these results, with learners noting increased knowledge, motivation, and application of new skills. Overall, the platform was seen as a valuable tool for professional development, particularly in fostering self-reflection and growth.

However, discussions indicated that these benefits were most evident among intrinsically motivated employees. To better support broader engagement, participants suggested integrating a chat function and embedding the platform into collaboration tools such as Microsoft Teams, which would enable easier access and peer interaction.

4.2.3 Evaluation of the Accompanying Workshops

The accompanying workshops on organisational development were rated very positively by both focus group participants and survey respondents. As part of the integrative strategic and operational approach to competence development, the accompanying on-site workshops with managers and employees served to systematically assess the strategic orientation and digital maturity of the participating companies, and to derive role-specific development pathways and incentive systems aligned with individual and organizational transformation goals. Users highlighted the strategic perspective, the relevance of the content, and the well-structured delivery. At Company DE2, the career framework and customisation to internal needs were particularly valued, while participants from Company DE1 emphasised the usefulness of structured competence development and the revision of role descriptions.

The workshops were viewed as an important contribution to the overall success of the learning platform, improving both its organisational alignment and practical applicability. Survey feedback confirmed high satisfaction across all thematic areas, and managerial participants recommended that such workshops be continued in future implementations.

4.2.4 Overall Platform Feedback

Overall, feedback on the learning platform improved over time. Participants in both focus groups reported average weekly usage between 2 and 3.5 hours. The first group appreciated the platform's structure and organisation, while the second emphasised its clarity and flexibility for on-demand learning. Different content types—such as podcasts, video modules, and interactive workshops—were consistently well received.

Both learners and managers offered suggestions for further enhancement, including gamification, social features, and certificate options. These contributions reflect strong user engagement and a shared interest in optimising the learning experience. By the end of the evaluation period, most users rated the platform positively, with the majority giving it four out of five stars.

5. Discussion

This study examines how a skill management platform is perceived by large companies in Sweden and SMEs in Germany, particularly concerning organisational and technological aspects. The study aimed to understand whether it is feasible to map a relevant and complete skill set for an individual using job role and company information. Participants from both the Swedish and German samples acknowledged the value of the skill management platform but emphasised several barriers to its effective utilisation. Swedish learners found the self-assessment component challenging and questioned the relevance of the platform's recommendations to their roles, while managers expressed concerns about system integration and trust in AI. Moreover, apprehensions were raised about the varying meanings or definitions of a specific skill depending on whom you ask. In contrast, German users reported an enhanced experience over time and stressed the importance of organisational support, such as workshops, to align business goals with learning priorities. Across both contexts, time constraints and a lack of facilitation emerged as significant barriers to adoption. Nevertheless, the platform demonstrated strong potential for fostering reflection, skill development, and organisational learning. There are differences between the two contexts regarding learning infrastructure, flexibility, and support, although the sample size is too small to draw robust conclusions.

5.1 Comparison of Findings With Existing Literature

Our findings align with the theoretical background presented in this article, particularly concerning the challenges of self-assessment bias, the adoption of AI-based learning recommendations, and the complexity of organisational integration. As noted by Swedish participants, especially those with extensive experience in their roles, self-assessment of skills proved to be challenging, which aligns with the known limitations of self-assessment methods, such as bias and a lack of clear reference points. However, self-assessments need to be evaluated carefully, since the reality has more perspectives than only the individual's reflection, as explained in the Johari window (Luft and Ingham, 1961). The Johari window includes people's perception of themselves and other people's perception of them, but not AI's perception of them. This raises the interesting question for the future, if the Johari window could be extended, for the age of AI? Furthermore, the mixed reactions to recommendations reinforce previous research highlighting the difficulty of maintaining relevance in learning recommender systems, given the continuously changing industry needs. From an organisational learning perspective, our study confirms that successful adoption depends not only on functioning technology but also on the integration of organisational processes with existing HR systems, as well as managerial support. Nevertheless, the engagement observed in the German SMEs illustrates how smaller firms may adopt such tools more readily when social learning is prioritised. In summary, our results contribute to the theoretical understanding of the complexity of skill platforms within the context of industrial transformations and underscore the need for user-centred strategies.

5.2 Recommendations for Stakeholders

To clearly synthesise our results and guide the future development of skill management platforms, we propose the following recommendations for stakeholders involved, see Figure 1. This pyramid visualises the multi-layered requirements for successful skill management, based on focus group insights from both a German SME and Swedish large enterprise context. It highlights three interconnected levels of action:

Enabling conditions (base of pyramid), aimed at **policymakers**, include recognising alternative learning paths, e.g., through micro-credentials or certificates, funding pilots for digital learning ecosystems, and building inclusive ways to develop skills.

Organisational integration (middle level), targeted at **companies and employees**, highlights aligning skill platforms with existing HR processes, fostering engagement among employees, and promoting the tool as a means to personal growth for employers. **Employees** should view the tool as a personal development tool and use it for reflection and feedback to continuously improve recommendations.

Platform design (top level), directed at education and platform providers, focuses on simplifying assessments, intuitive interfaces, meaningful progress visualisation, relevant content, building trust in AI, providing kits for onboarding support (e.g., workshop materials for strategic competence planning in companies), and interoperability with existing systems.

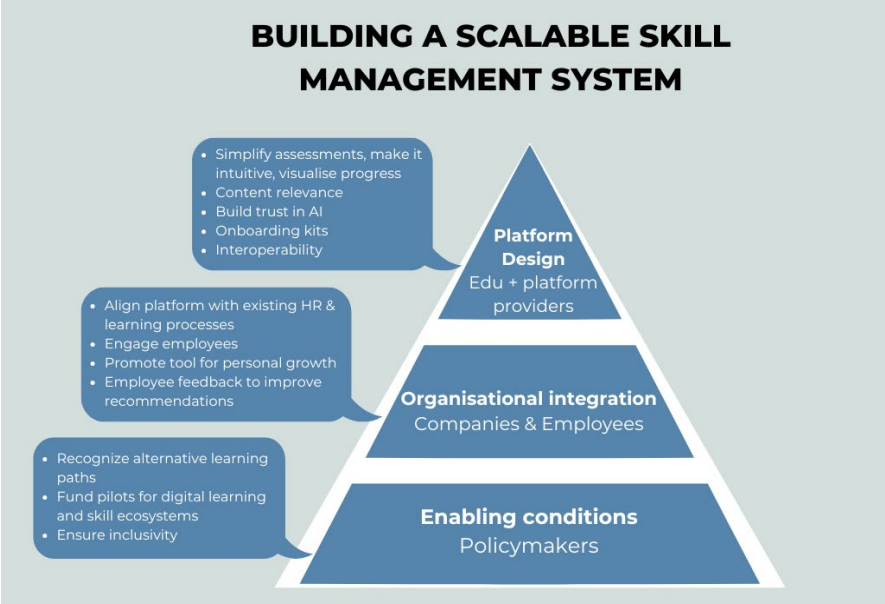


Figure 1: Recommendations in Building a Scalable Skill Management System

By illustrating these levels as a pyramid, we emphasis the foundational role of policy incentives and organisational integration to enable effective technical implementation of skill management platforms.

5.3 Discussion of Methodology

The mixed-method approach was intentionally chosen to be adaptive to the differing contexts and access conditions in Sweden and Germany. The Swedish sample from large corporations was studied through focus groups, while the German SME sample was studied through an online survey and longitudinal focus groups to capture evolving perceptions over time. We acknowledge that the small sample size limits the statistical generalisability. However, the findings serve as a valuable starting point for building knowledge of user needs, expectations, and improvements. This evaluation has a qualitative depth and offers sensitive insights, while the mixed-method design enabled triangulation across data sources and contexts. We interpret the results with humility and don't see them as definitive conclusions, but as an early foundation that can guide future development of skill management platforms. In this context, the small, purposefully selected sample allowed for qualitative insights into the early-stage development of skill management systems.

Although the two samples were evaluated using different methods, the decision to merge findings was based on shared use of the skill management platform and complementary insights from both contexts. The combination of structured focus groups and an online survey allowed for holistic understanding of user experience, platform integration, and perceived learning value across different organisational settings.

5.4 Future Work

In the future, more longitudinal studies should be done to explore the long-term impact of skill management platforms on employees' learning, their career development, and the organisational transformation. In addition, it would be beneficial to investigate how learning can be personalised in a structured way, especially concerning different organisational contexts. Lastly, future research should involve improving AI-driven recommendations based on human input and increasing adoption by embedding platforms in everyday workflows. Therefore, future research should involve more user perceptions and ideally involve more diverse participants.

6. Conclusion

AI-driven solutions to resolve massive skill gaps, e.g. in Europe, show potential both for large enterprises and SME contexts. Despite their different needs, in terms of flexibility and support, the study reveals commitment and belief in solutions to enhance upskilling in companies. The mixed-methods approach applied in this study allowed for a holistic understanding of the learners' and managers' perceptions of the studied skill assessment platform. This study reveals the challenges related to technology, taxonomy, and platform design, but also in organisational implementation and management.

This study contributes to theory by deepening the understanding of how digital skill management platforms are perceived across different organisational contexts and gives recommendations on how to build a scalable skill management ecosystem. By combining the data from two different contexts, it enriches the knowledge on challenges regarding trust, personalisation, and role alignment in AI-driven learning systems. Practically, the study provides hands-on actions for policymakers, companies and employees, and education providers. The resulting recommendations offer a guide for improving the usability and organisational implementation of digital upskilling tools.

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Ethics and AI Declarations

Ethical clearance was not required for this research. An AI tool was the studied object here, and other than that, AI tools were used for grammar and spelling checks and recommendations (Grammarly).

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Providing Distance Education on Sustainability Management for Brazilian Research Professionals

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Abstract: The adoption of distance education has become increasingly critical in addressing global education demands. Therefore, this paper explores the design, implementation, and outcomes of the "Sustainable Development Basics" online course developed in 2024 for the SENAI (Serviço Nacional de Aprendizagem Industrial which translates to "National Service for Industrial Training") Innovation Institutes (ISIs) located in Brazil. Targeted at researchers, the course is part of the "Sustainability Management" training track, which is embedded in an applied research management training program based on the ISI core processes. Moreover, the course content was incorporated into the online platform of the Corporate University of the Industry System, which is organized and run by the Brazilian National Confederation of Industry. The course structure entails a range of didactic elements, including guided self-study modules, practical exercises and assessment quizzes. These modules are designed to provide a comprehensive understanding of sustainability principles, strategies, and frameworks, with a focus on real-world applications within industrial and research environments. The course covers key topics such as sustainability in the industry, sustainability management in Research & Technology Organizations (RTOs) and sustainability reporting standards. A notable aspect of the course and contribution to the field of distance education is the combination of learning resources such as videos and presentations with self-study exercises and quizzes to reinforce learning outcomes. Further, the distinct framing and application of learning objectives play a vital role in the facilitation of the course. This paper provides best practices for course design, discusses distinct challenges and feedback gathered by participants. Furthermore, it highlights implications for managers aiming to adopt similar distance education initiatives and underscores the importance of combining synchronous and asynchronous education methods. The paper outlines future research opportunities in distance education, namely the exploration of adaptive learning technologies and the cross-cultural applicability of course content. Our findings underscore the importance of aligning the course content with relevant industry and research challenges and leveraging digital platforms to create flexible, impactful learning experiences. Furthermore, these findings contribute to advancing the field of distance education and provide actionable guidance for practitioners aiming to address sustainability through innovative education solutions.

Keywords: Distance Education, Sustainability Management, Professional Education, Brazil, Research & Technology Organizations

1. Introduction

Due to the effects of the COVID-19 pandemic, distance education gained substantial traction in the education system both for professionals and students (Pregowska et al. (2021). During this time, physical presence for education purposes was limited in many countries due to government regulations, leading to a surge in the usage of online education tools. However, the technologies developed during this timeframe are still relevant today and are implemented worldwide (Garlinska et al. (2023). Particularly in the professional education sector, online learning programs, webinars and video recordings are continuously offered. In the case of Brazil, distance education for professionals provides the possibility to interact with experts from abroad and tap into unique knowledge assets. SENAI is in charge of coordinating 28 Innovation Institutes is one of the main providers of education in Brazil. The ISIs have been established in close cooperation with the Fraunhofer Institute for Production Systems and Design Technology (IPK) and serve as national innovation hubs, aiming to strengthen the competitiveness of the Brazilian industries through applied research and advance technological solutions (Will et al. (2020). In consultation between the two entities, it was established that a crucial area in which the researchers of the ISIs could benefit from an increase in their knowledge stock is the topic of sustainability. This is due to an increased focus of the Brazilian national government on this topic and heightened global industry demands relating to sustainable technologies (Prá Carvalho, Dalarosa & Zarelli. (2018; Udemba & Tosun. (2022;

Gramkow & Anger-Kraavi. (2018; Maçaneiro, Da Cunha & Balbinot. (2013). Therefore, Fraunhofer IPK created a "Sustainability Management" training track, that is part of a wider applied research management program and entails an online training course aiming to familiarize especially junior ISI researchers with the basics of sustainability management relevant in the context of an RTO. Hence, this paper will first delve into the relevant literature related to the field of distance education. Following the "Applied Research Management Program" will be introduced and subsequently the design and content of the "Sustainability Training Track" will be highlighted, with specific emphasis placed on the "Sustainability Basics Course". Subsequently, the feedback of the course participants will be discussed and recommendations for managers and researchers provided.

2. Literature Review

In this literature review the origin of distance education and its current status will be discussed. Further, the importance of distance education in Brazil and for the ISIs will be highlighted. Concluding the section, the best practices and challenges in the domain of distance education will be illustrated.

2.1 Distance Education and Learning

The first form of distance education was recorded in 1728 in the United States of America where the teacher Caleb Philip provided the opportunity to study material and lessons via mail (Katane & Katans. (2015). Over the following decades the concept of distance education became increasingly popular for universities worldwide, reaching its peak during the COVID-19 pandemic (Zawacki-Richter. (2023). Due to technological advancement and societal changes, the definition of distance education has shifted over the years. Hence, this paper implies a more recent definition and follows (Saykili. (2018) who defines distance education as "a form of education which brings together the physically-distant learner(s) and the facilitator(s) of the learning activity around planned and structured learning experiences via various two or multi-way mediated media channels that allow interactions between/among learners and facilitators as well as between learners and educational resources." Further, distance education can be classified into two separate delivery methods: asynchronous and synchronous methods (Koehler & Blair. (2003). Hereby, both approaches are learner-centred, but while asynchronous methods emphasize the availability of education content at all times, such as recorded lectures, synchronous methods focus on real-time interaction between the learner and the educator in, for example, live online classes (Shahabadi & Uplane. (2015).

2.2 Distance Education in Brazil

In Brazil, the first forms of distance education were introduced in the late 19th century while the concept was only officially established in 1996 by the National Educational Law of Policies and Bases (Baxto, Amaro & Mattar. (2019). Over the last decades distance education has increased in popularity in Brazil particularly higher education institutions. Considering the geography of Brazil, distance education enables the distribution of knowledge into various and remote regions of the country (Baxto, Amaro & Mattar. (2019). Moreover, distance education for professionals offers a valuable opportunity for the country's workforce, which has to an extent been utilized by companies through the creation of corporate universities (Porto & Berge. (2008). The authors argue that these institutions offer distance education to employees on a variety of topics through customized learning content. To generate such content, third-party organizations are often employed or educational content from expert institutions is utilized (Porto & Berge. (2008). Typically, companies undertake the effort to create a corporate university to continually increase the skills and knowledge of the workforce and thus increase their competitiveness. SENAI and the ISIs also utilize the services of a corporate university, namely the Corporate University of the Industry System, which was created by the Brazilian national confederation of industry. It has been established in 2013 and aims to enhance the strategic skills and competencies of employees within industry system, specifically the National Industry Confederation, Industrial Social Service, and state-level industry federations across Brazil through a wide offer of courses and training programs.

2.3 Challenges and Best Practice in Distance Education

To facilitate high quality and effective distance learning content, the environment of the recipients needs to first be analysed. This holds particularly true for distance education programs in emerging economies such as Brazil, where the concept of distance education is not well established, bureaucracy is not always operating efficiently and the necessary technological tools are not widely available (Baxto, Amaro & Mattar. (2019; Barikzai, Bharathi S & Perdana. (2024). Further, experiences from previous distance education programs need to be analysed

(Geçer, Bagci & Atar. (2023; dela Peña Bandalaria. (2023). When creating the structure and content of a distance education program, various aspects need to be taken into consideration. This is particularly important to overcome challenges in distance education such as lack of self-discipline, low motivation, non-frequent feedback, indefinite content and time constraints due to employment responsibilities (Geçer, Bagci & Atar. (2023; Yaw Koi-Akrofi, Owusu-Oware & Tanye. (2020). For a successful distance education programme, a structured curriculum should be developed that follows a logical sequence and contains a comprehensive description of the planned content (Khan et al. (2017; Singer-Coudoux, Buxmann & Will. (2024). Further, when creating the educational content, the selection of suitable teaching materials is crucial (Adalikwu & Iorkpilgh. (2013). Empirical studies show that video-based learning is often considered best practice in distance education (Yousef, Chatti & Schroeder. (2014). This approach should be complemented by self-study units that allow participants to engage deeply with the material and improve their critical thinking skills (Lim et al. (2024; Turan & Koç. (2018). Further, the use of short-format instructional videos is particularly beneficial for distance education (Laparra et al. (2023; Sitzmann & Ely. (2011; Yousef, Chatti & Schroeder. (2014). The presentation of the content should begin with a convincing introductory text for each learning unit and contain clearly defined learning objectives (Martin & Bolliger. (2022). The objectives must be specifically tailored to the virtual learning environment, should address the audience, entail an action verb that describes the desired behaviour that the learner is able to display after the training and to which standard, and lastly point out under which conditions the behaviour should be exhibited (I-Tech. (2010). Further, the objectives should reflect what kind of cognitive processes are expected to be displayed by the learner, these range from listing learned facts to synthesize and assess the learned content. Hence good learning objectives set realistic expectations and enable an effective assessment. To ensure active engagement with the material, learning success should be monitored through assessment mechanisms such as quizzes and interactive exercises (Khan et al. (2017). To maintain motivation and maximize learner engagement, it is also recommended to offer certification upon completion of the course (Cumberland, Petrosko & Jones. (2018).

3. The Applied Research Management Training Program

Fraunhofer IPK and SENAI have a long-reaching history of cooperation. For example, the Fraunhofer IPK, was heavily involved in the creation of the ISI Network, which now acts as an important pillar of the Brazilian innovation system (Will et al. (2020). In total there are currently 28 ISIs that focus on applied research in various areas, including laser processing, advance health systems or biosynthetics. Together these two entities structured the ISI core processes, which are namely: Strategic Management, Marketing & Sales, Applied Research & Development / Innovation and Project Management & Service Delivery. These core processes constitute the activities that, if executed properly by an ISI, generate value. Hence, these processes are vital to the work of ISI researchers and inspired the creation of the “Applied Research Management” training program. The program is based on these processes and targets ISI researchers. Each of these core processes acts as a section of the training program and contains training on topics related to these processes. Three training courses are conceptualized per topic with varying complexity levels, namely basic, advanced and expert. The training courses follow either asynchronous or synchronous delivery methods. In figure 1 the training topics of the ISI core process of strategic management are depicted. The highlighted topic of “Sustainability Management” entails the course “Sustainable Development Basics”, which will be discussed in more detail in the following chapters.



Figure 1: Excerpt of the Applied Research Manager Program

3.1 Design of the Training Track for Sustainability Management

The topic of sustainability has been identified by SENAI as a crucial area for the competitiveness and innovation capability of the ISIs. Hence, one of the main objectives of the cooperation between SENAI and Fraunhofer IPK was to create training content for ISI researchers that addresses the topic effectively and takes into consideration their positions within the institutes. Here, the training track "Sustainability Management" aims to contribute to two objectives: First, to strengthen SENAI's strategic organizational competence in sustainability management and enhance the ISI Network's competitiveness. Second, to empower ISI researchers to integrate sustainability concepts into their research activities. The training track encompasses three different courses with varying skill levels and guide researchers through sustainability concepts and assessments. The first course, "Sustainable Development Basics", requires approximately four and a half hours of learning time. It is delivered on the online platform of the Corporate University of the Industry System and consists of a mix of web-based trainings and self-study sessions. It introduces basic but key sustainability concepts. By correctly answering a quiz the learner can advance within the course. The main objectives of this course are to explore the current trends of sustainability in the industry and in research institutes, highlighting concepts and strategies of sustainability management and to dive into practical examples of sustainability programs and actions. Upon completing the first course, participants can apply for the course "R&D Project Impact Assessment. This course has a duration of 8 hours and is delivered through live online sessions and exercises over three days. The focus is on assessing the sustainability impact of R&D projects. Participants engage in discussions, peer reviews and interactive exercises, leading to a plenary session where they present their results. The main objectives of this course are to equip researchers with the ability to measure and demonstrate their contributions to the Sustainable Development Goals (SDGs) and assess the sustainable impact of their R&D projects. The final course, "Planning Collaborative R&D Impact", has a duration of 16 hours. Conducted as a two-day onsite training in Brazil, it emphasizes collaborative ideation of R&D projects with a positive impact on sustainability aspects. Participants work together in groups, receive coaching and refine their project proposals. The main objectives of this course are to enable researchers to plan their R&D project's sustainability impact in advance and enhance their ability to set their project proposals apart from competitors. Each course builds upon the previous one, ensuring a progressive learning path that allows researchers to develop a deep understanding of sustainability in R&D.

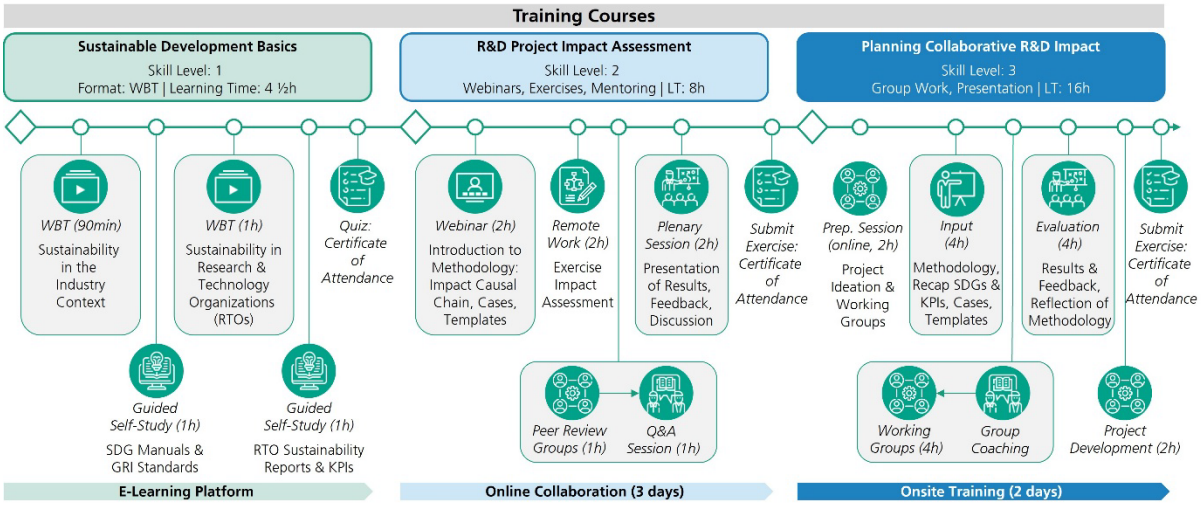


Figure 2: Structure of the Training Track for Sustainability Management

4. Configuration of the Sustainable Development Basics Course

For the creation of the course "Sustainable Development Basics", the Fraunhofer IPK team took inspiration from best practice examples highlighted in chapter 2.2. The target audience of the course are ISI researchers that are at the beginning of their careers and are aiming to increase their knowledge on sustainability. The delivery method of the course is asynchronous. This method was chosen to scale the accessibility of the content and thus allowing numerous researchers to engage with the material at their own pace. The overall course structure is depicted in figure 3 and based on a modular approach, consisting of six modules with a total estimated learning time of 4 1/2 hours. These modules cover different aspects of sustainability and are designed to provide a progressive learning experience. These were integrated in the platform of the Corporate University of the

Industry System and can be separated into different categories: Web-Based Training (WBT) or self-study modules. In WBT modules, a pre-recorded video with an average length of 20 minutes is available for the learner to engage with. In the self-study modules, various documents are provided that the learner should interact with in the timeframe of an hour. Each module begins with an introduction text that highlights the content of the module and its learning objectives. Hereby each module contains three learning objectives that gradually increase in the complexity of the cognitive processes that the learner should be able to demonstrate after finishing the module. If the module contains a video, a CV of the speaker is also provided to the learner as well as the presentation shown in the video. If the module is a self-study session, the learner is provided with documents that relate to the course and instructions on how to interact with the material. In the modules 2, 3, 4 and 5, quiz questions related to their content are provided. The learner is required to answer 80% of the quiz questions correctly to be able to start the next module. This process was integrated to control for the learner's engagement with the content of the modules. After the successful completion of module 6 and thereby the completion of the course, the learner gets provided a certificate of successful completion. This approach was used to strengthen the motivation of participants and provide a documentation of their participation, which in the corporate context can be used for further career development.

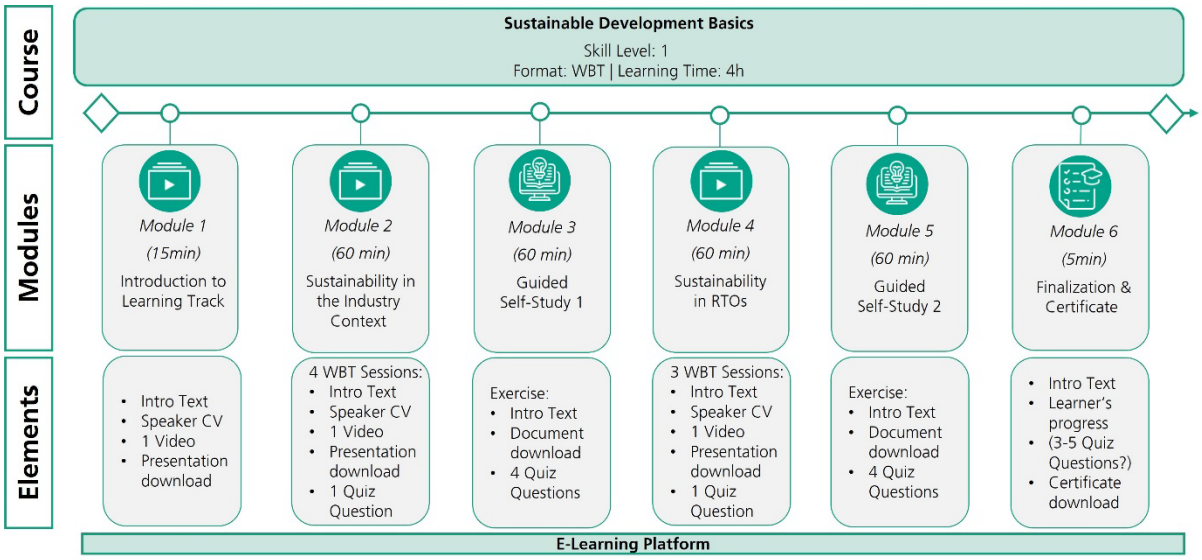


Figure 3: Structure of the Sustainable Development Basics course

5. Content of the Sustainable Development Basics Course

The "Sustainable Development Basics" course aims to provide ISI researchers with a rudimentary overview of the concepts related to sustainability in the industry as well as for RTOs. Module 1 entails an introduction to the course, track and overall training program. It highlights changes to previous training courses and lays out the structure and focus of the following modules. Module 2 consists of four videos that focus on the topic of sustainability in the industry context. In the first video the concept of sustainability and the SDGs are illustrated. Following, various sustainability initiatives, regulations and standards are introduced. Here a specific focus is put on the Brazilian economy. Subsequently, the steps to create a robust company strategy on sustainability are outlined and methods to counteract pressing environmental challenges are presented. Lastly, best practice related to the different dimensions of sustainability are presented and strategies for RTOs to support small and medium enterprises in sustainability actions are provided. Module 3 constitutes the first of two self-study sessions. In Module 3 the focus lies on the SDGs. The learners are provided with two documents to read, namely the "SDG Compass" and "A short introduction to the GRI Standards". The learners are asked to contemplate how sustainability reporting can be made attractive to potential RTO customers. Following, Module 4 contains two videos that focus on the RTO perspective in the context of sustainability. The first video highlights the drivers of sustainability for RTOs. Hereby, different impact perspectives are explained and sustainability actions by various RTOs presented. In the last video, the topic of assessing the sustainability impact of R&D activities from RTOs is introduced. Further best practices examples for the communication of positive sustainability impact are given. Module 5 is the second self-study session and focuses on the sustainability report of the Fraunhofer-Gesellschaft. Learners should focus on the integration of sustainability in the work of researchers and the Fraunhofer-Gesellschaft governance structure. They should also theorize about possible sustainability actions

that their RTO could engage in. Finally, Module 6 presents the learners with a final quiz relating to the content of the previous modules. Once correctly answered the learners can download their participation certificate.

5.1 Implementation of the Sustainable Development Basics Course

The implementation process of the ”Sustainable Development Basics” course on the platform of the Corporate University of the Industry System was carried out by researchers of Fraunhofer IPK, SENAI National Department (DN) experts and professionals from the Corporate University itself. Fraunhofer IPK provided the produced course material to the Corporate University of the Industry System, who were responsible for the structuring and integration of the material into the platform. Therefore, an authoring tool designed for creating educational content was utilized. Hereby, the content was generated in using the Sharable Content Object Reference Model (SCORM) format, ensuring compatibility with the virtual learning environment. Following, the created course was tested by SENAI DN experts and Fraunhofer IPK researchers to assure a well-functioning training process and report potential flaws. Before opening the course to potential learners, they were informed via E-Mail that a new course has been created and what topics will be covered by it. A 30-minute webinar was also provided in which a Fraunhofer expert introduced the course concept, content and benefits. These activities were carried out to promote the “Sustainable Development Basics” course, raise interest and increase the participation numbers. The course was officially launched in September 2024.

6. Feedback for the Sustainable Development Basics Course

The following section presents an analysis of the course evaluation that was conducted in January 2025. Out of 50 individuals who started the course, 28 completed the full program and provided feedback. Participants rated their level of satisfaction/agreement with the following questions/statements using a five-point Likert scale. Notably, 100% of these participants expressed overall approval of the course. Figure 4 shows that 96 % of participants were satisfied or very satisfied with the course, highlighting its effective design. This high satisfaction reflects the successful alignment of content, format, and workload with participants’ professional routines.

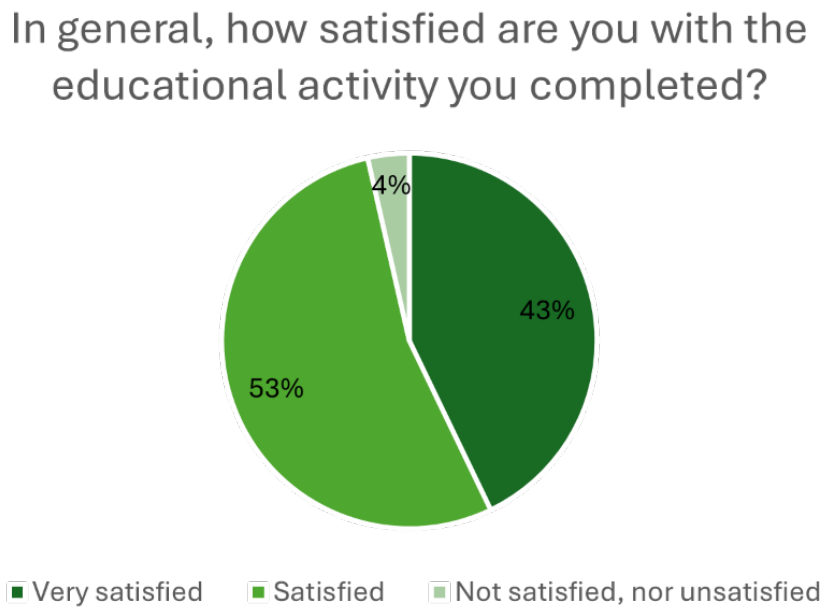


Figure 4: Level of overall Satisfaction

Figure 5 shows that 96 % of participants agreed or strongly agreed that the course content contributed to their professional development. This result emphasizes the course’s practical relevance and its effectiveness in addressing the specific needs of professionals working in research and industrial settings.

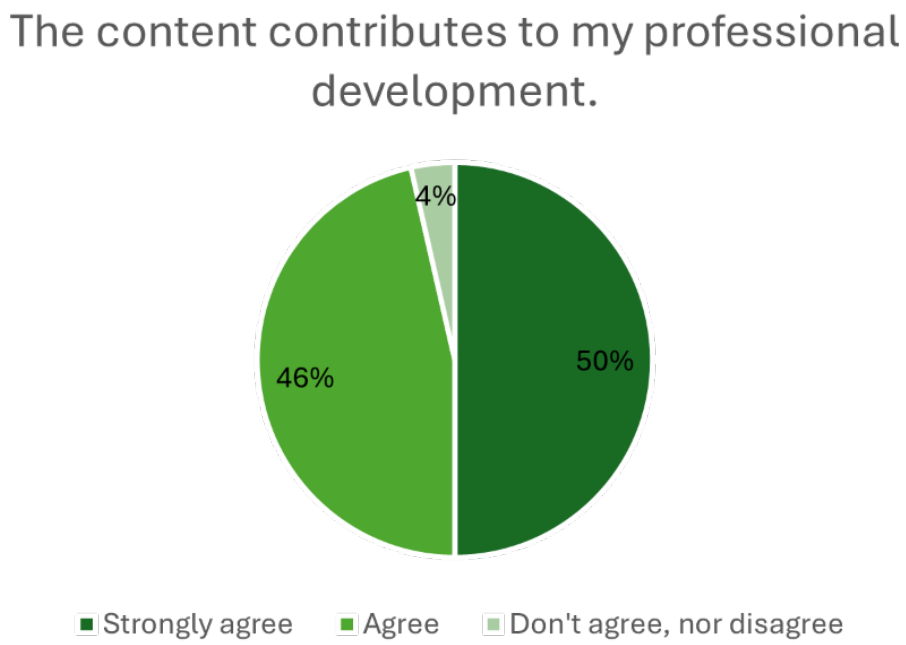


Figure 5: Contribution to professional development

Figure 6 illustrates participants' satisfaction with the educational workload. This aspect is particularly significant given that the course was conducted in a standard workplace setting alongside participants' regular professional duties, a critical consideration in the course's design. Notably, 27 out of 28 participants (96 %) agreed that the educational workload was appropriate, indicating a high level of alignment between course demands and the realities of workplace-based learning.

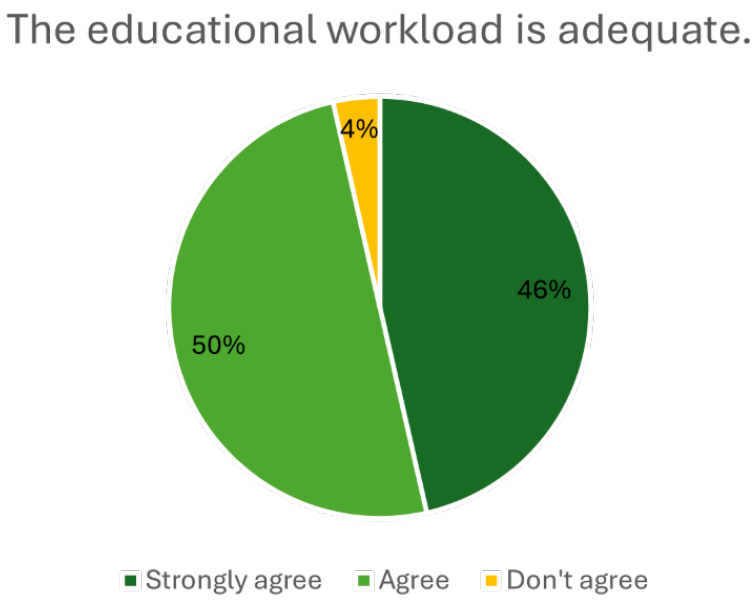


Figure 6: Adequateness of workload

The overall feedback reflects a high level of satisfaction with the course. However, several participants expressed a desire for enhanced interaction, specifically through direct engagement with instructors in synchronous sessions. Additionally, there was a clear interest in expanding course content to address contemporary topics such as artificial intelligence. One participant also suggested that the inclusion of case studies tailored to the organizational context could significantly enhance comprehension, noting: *"I believe that the implementation of case studies applied to our system would facilitate understanding."* In addition, the need for technical depth was highlighted, with one participant stating: *"More technical segmentations, we have seen many actions done by*

Fraunhofer and I would like to apply in a more technical way in my ISI." The feedback points to participants' interest in more interactive, technically focused content that reflects current industry and research challenges.

7. Discussion and Conclusion

The very high satisfaction rate of course participants highlights the success of our modular asynchronous distance education approach tailored to RTO professionals. Further, a key success factor of the course was the alignment with the workplace realities of RTO professionals in Brazil which is highlighted by the positive feedback related to flexibility, manageable workload and practical relevance. Hence, these results underline the method of building the course on best practice processes. Particularly, the structural design, length and content relevancy for the target audience of the course played an important role in the positive feedback. However, it needs to be pointed out that there are areas for improvement derived from the participant feedback. Most notably is the integration of synchronous elements such as Q&A sessions or webinars that foster the engagement between learners and instructors. Moreover, the integration of learner related case studies and more technical content highlight an avenue for specialising course content. Future iterations of the distance education course should integrate such specializations and operate a hybrid model that combines synchronous and asynchronous elements. The courses' success provides guidance for managers and distance education instructors that aim to facilitate learning content for professionals. Emphasis should be placed on understanding the needs of the target audience and address real-world challenges. Further, structuring the content in different modules that consist of short video sessions or self-study material that can be accessed in a flexible manner can have a positive influence on the success of the distance education program. Enabling learners to engage directly with the instructors via, for example, Q&A sessions, provides an opportunity to increase motivation and resolve pending questions. Lastly, future research could focus on the exploration of adaptive learning technologies like AI and the cross-cultural applicability of course content.

Ethical Declaration

This research did not require ethical clearance, as it does not involve procedures requiring prior approval from an ethics committee.

AI Declaration

For the creation of this paper no AI tools were used.

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Review of Empirical Studies on Video Conferencing Platforms and Hardware for Best Practices

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Abstract: Video conferencing (VC) has become invaluable in education, catapulted during the COVID19 pandemic which was declared by the World Health Organisation in March 2020. It became a service connecting a far-flung remote teaching and learning across the globe. In the process, different tools and methods serve diverse ability to keep virtual classrooms engaging and efficient. The forceful shift to incorporation of online teaching and learning resulted in a new era in education which continued even after the end of the pandemic two years later. The implication of recommendation on adoption of VC systems and good practices is to collect best practice scenarios of educational VC carried out against a backdrop of a body of literature. The aim of study is to conduct an empirical exploratory literature review of VC technologies and methods to engage students online in various classroom environments by the recent drastic changes. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used to include the articles to be reviewed. This paper is based on an analysis of 18 research articles with empirical studies specifically from two electronic databases, namely the Institute of Electrical and Electronics Engineers (IEEE) and Science Direct which are open and accessible in the field of educational technology searched using the search strings relating to VC in Education. The analysis categorised the findings into three areas: 1) VC Software Platforms (2) Platforms integrated with VC Software Platforms and 3) VC Hardware. This review provides the information to enable ideating a portable VC toolkits and online applications for engaging learning experience design in higher education classrooms.

Keywords: Video Conferencing, VC Platforms, Online Teaching and Learning, Virtual Classroom, Portable Hardware Tools

1. Introduction

The COVID19 pandemic declared by the World Health Organisation in March 2020 caused a massive disruption to the education sector. The only connection between educators and learners was through Video conferencing (VC) which had become an invaluable service connecting the far-flung remote teaching and learning across the globe. There was no time to assess which software platforms, hardware tools and methods would serve ability to keep virtual classrooms engaging and efficient. In the unprecedent period of the pandemic, Camilleri and Camilleri (2021) highlighted educators were pressurised to utilize digital technologies including learning management systems (LMSs) as well as VC programs to reach the students isolated at home to prevent contagion (Bolumole 2021, Gandolfi, Ferdig and Kratcoski 2021). Thus, the forceful shift to incorporation of online teaching and learning leading to the development of diverse ability from a global laboratory of VC system resulted in a new era in education after the end of the pandemic two years later. Cole, Ray and Zanetis (2004) defined VC as synchronous audio and video communication through computer or telephone networks between two or more geographically dispersed sites. Lawson et al (2010) in their literature review, stated that VC closely followed the trajectory of its status as a 'cutting edge' technology in different educational environments. This steered the way as Camilleri and Camilleri (2022) had put it for the mushrooming of a lot of VC tools, platforms and apps like Zoom, Google Meet, Microsoft Teams and Slack. Paying attention in a class, staying engaged, and actively participating in a lecture have been widely stated as critical components for learners' academic success.

The implication of recommendation on adoption of VC system is to collect best educational VC platforms and hardware carried out against a backdrop of a body of literature. The aim of study is to conduct an empirical exploratory literature review of VC technologies/methods engaging students online in various classroom environments by the drastic changes during the pre-Covid through Post Covid-era. The scope of the review covers the evaluation of VC platforms and hardware for the ideation of a VC Toolkits within the 2024 timeframe of the ERASMUS+ Portable VC Toolkits and Online Applications for Engaging Learning Experience Design in Higher Education Classroom (EdViCon).

2. Methodology

The search for relevant literature was specifically from review articles published in journals from two electronic databases, namely the Institute of Electrical and Electronics Engineers (IEEE) using IEEE Xplore and ScienceDirect Search which are open and accessible in the field of educational technology. The following search strings were used: Videoconferencing platforms and tools, online teaching and learning, Virtual conference: hybrid, online conference, Zoom, Teams, Google, Meet/Hangout, Webex, Adobe Connect and Skype; Online application: Software, platform and system; Portable VC tools: Mobile and remote; Engagement: Interaction, communication and discussion; Learning Experience Design: Learning environment and flipped classroom. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram (Moher et al, 2009) was used with the four phases: identification, screening, eligibility, and included (Fig. 1.). The search period was set starting from 2020 to 2024 covering at least 5 years based on the recommendation of Crompton and Burke (2020) to explore how video conferencing system evolved from empirical papers only. Manually extracted data based on content analysis such as article type, journal name, year of publication, topic, title, research methodology and research results on the VC technologies/methods, specifically on the software and hardware tools engaging students online in various classroom environments were conducted. Only original and peer-reviewed literature written in English was selected.

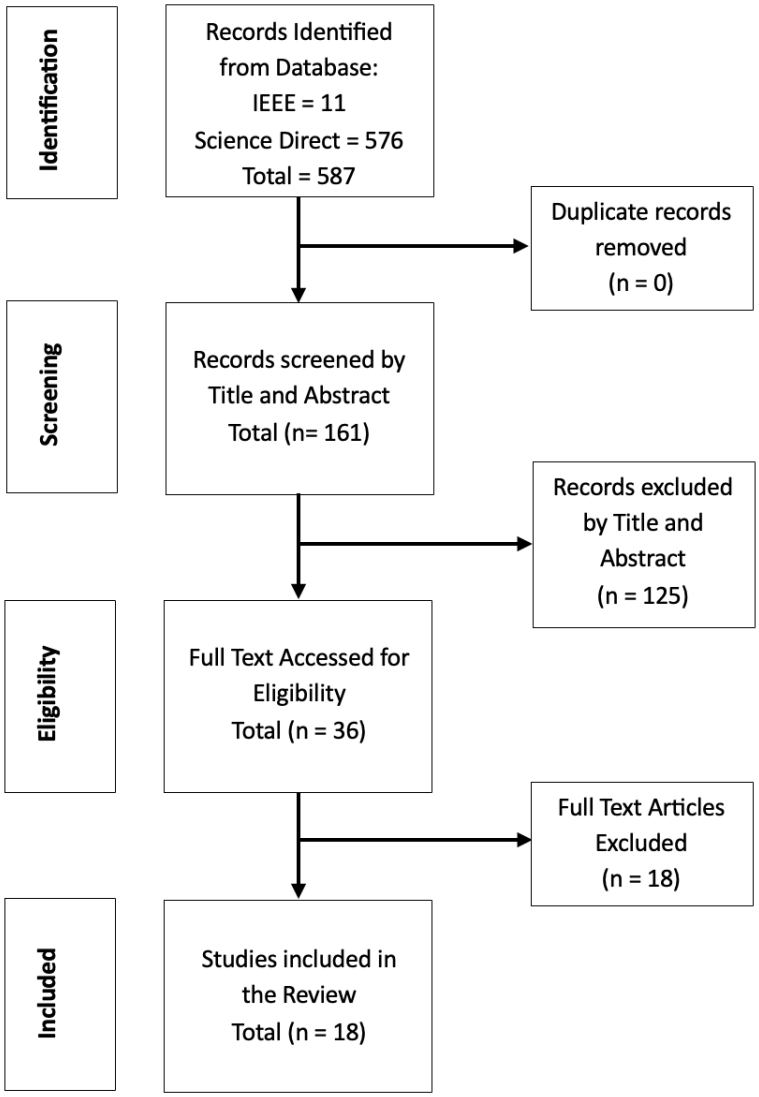


Figure 1: PRISMA flow chart of selection process

The initial sample was 587 scientific articles based on previously determined keywords. Subsequently, the articles were selected based on title, abstract, and keywords with 161 relevant empirical studies being found. Following that, 36 were identified as appropriate to the selection criteria after thoroughly reviewing their entire

content based on criteria 2 and 3. Finally, 19 papers were analysed where the distribution included 2020 (n = 2), 2021 (n = 4), 2022 (n = 5) and 2023 (n = 7) while there was no related literature in 2024.

3. Results and Discussion

The literature on VC reflects much of the academic material available focusing on university experiences in distance learning, in which a range of VC platforms and hardware were used to facilitate learning at a distance. The articles were categorised into three areas: 1) Videoconferencing Software Platforms (2) Platforms integrated with Videoconference Software Platforms and 3) Videoconferencing Hardware.

3.1 Videoconferencing Software Platforms

All articles reviewed were made in reference to the technology specifically VC software platforms that allows teachers-students in different locations to hold real-time face-to-face teaching and learning. Table 1 shows the VC software platforms and the analysis identified from literature reviewed.

Table 1: Videoconference software tools from research articles

Software Platform	Analysis of Research Articles	References
Zoom, Microsoft Teams, Google Meet	Implication that gender could be contributing factors from their studies on 254 female students' perception on using video conferencing tools. 83.07% perceived their computer self-efficacy using Google Meet while 56.69% Zoom and 5.51 Microsoft Teams.	Bui et al. (2020)
Zoom	The video broadcasting potion of Zoom are used, however, the Zoom chat and Zoom polls are replaced by own chat and polling options of Acadly, a Classroom Response System and Attendance Automation Platform) launched in 2017.	Vashisht & Gautam (2020
Zoom	The engagement with the Zoom VC in the platform Technology acceptance model (TAM) with a cross-sectional research design explained how the use of technology influences learning outcomes based on 2 variables: PU (extent to which one believes that using specific technology will develop their performance), PEoU (partly refers to the mental effort and ease of learning exerted when using technology), and behavioural intentions in reference to Zoom. The main conclusion drawn is that PEoU with Zoom strongly affected PU, attitude, and perceived levels of learning when using the platform. Further, PU with Zoom predicted intentions to use Zoom in the future, directly and indirectly, on the relationship between PEoU and behavioural intentions; however, PU failed to influence perceived learning outcomes in the video conference class. Therefore, while PU predicted future use, it did not influence how well students reported their current performance in their video conference course. In consideration of findings, students and instructors should be well trained on the use and functionality of video conference software before its implementation in video conference classrooms.	Railey et al. (2021)
Zoom, Google Meet, Skype, Discord Tool	A case study analysed the use and impact of VC platforms in learning process with findings that vast majority of teachers have a very high knowledge of the Zoom and Google Meet platforms and only medium-low knowledge of the Skype, Microsoft Teams and Discord tools. Thus, it influenced their decisions to use Zoom and Google Meet tools more frequently to teach classes as evidenced by the 56.3% responses of students to usage of Zoom. Aligning to the students' perception, similar trend was observed in their knowledge in the scale of medium-high knowledge of the Zoom and Meet platforms while however, they have low-zero knowledge of the Skype, Microsoft Teams and Discord tools. They concluded their study indicated 66.6% of both teachers and students have stated that VC has not affected their educational development.	Rio-Chillccee et al. (2021)
Google Classroom, Zoom, Cisco Webex, Microsoft Teams	Comparison indicated that Google Classroom was both educators and students' top preference with 97.3% and 94.2% respectively followed by preference for Zoom was 22.0% by educators and 10.0% by students. Microsoft Team preference was 14% by Educators and 11.0% by Students. Less than 10% of both educators and students indicated Cisco Webex.	Saidi et al. (2021)
Zoom, Google Meet	The comparative investigation on using zoom and google between 2 years, the use in 2021 dominated more ($r = 0.346$, $p < 0.01$), with a shift from often to almost always.	Hurajova et al. (2022)
Microsoft Teams	A statement was made that a difficult thing about teaching remotely with Microsoft Teams program, only four faces could be seen at the same time. This related to the need for visibility of students and requested to use programs at home that are only accessible at their school.	Klusmann et al. (2022)

Software Platform	Analysis of Research Articles	References
Microsoft Teams	The high eigenvector centrality value of MS Teams represents that the students are more prone to the "off-the-shelf" resources prepared by the instructors. Microsoft Teams and the Learning management System (LMS) have shown a high clustering coefficient that denotes their tendency toward making clusters in the whole network indicating the importance of Microsoft Teams. This attributed to the audio-visual feature preference.	Muhuri and Mukhopadhyay (2022)
Zoom	Zoom synchronously connected remote learners to in-person learners, peer mentors, and instructors in the First Year research Immersion (FRI) research labs. Students perceived zoom was a good attempt to enable them to converse about what was happening in lab without their physical presence. They were also able to be engaged throughout the process in asking questions about the steps.	Shamoon-Pour et al. (2022)
Zoom, Microsoft Teams, Google Classroom, Click Meeting, Discord Tool	From 621 respondents, there had been a visible rise especially in the usage of Zoom, Microsoft and Google Classroom during the Covid-19 Pandemic. Microsoft Teams increased in knowledge about the tool by 73 percentage points with the highest number of respondents indicated the use of MS Teams with 3.9 on a 5-point scale). Zoom increased in knowledge about the tool by 62 percentage points, was in second place (3.14)in usage. Google Classroom increased in knowledge about the tool by 27.21 percentage points, was in second place (1.62). The most frequently used e-learning tools during the COVID-19 pandemic have been mainly VC platforms such as MS Teams and Zoom.	Stecula and Wolniak (2022)
Zoom, Google Classroom	The students completely agreed on screen sharing functions in the Zoom online class which is an essential skill for online class effectiveness. The features of Zoom applications in the online class are vital instruments to enhance respondents' online learning process with reference to chat function for them, raise hand and students poll functions as important feature to engage students more in the Zoom online class. Zoom was agreed to work as a catalyst of make the classes live and induce as a source of interaction among the students. The students have given second priority on Google classroom so that they can enjoy all benefits of uploaded materials of online class afterwards to minimize confusion.	Alom et al. (2023)
Zoom	Identified indicators and characteristics of engaging teaching videos to recorded lecture videos using Zoom was used to design an AI- enabled that autogenerate a report on engaging teaching videos.	Verma et al. (2023)
Zoom	Students' engagement, as reported during their typical Zoom classes, was explained in part by their motivations, anxiety, and mediated by mind-wandering. These results were important as it encouraged instructors to better attend to factors that positively impact students' mind-wandering and online engagement.	Wong et al. 2023
Webex, Zoom	Participants from 28 schools listed that WeBex and Zoom were the frequently used during VC sessions.	Fütterer et al. (2023)

Figure 2 indicated that Zoom was the most frequent investigated or mentioned VC software platform followed by Microsoft Teams, Google Meet, Google Classroom and Discord Tool. The rest that included Webex, Skype, and Click Meeting only occurred once.

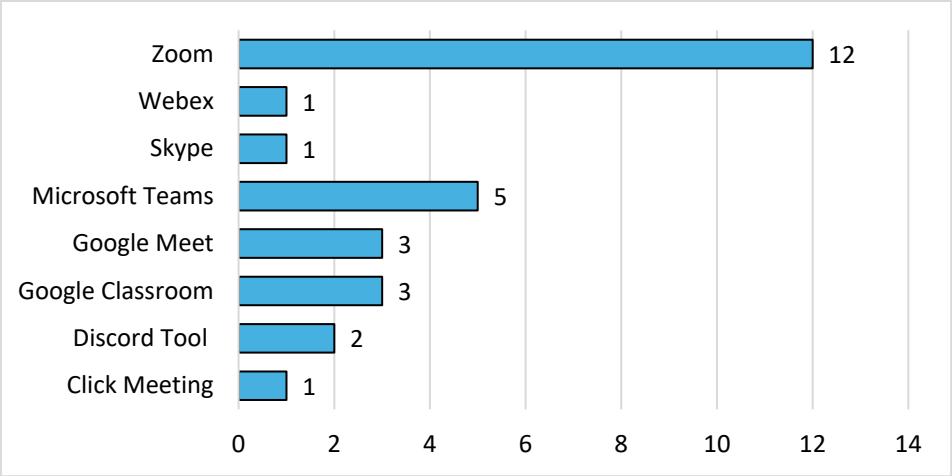


Figure 2: Frequency of video conferencing software platforms in research articles

3.2 Platforms Integrated With Videoconference Software Platforms

Table 2 is a review of learning platform which are communication tools that can be used in conjunction with or integrated into VC platforms to enhance engagement of students during the sessions and improve learning outcomes for effectiveness. These are interactive polls and questions and answers sessions, real-time brainstorming, gamification all with real-time feedback.

Table 2: Platforms integrated with Videoconference Software Platforms – communication tools – learning management software

Software	Analysis of Research Articles	References
Kahoot, Socrative, Blackboard Mentimeter, Poll Everywhere, Moodle, Brightspace and Canva.	The platforms were integrated into the Acadly product to help instructors to boost engagement inside the classroom. The pandemic necessitated a change in the approach to be more suitable to synchronous online learning. Zoom chat and Zoom polls were replaced with Acadly's own chat and polling options integrating other platform and sends all learning data back to the LMS Gradebook in the system, collected and consolidated automatically.	Vashisht & Gautam (2020)
Edpuzzle, Quizzez, Kahoot, Moodle, Schoology, Flipgrid, Edmodo, Padlet, Jamboard	The top 3 types with students' dependence on the preference by educators were Schoology followed by Edmondo and Flipgrid while all the others were reported with less than 10% among 485 educators and 485 students as respondents. This analysis helped educators to choose the most effective and convenient platform preferred by students which consequently would assist in identifying the most appropriate approach.	Saidi et al. (2021)
YouTube	An increase in familiarity noted YouTube was the most popular social network with services and applications adapted to e-learning .	Stecula and Wolniak (2022)
Whiteboard	The white board function and screen annotation functions were reported by student's perception as important to enhance students' engagement in the online learning process	Alom et al. (20223)
Blackboard	Seewo interactive whiteboard has customized an "interaction" toolkit for Seewo Pinco, which includes a voting system. With the voting system, teachers can display multiple-choice questions on the board, and students can select their answers using their personal devices. The answer distribution is then presented on the board. Students can see whether they chose the correct answer and how many of their peers selected each option. Teachers can also assess how well students have mastered the content and provide customized feedback immediately. This voting system is known as a student response system (SRS), also referred to as clickers or classroom response systems (CRS). By allowing students to interact with the teaching content in real-time through their personal devices, the voting system ultimately strengthens teacher-student interactions. It was perceived usefulness in improving the learning process (PU-process) and perceived usefulness in enhancing learning outcomes (PU-outcome). IWBs were reported to be significant in PU-process but cannot guarantee PU-outcome. To ensure PU-process, teachers should not focus too much on the entertainment provided to avoid distracting students, nor should they treat IWBs as ordinary information presentation tools. It was reported that it enhanced teacher-student interactions, captured their attention, promoted learning engagement, and alleviated learning anxiety. Furthermore, the Seewo interactive whiteboard can also be beneficial for teachers, as it assists in accessing learning materials, diversifying knowledge presentation, and emphasizing key information.	Lou et al. (2023)
Blackboard, YouTube, TikTok	Without segregation or comparisons of the tool, It was reported to be widely used in the study and proven to be effective in learning and online teaching platform of the university. Students have shown greater enjoyment when that enjoyment or gratification has come from the sensation of learning, and not from any other type of application used is widely known by the students, so their predisposition toward it will be positive indicating personal satisfaction levels increase. TikTok was stated as social network that students have shown greater enjoyment when that enjoyment or gratification has come from the sensation of learning, and not from any other type .In general Post-Covid era, comparison between videoconferencing and face-to-face did not show any difference in perception.	Gil-Cordero et al. (2023)
Moodle	50 % of the respondents do not have the sufficient skills to create online tests and assignments and to use advanced features of Moodle; study revealed that faculty have an adequate level of readiness when it comes to online teaching as they possess the minimum requirements in terms of access to hardware (90 %), t	Zgheib et al. (2023)
AI tools	AI-powered technologies are playing a pivotal role in making virtual meetings more efficient, accessible, and engaging. seamlessly integrates with major VC platforms like Zoom and Microsoft Teams to eradicate background noise, such as keyboard clicks and ambient chatter, ensuring pristine audio clarity	Verma et al. (2023)

Software	Analysis of Research Articles	References
	for all participants. From real-time transcriptions to emotion recognition and intelligent meeting summaries, AI in VC is transforming how teams connect — smarter, faster, and more securely. Intelligence-enabled tool from the reports generated by this manual annotation. With the assistance of this tool, the engagement enhancing teachers' behaviours and movements can be identified from recorded lecture videos, and a report can be generated on engaging teaching videos. For the classification task of video analysis, the deep learning model is adopted in this research. The model is trained with manually annotated videos and determines class imbalance issues and misleading metrics. assist the education institutes in creating moderation in the lecture delivery and whether the teachers are utilising the technology effectively. Additionally, this can help teachers recognise the presence or absence of engagement-enhancing behaviours and movements during their video conferencing sessions.	

3.3 Videoconferencing Hardware

The VC hardware refers to the tangible components and equipment *n*ecessary to enable high-quality VC experiences. The VC hardware tools are essential components to facilitate clear audio, visual and video communication in both virtual, face-to-face and hybrid education classrooms. As this review is focus on portable hardware, most affordable, convenient, and adaptable technology, with audio and video capabilities to facilitate VC software are identified from research articles as listed in Table 3.

Table 3: Videoconference portable hardware tools from research articles

Hardware Tool	Analysis from research articles	References
Laptop, Smartphone, Tablet	Among the types of devices used by the 254 female students as respondents, 80.31% used smartphone during VC, while 70.47 used laptop and 7% used tablet.	Bui et al. (2020)
Webcams, headphones, VCS, cameras and tripods 3D cameras	Few participants were lacking these tools; students perform a task with such a laboratory, they can typically observe the machines, steps and results via webcams. Proper teaching equipment and hardware on both sides must be ensured. Insufficient sound quality or choppy audio transmission during live sessions can be frustrating and annoying. With 3D cameras and tripods, students could observe the experiment from multiple angles	Grodotzki et al. (2021)
Laptop, Second larger screen, Good keyboard, Tablet	The respondents made up of 1,115 Dutch educators with 76.7% females and 22.7% males expressed the need of more facilities at home to enable them to provide online education during the Covid-19 pandemics.	Klusmann et al. (2022)
iPod Touch	iPods provided the most affordable, convenient, and adaptable technology, with audio and video capabilities to facilitate mobile Zoom conferencing in the lab. Additionally, to address cleaning and disinfection guidelines, plastic cases and screen protectors	Shamoon-Pour et al. (2022)
Laptop, Tablet, Smartphone	Research shows that the most used e-learning device was a laptop. Most of the respondents found it very useful in e-learning with the usefulness score was 4.75 on a 5-Likert Scale. The usefulness of tablets (3.18) and smartphones (3.35) was assessed at an average level.	Stecula and Wolniak (2022)
Laptop, tablet, smartphone	General availability of technology like laptop and smartphone to use for digital distance teaching indicated that 98% were able to use the technological devices and 99% from the high familiarity group were able to take home and use the one-to-one tablet for school trial with *t*-test showing statistically significant differences in the frequency of tablet use in class for mathematics. Familiarity with technology seems to be important for how distance teaching was organized (e.g., percentage of digital distance teaching) but, consistently, did not contribute to student-observed learning activities, student-perceived cognitive activation, and students' effort in learning in digital distance teaching. By explicitly connecting tools with student-observed learning activities, students were observed to use tools mostly for passive or active learning activities, as known from studies for face-to-face teaching.	Fütterer et al. (2023)
Multimedia speakers, omni-directional mic, document camera, a tracking camera.	All the hardware tools were installed in the classroom to supplement the Seewo Interactive Whiteboard hardware system.	Luo, et al. (2023)

Hardware Tool	Analysis from research articles	References
Laptop, webcam, microphone	90% have accessed to supplementary tools indicated a high level of technological readiness in term of access to equipment.	Zgheib et al. (2023)

4. Discussion

It was the COVID19 restriction that plunged the educational institutions from conducting physical classroom to online classroom using VC modalities leaving no options. The software VC systems alone are not sufficient to communicate the teachers' writing on a board, presentation slides, the gesture and posture, and engage students in groups or individually with differentiated or engaging activities. Hurajova et al. (2022) described the period as the transition to the online environment being sudden and unexpected that the instructors were unprepared for this crisis, not having adequate time and facilities to plan distance education consistently. Prior to this situation, the education research was delving on the evolution of traditional face-to-face education towards digital education with the advancement of the technologies in developing 21st century students coming from the alpha, Y and Z generations (Chan, 2022). The popular VC platforms for education prior COVID19 were listed as Zoom, Google Meet, Microsoft Teams and Webex Meetings. Rio-Chillccee et al. (2021) and Stecula and Wolniak (2022) attributed to knowledge of usage. According to Klusmann et al. (2022) knowledge of VC software for online education is essential to access to suitable software that should serve the needs of teachers as well as students. Thus, it explains that the most frequent use or mentioned in the same order indicated in Figure 2. In addition, they stated the usage relates to the need for visibility of students, as some online programs teachers were now using for their teaching could only display a maximum of four student videos as in Microsoft Teams. Fütterer et al. (2023) reported the familiarity towards the VC software platform that led to the emergency use during the crisis. Vashisht & Gautam (2020) and Saidi et al. (2021) indicated that these tools have been integrated into the LSMs provided by the education institutions. This is attributed to the software being provided by the education institutions based on the familiarity in using the platforms.

The activities involving lectures, student presentations, group-formation and group work, live quizzes, peer-group assessment, and collaborative design and facilitation are some of the activities that require integration of video-conferencing functionalities and various web-based software. Martin et al. (2020) emphasised that engaging the learner in the online course is vitally important as they are separated from the instructor and peers in the online setting. Accordingly, engagement is examined through the lens of interaction, participation, community, collaboration, communication, involvement and presence. Research from the reviewed articles shows that the students engage and participate less in the online sessions, feel or get excluded by turning off video and microphone for avoiding technical issues or due to the absence of social norms, and require higher levels of motivation to be active in the courses. Stecula and Wolniak (2022) indicated that proper resources also positively influence the absorption of e-learning content. Gil-Cordero et al. (2023) stated that effectiveness in learning is measured with respect to two variables, from a perspective not only of academic satisfaction and by the learning achieved, but also from a user perspective through user satisfaction. Several engaging and real-time collaboration platforms with gamification features data-driven and interactivity-focused to engage students and receiving immediate feedback from students that include Kahoot, Quizzizz, Mentimeter, Polls, mentioned in the review articles (Table 2) have unique features are used based on the knowledge and familiarity (Stecula and Wolniak, 2022). Aldalur and Perez (2023) indicated that such VC platforms with gamification is a strategic attempt that can turn learning into an immersive activity. Blackboard can be used to facilitate discovery learning.

There should be a strategy to utilize mobile devices to maximize all students' connection to in-person learners, peer mentors, and instructors in online remote situation in real-time. Shamoon-Pour et al. (2022) shared that approach must include giving students responsibilities that allowed them to be engaged and feel like meaningful participants in their investigation on the First Year research Immersion (FRI) research labs. Additional online applications and accessories, the VC hardware are used along with video conferencing systems for sending the information interfaces a student gets in a face-to-face classroom. Gladović et al. (2019) reviewed that the basic equipment for VC include camera and its functionality of zoom option and resizing, audio equipment relating to sound which was immensely important as a delay in sound transmission of only 0.5 second would lead to a discrepancy between speech and body movement which would impede teacher-student interaction and lastly lighting and background. The digital capabilities in the online teaching context involve even the use of camera setup, light settings, body language, eye contact, and other digital and non-digital tools, depending on the field of study. For the educators, managing multiple devices and acting in front of the camera to provide a good experience for the viewers is different from face-to-face interaction. A big challenge is the resolution of the delivered VC platforms should be optimal to cater to the needs of all the students who might encounter Internet

speeds and or data plan restrictions as mentioned by majority of the articles. Some teachers still have difficulties at a psychological level due to this new teaching modality. The teachers mentioned that they needed to be in constant training to learn the new digital tools. Reliable equipment needs to be available, which provides good sound quality and is supported by a fast connection. Grodotzki et al. (2021) highlighted the use of 3D camera. The review by Atal et al. (2023) demonstrated how 360° videos are a preferred method of overcoming the limitations of standard video as they can provide a more realistic and authentic experience. The evolution and advancement into Artificial Intelligence technology will play a pivotal role in making VC more sophisticated as educational institutions are adopting the model of hybrid learning (Verma et al. 2023).

5. Limitation of the Review

The review has encountered limitations related to the scope of the purpose confining to VC software platforms and portable hardware from empirical research articles. Most of the research articles reviewed between 2000 and 2024 did not relate to a broader comparison of various individual platforms and their suitability for educational context but rather congregated approach with hypotheses on skill, competences, experiences, effectiveness, mental health, and satisfaction of using these platforms. Furthermore, most articles concentrated on usefulness in improving the learning process (PU-process) and perceived usefulness in enhancing learning outcomes (PU-outcome). Majority of the research articles are from the aftermath of COVID19 pandemics plunging the education institutions to go online classes with comparatively studies between pandemic and post-pandemics era. The main tools for teaching and learning are being emphasised that the technology used must be clearly introduced to Educators and students to ease the online learning process and consequently enhance students' ability to perform successfully. Instructors must be well informed about the features, usefulness, and technical issues of VC platforms and hardware to extend their knowledge and confidence in using the system as highlighted by Bailey et al. (2021).

6. Conclusion

In the new post-COVID era of virtual classrooms, the educators are now required to teach partially or entirely online, and universities are trying to equip them with additional accessories, software and other resources in the absence of classroom resources. Furthermore, engaging students in the absence of visual clues, room for interaction, lack of understanding about online norms, and lack of technology knowledge etc. reduced the online engagement, which reduces the quality of contact hours. The 18 articles have been analysed categorised into three areas: 1) Videoconferencing Software Platforms (2) Platforms integrated with Videoconference Software Platforms and 3) Videoconferencing Hardware. This review has provided sufficient information to enable ideating a portable video conferencing toolkits and online applications for engaging learning experience design in higher education classroom. It has indicated that basic knowledge of usage and familiarity are the foundation of adopting VC platforms. As for the hardware, audio-visual aids includes headphones, tracking cameras and extended screen are essential tools for visibility and audio quality to engage students with the educators. However, further research should be conducted to address the gap in understanding how the VC tools can effectively support smooth VC to improve the online classroom atmosphere and the dynamics of interaction between educators and students.

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Ethics and AI Declaration

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No AI tools were used the creation of this paper.

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The Findings of Focus Group Study on Independent Learning in A Digital Age

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Abstract: All students need to learn independently, yet the fast-changing world, especially with technology, creates many obstacles. In major cities like Hong Kong, where institutions vigorously promote contemporary educational patterns, the problem is more complicated and serious. Given the abundance of technologies, it is vital to understand how Hong Kong university students view independent learning and their expectations for its use in the digital age. The CUHK Independent Learning Centre (ILC) has been operating for over 30 years. Extending the language centre model makes this centre special. The ILC surveyed CUHK students in 2022 to learn about their opinions on autonomous studying and their expectations for help. A follow-up focus group study has been conducted to clarify the results and verify the first analysis by blending qualitative insights with the mostly quantitative findings. The principal objectives of the focus group study are to explore the viewpoints of students and aid ILC in improving its support for student needs. Students who completed the survey were invited to meet ILC hosts in 2023. Students discussed numerous issues with two ILC lecturers. All discussions were taped and transcribed into Word. Thematic analysis of student interview replies was done using QualCoder V3.5. Further content analysis showed that student perspectives fall into four main themes and different sub-themes, with a total of 480 instances recorded. The interpretation demonstrated that students comprehend independent learning, its concept, its practice at CUHK, self-efficacy, technology use, teacher assistance, and future support. Many students appear self-aware and secure in learning. They appear prepared to define independent learning in a digital age and traverse an information- and technology-rich environment. Although survey and focus group results varied on how significant in-person instruction by educators is in autonomous learning, focus group findings generally agree with survey results. In general, the assessment of both findings shows that most CUHK students enjoyed independent study.

Keywords: Independent Learning, Focus Group Study, Higher Education in Hong Kong, Independent Learning Effectiveness, Student Perception

1. Introduction

Independent learning is crucial for all learners, as it fosters critical thinking, self-regulation, and lifelong learning skills. However, the rapidly changing world, particularly the swift advancement in technology, has introduced numerous challenges for learners striving to practice effective independent learning. This situation is particularly complex in metropolitan areas like Hong Kong, where universities actively promote the adoption of the latest educational trends and technologies. Moreover, The COVID-19 pandemic necessitated a sudden shift to online learning, which exposed several challenges. The social isolation resulting from the pandemic is widely regarded as a significant factor contributing to the increased use of online platforms for independent learning. Michael K. Ponton contended that independent learning does not necessarily correlate with social isolation. Independent learning transpires when an individual enrols in and engages with a college course perceived to offer personal fulfilment. Independent learning denotes the interactive and emergent agency that recognizes the relationships among the individual, environment, and activities via self-efficacy assessment. (Ponton, 2006, P.46) Students frequently reported experiencing challenges in adjusting to online formats, frequently feeling exhausted by the absence of structured guidance and interaction that are present in traditional classroom settings. This transition underscored the necessity for students to cultivate independent learning skills, a skill that many were not yet familiar with before the pandemic.

Even though universities in Hong Kong encourage independent learning and the use of technology, students frequently find themselves inadequate for the expectations that accompany these initiatives. Students may experience feelings of confusion and frustration because of the absence of in-class interaction and support, as they may be unsure of how to effectively employ the available technology for their learning. The Independent Learning Centre (ILC) at the Chinese University of Hong Kong (CUHK) has been established for more than three decades. It provides various services, including workshops, self-learning materials, talks, and student events, to support students' academic requirements and enrich their understanding of different subjects. In order to gain a deeper understanding of CUHK students' perspectives and reflections on independent learning, as well as their expectations about assistance for independent learning, the ILC conducted a survey in 2022 to gather input. The title of the survey is “The Survey of the Effectiveness of Independent Learning”, and it was the first formal study on student’s perception and expectations on independent learning in Chinese University of Hong Kong. The purpose of this survey is not just to find out the needs or preference of CUHK students on independent learning

but also aims at providing valuable information for the relevant parties to better assist students in facing campus challenges and future endeavours.

The study of the survey examines users' perceived needs, expectations, and self-efficacy in the context of independent learning. Of the 221 valid responses from undergraduate and postgraduate students, over half indicated agreement that the University fosters a conducive independent learning environment and reported successful experiences in independent learning. Participants rated the Independent Learning Centre favourably; they engaged in the workshops and consultation sessions and utilized the resources provided or recommended by the Centre to support their independent learning. This study not only exemplifies the facilitation of independent learning in higher education institutions but also carries pedagogical implications. The survey reveals university students' perceptions of independent learning in the 21st century and defines the characteristics of a successful independent learner. Participants credit their success to the formulation of learning goals and strategies, which they progressively achieve through sustained self-motivation and suitable guidance from teachers. The findings of the study indicate that independent learning in contemporary pedagogy must include suitable assessment and teacher support. Furthermore, independent learning at the university level may extend beyond language acquisition. However, our findings indicate that some students particularly favour independent learning in skills pertinent to public examinations and specific elements of academic writing. Consequently, universities should not only provide support for language acquisition but also expand the principles of independent learning to encompass additional educational dimensions, thereby fostering a more viable and enduring future for independent learning. (Chao et al, 2023, P.47-48)

To further explore the result and the meaning of the findings, a subsequent focus group study that can complement the predominantly quantitative outcome with a qualitative outcome was conducted.

2. Reasons for Conducting a Focus Group Study on an Independent Learning Survey

A more comprehensive understanding of the motivations behind all survey responses can be achieved through a focus group study. Surveys are efficient at quantifying public opinion or behaviour; however, they frequently fail to clarify the underlying causes. Morgan (1997, P.3) contends that focus groups are particularly effective for examining complex subjects and understanding the rationale behind discerned trends in quantitative data. Focus groups can produce comprehensive, descriptive data that clarifies the rationale behind survey findings, as emphasized by Krueger and Casey (2009, P.19). Researchers can examine the reasoning behind survey replies via focus groups. The quantitative results can be clarified by the motivations, perspectives, and convictions expressed during participant conversations.

Survey data may occasionally be abstract or lacking in context. Liamputtong (2011, P.2-4) argues that focus groups provide researchers with a more comprehensive understanding of the ways in which individuals' beliefs and behaviours are influenced by their experiences and social contexts, as opposed to surveys alone. Wilkinson (1998, P.341-342) contends that focus groups are essential for the analysis of the context of attitudes and beliefs. A venue for contextualizing findings by examining real-life experiences and viewpoints is provided by focus groups. This can help researchers understand the relationship between survey responses and the daily lives of participants, as well as the broader social context.

Focus groups are more exploratory in nature, while surveys are methodically constructed to evaluate certain concepts. Morgan (1997, P.6) stresses the exploratory nature of focus groups, which enables the identification of unexpected insights and the development of innovative research inquiries. The interchange of opinions may deviate from the scheduled questions as the discussion progresses, indicating that a focus group can uncover unexpected themes, perspectives, or issues that were not initially considered in the survey design. This could result in a more profound comprehension of the subject matter and innovative research opportunities.

Occasionally, survey queries may be misinterpreted, leading to ambiguous or perplexing results. Powell et al. (1996, P206) suggest that focus groups can be implemented to clarify the significance of survey questions and responses, thereby allowing researchers to interpret the data in a suitable manner. Focus groups enable the clarification of ambiguity through investigating and follow-up inquiries. Focus groups offer a method to address these misunderstandings by explicitly questioning participants about their understanding of specific questions or concepts.

By combining surveys with focus groups, data triangulation is facilitated, thereby improving the dependability and validity of the research results. Flick (2018, P.542-543) emphasizes the importance of triangulation in qualitative research, particularly the integration of surveys and focus groups, to improve the dependability and

validity of the results. The validity of the research is improved by triangulation, which provides a variety of perspectives on the same phenomenon. The conclusions are more robustly supported when qualitative and quantitative data converge.

In summary, focus groups offer a more comprehensive, contextual, and exploratory comprehension of the data, thereby significantly improving survey research. They help researchers in the following ways: clarifying the fundamental rationale of phenomena, identifying unforeseen discoveries, resolving uncertainties, formulating new hypotheses, triangulating data, and verifying findings. Consequently, this will facilitate the primary objectives of attaining a more comprehensive understanding of students' perspectives on independent learning and enabling the ILC to improve its support for student needs.

3. Process and Research Method of the Focus Group Study

In 2023, students who had completed the survey were granted the opportunity to partake in in-person interviews with ILC hosts. The students were guaranteed that all submissions would be treated with the utmost confidentiality and that the research team would exclusively use them for the purpose of research and publication in the invitation. Sharing from the students will not have any impact on their GPA at the university, as this initiative is a component of the non-formal education curricula. All information will be stored in a secure location at the Independent Learning Centre (ILC) for a maximum of five years. Even if the students have given their consent, they may subsequently change their mind and withdraw it by writing to the ILC. They may also contact The Survey and Behavioural Research ethical Committee of the Chinese University of Hong Kong (CUHK) if they have any concerns regarding the ethical issues.

A total of 19 students participated in the study, divided into five groups. Ten questions in four categories have been prepared to facilitate the discussion (*please see Appendix 1 for the questions), which is limited to one hour each group. Guided by two ILC teachers, students addressed the prepared questions to engage in debates and articulate their perspectives on several themes pertaining to independent learning.

The interviews were conducted in English and have been recorded. A part-time assistant has since been employed to transcribe all recordings. The data acquired from these interviews were processed utilizing Qualitative Data Analysis (QDA) technology, especially QualCoder V3.5. Qualitative Data Analysis (QDA) technologies offer a systematic framework for the management and examination of extensive qualitative data, guaranteeing meticulous and transparent analytical procedure. (Miles, 2019, P.6-P11.) This grounded theory enables the researcher to initiate a study without the necessity of testing a hypothesis. Instead, it enables her to formulate hypotheses by attentively considering the statements of the research participants. The process is referred to as hypothesis-generating research, as it entails formulating hypotheses post data collection, rather than hypothesis-testing research. The grounded theory method emphasizes two fundamental principles: (1) inquiry instead of quantification, and (2) hypothesis generation through theoretical coding. (Auerbach & Silverstein, 2003, P.19) Following this approach, the using of QDA for theoretical coding facilitates the organization of material into digestible chunks, hence enhancing navigation and retrieval of pertinent information. Moreover, theoretical coding technologies like QDA, streamline the coding process, enabling researchers to annotate data segments with pertinent codes, hence aiding in the identification of recurring themes and patterns for building an abstract theoretical understanding of the studied experience. (Charmaz, 2025, P.5).

QualCoder V3.5 has been employed in this research to do theme analysis, enabling a thorough evaluation of student responses to the interview questions.

4. Result of the Qualitative Data Analysis (QDA)

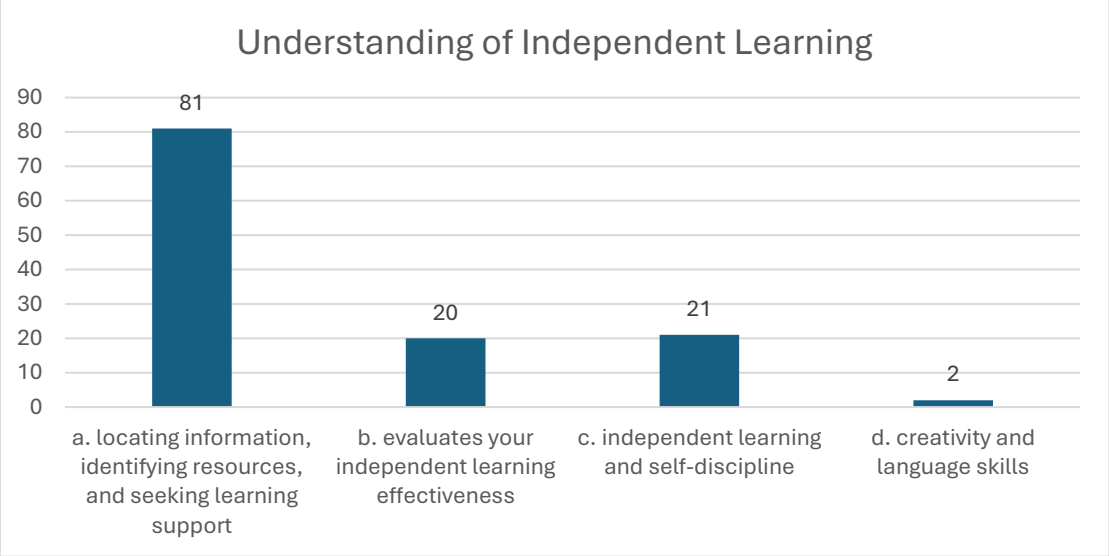
When it comes to managing and analysing vast amounts of qualitative data, QDA technologies offer a standardized framework that assists in this process (Miles, 2019, P.6-P11.) The data may be organized into more manageable chunks with the assistance of these technologies, which makes it simpler to navigate and retrieve information that is relevant. In addition, QDA tools make the process of coding easier by enabling researchers to tag specific sections of data with appropriate codes. This, in turn, assists in the identification of concepts and patterns that appear repeatedly (Charmaz, K. (2014). Constructing grounded theory (2nd ed.). SAGE Publications). Analysing the transcripts with QDA tool: QualCoder V3.5, it was discovered that the opinions of the students that were gathered from the focus group could be classified into a variety of main themes and sub-

themes. There are two to five sub-themes associated with each main topic, and a total of 480 documented instances have been assigned to each of these sub-themes.

The first main theme is "Understanding of Independent Learning". It has encompassed 124 recorded instances, categorized into four sub-themes. Mostly, these instances refer to students seeking suitable information or resources and seeking learning support. Students also find self-evaluation and self-discipline are crucial component of independent learning.

Table 1: Main theme: Understanding of Independent Learning

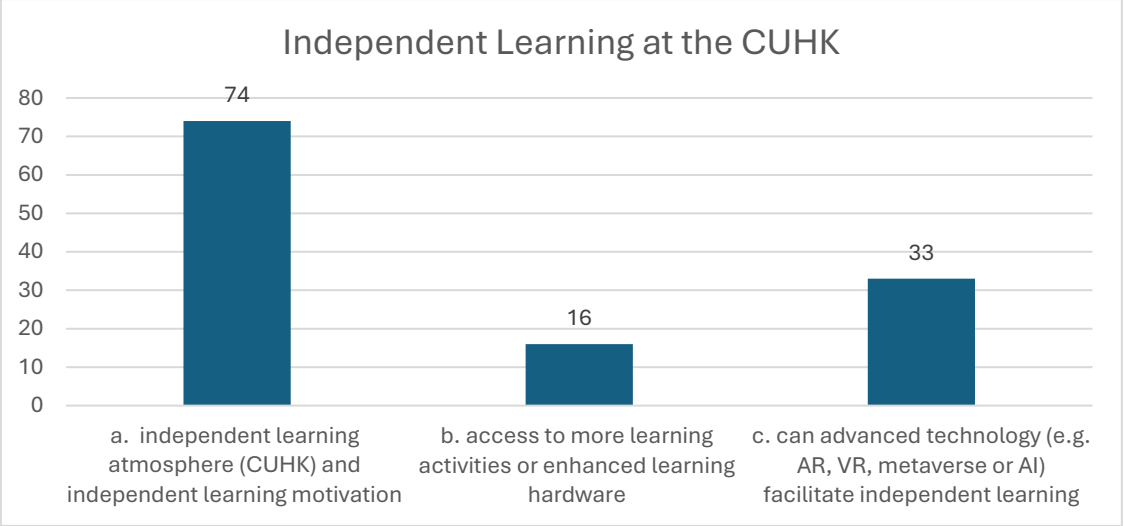
1.Understanding of Independent Learning (30%)	Coding Result (Instances)
a. locating information, identifying resources, and seeking learning support	81
b. evaluates your independent learning effectiveness	20
c. independent learning and self-discipline	21
d. creativity and language skills	2
Total	124



The second main theme is "Independent Learning at the Chinese University of Hong Kong (CUHK)". It has encompassed 123 recorded instances, categorized into three sub-themes. Many students acknowledged that CUHK fosters positive independent learning and regard themselves as moderately to highly motivated independent learners. Students often express concerns on the utility of advanced technologies, such as AI and enhanced learning hardware, in enhancing their learning effectiveness.

Table 2: Main theme: Independent Learning at the Chinese University of Hong Kong (CUHK)

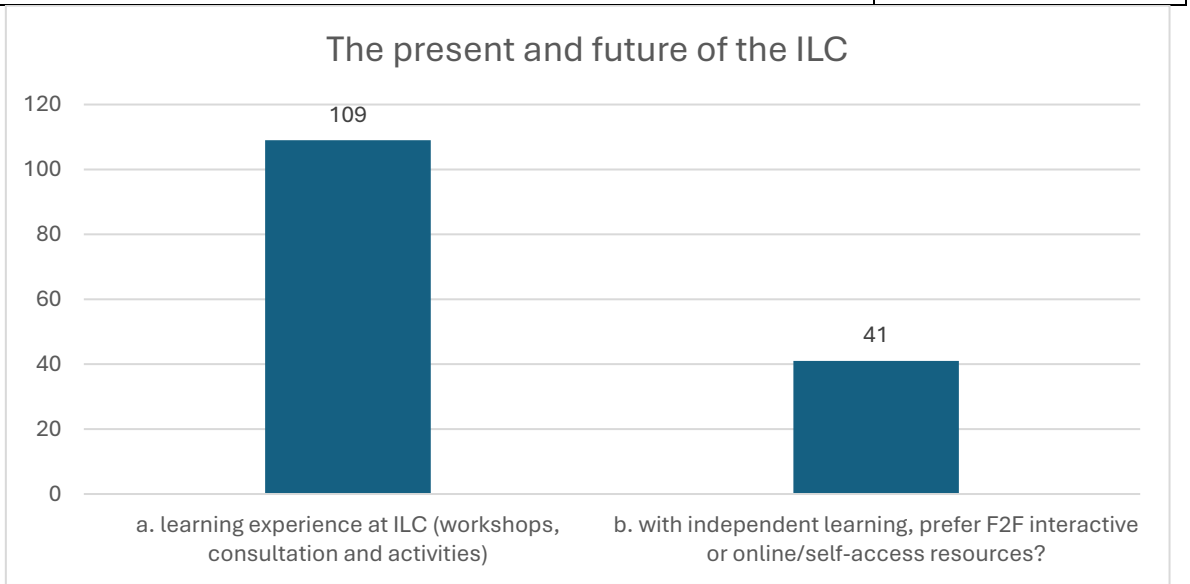
2. Independent Learning at the CUHK (30%)	Coding Result (Instances)
a. independent learning atmosphere (CUHK) and independent learning motivation	74
b. access to more learning activities or enhanced learning hardware	16
c. can advanced technology (e.g. AR, VR, metaverse or AI) facilitate independent learning	33
Total	123



The third main theme is "The present and future of the ILC". It has encompassed 150 recorded instances, which is highest among the four themes, and all the instances could be categorized into two sub-themes. Students were eager to discuss the learning activities they engaged in at ILC and their perceptions of the experience. Some of them choose to discuss their preference towards independent learning with teacher guidance, peers, or online/self-access resources.

Table 3: Main theme: The present and future of the ILC

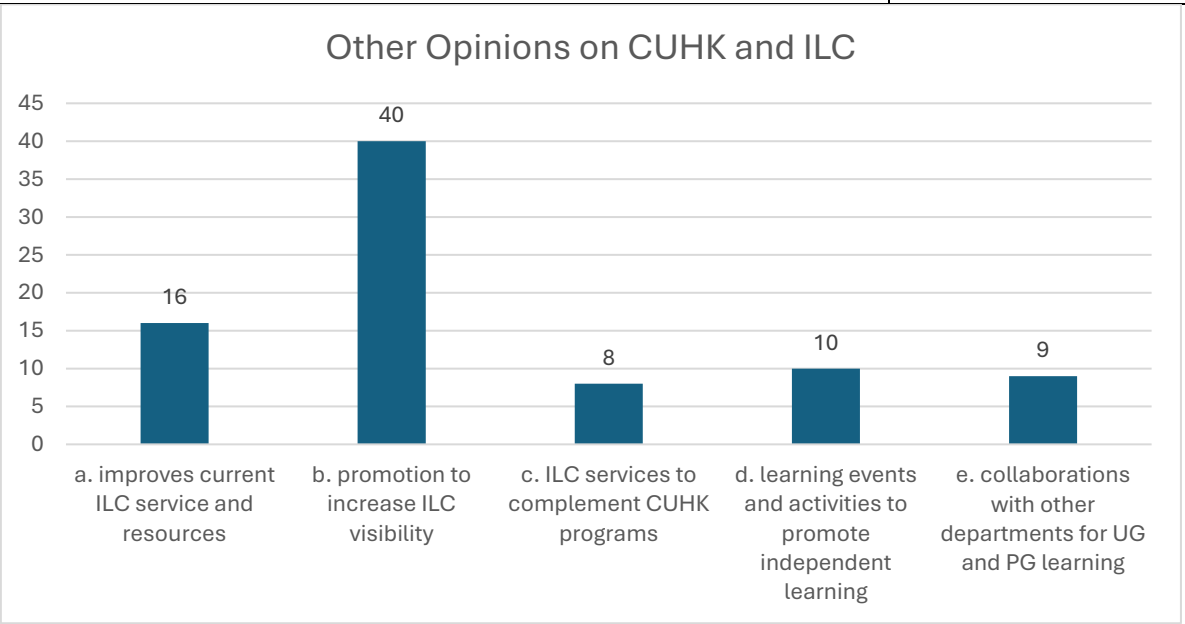
3. The present and future of the ILC (30%)	Coding result (Instances)
a. learning experience at ILC (workshops, consultation and activities)	109
b. with independent learning, prefer F2F interactive or online/self-access resources?	41
Total	150



The fourth main theme is "Other Opinions on CUHK and ILC". It has encompassed 83 recorded instances, categorized into five sub-themes. The distribution of instances suggests that students consider ILC highly beneficial and desire enhanced promotion of it. They also expect continuous improvement of services and resources on ILC, along with more chances for independent learning engagement.

Table 4: Main theme: Other Opinions on CUHK and ILC

4.Other Opinions on CUHK and ILC	Coding result (Instances)
a. improves current ILC service and resources	16
b. promotion to increase ILC visibility	40
c. ILC services to complement CUHK programs	8
d. learning events and activities to promote independent learning	10
e. collaborations with other departments for UG and PG learning	9
Total	83



5. Discussion

Based on the results of the QDA, it appears that students at CUHK have a profound understanding of independent learning and anticipate receiving support from the teacher. Students assert their accountability for establishing their own learning objectives and strategies; nonetheless, they highly value the direction and support provided by their teachers, as indicated by the insights gathered from focus groups. One student from the study group stated, "My understanding about independent learning is that this learning is that you decide on what you want to learn and how much you want to reach, and the decision are made by yourself." (Informant A) Similar sentiments can be observed among other participants of the focus group. The ability to determine your own learning objectives and areas of concentration undoubtedly demonstrates autonomy and control over one's educational journey, a notion supported by numerous scholars as a significant component of independent learning (Chan, 2011) Many concurred that independent learning entails attaining one's educational objectives by identifying appropriate information and resources. A student remarked, "I do agree that being able to locate like suitable resources or seek help when necessary is part of the independent learning. Because if you cannot locate the suitable resources, you are going towards the wrong direction, which you may get lost in it and feel very like you do not know how to begin with all the help." (informant B) Nonetheless, educator assistance is considered essential throughout the entire process of autonomous learning, particularly when establishing personal learning objectives. Informant A remarked: "when I come to this place, I find that all the learning objectives are set by yourself. So the teacher will give the advice according to the learning objective of yourself. So I think the advice is more personalized." (informant A) The guidance appears to be more individualized. Teacher guidance can identify individual needs, which is fundamental to independent learning and is crucial for addressing difficulties and challenges, as noted by informant B: "I think during the learning process, we may face a lot of problems or difficulties. So some you can, like solve it by yourself, but some you may need more support from the seniors. So I think this is crucial for independent learning." These understandings regarding independent learning align with the survey's findings in which students view independent learning as the active reflection and systematic attainment of their learning goals. They believe that a successful independent learner

must exhibit a strong motivation to reflect on their own learning needs. The survey results reveal that students favour self-directed learning with teacher guidance as the optimal method of independent learning (Chao et al, 2023, P.46-47)

The QDA results also revealed that students perceive self-discipline, which refers to self-determination, because of self-motivation and as a crucial component of effective independent learning. The results of this survey align with the results from the previous survey. The study's findings indicate that students believe that a high level of motivation is essential for effective autonomous learning and self-reflection on their educational needs. (Chao et al, 2023.P.46-47) One of the students from the group stated, “I think self-discipline is definitely important, but that could be… I think it's also related to our motivation. If you have a very strong motivation, then of course you will be very disciplined. You will spend time every day to do some preparation for yourself early” (Informant C) While Some students exhibited doubt regarding the correlation between self-discipline and self-motivation, while others firmly believe in a link between the two. A student remarks, " I think self-disciplines is a result due to self-motivation. Because I think I have the motivation to learn something, but I have only the motivation. For example, today I have the motivation and tomorrow I don't. Another parties or the school to help us is to form a systematic way, or to help us to keep that motivation and keep that discipline. It's providing us the regular time to meet up, to learn new things. That's the way to help to balance motivation.” (Informant D) Self-discipline's capacity to motivate and regulate oneself to achieve a specific goal through the effective utilization of time, energy, and resources aligns with the principles of self-determination theory (SDT). SDT posits that students who perceive their learning as self-determined or autonomous regard their studying as a self-chosen, volitional act that reflects their individual aspirations and views. (Willems and Lewalter, 2012, P3098-3100) Self-determination is considered essential not just for sustaining motivation but also to achieve one's established learning objectives. One of the students stated that “I agree with him that set goal is very important. It's like the end. You need to know where you want to go, but the self-discipline is like the process. So, when you set a goal, you definitely need to be self-disciplined to go through this road.” (Informant E) Consequently, we assert that all autonomous learners should reflect on their self-determination to attain effective and successful learning outcomes.

While numerous instances about student’s learning experience and independent learning at CUHK indicate that they acknowledge the integration of emerging technologies, such as VR and AI, as an important development that can enrich educational experiences, most students also regard effective guidance from teachers as crucial for maximizing the advantages of these tools. In certain instances, students asserted that such guidance is essential for the effective execution of independent learning, student remarked, “I think advanced technology is beautiful because I'm an economics student. So maybe when I learned the math, instead of just memorizing the formula blindly, maybe I want to see the method, the step-by-step proof. If I Google or find a textbook, it will take me one hour to find the relevant one. For example, if there's relevant AI, I can just ask them the question: Can you please prove this formula for me? And then they will do it for me. So they will do the calculation. I think also for medical students, I'm not sure, but this is what I've heard before, I think they need to look at the diagram and stuff, so maybe if they use a VR or a large screen to make it very big, it will make them remember it better. I think if technology is used in the right way, it can help students save a lot of time and improve their learning.” (Informant F) Student emphasized the substantial educational advantages of modern technologies. Technologies such as VR and AI can accurately and effectively demonstrate intricate processes, uncover hidden and challenging-to-observe areas, and allow students to tailor and engage with them based on their personal tastes and behaviours. Thus, they are unequivocally “beautiful” instruments. However, student also believe we should exercise caution in utilizing technology for learning “I think maybe we need to be careful. As I mentioned, we can learn with enjoyment, but we can't learn to enjoy it. I think I'm worried that if we involve too much AR, VR most advanced technology because it has very good potential to be an entertainment equipment instead of a learning equipment. Maybe we will lost in some games or videos instead of learning itself.” (Informant G) Informant G has pointed out that the issue of learning with technology lies in the potential erosion of focus or objectives, so reducing education to mere pleasure, hence, informant G would recommend “instead of we purchase more AR/ VR equipment, maybe we need to involve more tutors or just more experienced educators. I mean just more experienced tutors so we can better feed the knowledge instead of feeding the knowledge by some video or by some tool…It can be an assistant, but it can't be a very major part of your learning process. So that's my opinion. I think we need to be careful with it.” In this era, students are inherently inclined to use technology for learning. However, guidance from teachers or peers is crucial. A student expressed, “I think activities like the teachers or professors or the peers, they could help me to define what I need and give me some guidance. If there is some hardware to support, to add some reality, it's also great. But it's not necessary.” (Informant H) The student has observed that it is also advantageous to have hardware available that improves realism. Nevertheless, it is not required. Another student stated that: “sometimes I think it's about going back

to the very basics and doing like the most simple and straightforward ways of finding help. And for me personally, I think that's like having workshops, doing interactions" (Informant I) Other students have express similar opinions as they have found genuine human connection activities, such as workshops and consultations, are more fundamental and direct for learning, thus superior. One of the most significant findings of the independent learning survey is that students prioritize teacher guidance over technological alternatives. (Chao et al, 2023, P.46-47) The survey results suggested that many students are in favour of CUHK providing a greater variety of learning activities, including both in-person and online activities, as well as all available e-resources for independent learning. They are of the opinion that technology should perform a supportive function in this type of learning environment.

A significant number of students consider the Independent Learning Centre (ILC) essential and advocate for its promotion. A student remarked, "I'm 100% satisfied with the ILC Service because I told... I already said that it not only helped me to gain the knowledge, but I also gained the practical tips. I think that is the life-learning skills I gained." (Informant J) Similar opinion has been expressed by other students on different groups, and it also aligned with the findings of the independent learning survey. The diagram (Figure 1) below, which is based on questions and result from the survey (Chao et al, 2023, P.46-47 & P.49-50), demonstrates that the areas in which students have most frequently requested assistance for independent learning are on practical area such as academic support (*writing and oral presentation) and life-long learning.

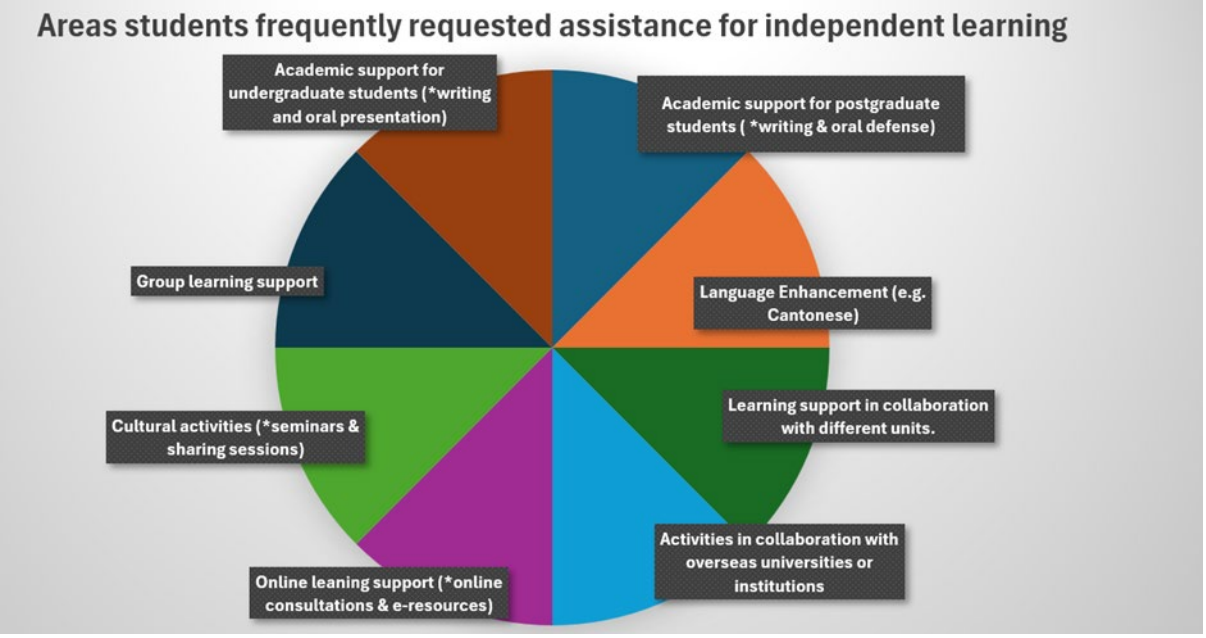


Figure 1: Areas students frequently requested assistance for independent learning

This finding is consistent with the data collected form ILC, which indicated that many students participated in the ILC workshops or sought consultations were mainly focus on these two domains. Nevertheless, despite the elevated utilization rate and the abundance of accessible resources, students persist in anticipating further assistance or novel advancements in these two domains in the future. (Chao et al, 2023, P.47) The services and resources of the ILC are seen as highly beneficial and significant; therefore, students have proposed many initiatives, including increased collaboration with different departments, the organization of additional events, and enhanced networking opportunities with professors and tutors to promote and strengthen the ILC.

6. Conclusion and Suggestions

In conclusion, the attempt to use focus group studies to further examine the outcomes and implications of the independent survey conducted in 2022 was effective. We can see that the result derived by employing a qualitative research methodology, which is a focus group study, align with the findings of the independent learning survey. Utilizing the QDA tool, QualCoder V3.5, to categories and analyse the instances collected from the focus group study enhances our comprehension and provides robust support regarding CUHK students' perceptions and expectations of independent learning. Students at CUHK have a solid comprehension of independent learning, which highlights the value of both self-determination and the support of educators. The

incorporation of contemporary technology, including virtual reality and artificial intelligence, is regarded as advantageous; yet, students emphasize the importance of preserving a balance between technological engagement and direct human interaction, effective guidance from teachers is considered crucial for navigating challenges and enhancing their educational experience. This conversation illustrates the students' need for a learning environment that not only gives them the ability to take responsibility for their own education but also provides the essential support for them to achieve their goals. There is a collective goal for a more enriched educational experience, which is highlighted by the lobbying for expanded resources and initiatives from the Independent Learning Centre. This further demonstrates their dedication to delivering effective outcomes for independent learning.

The findings of this study suggest that universities should go beyond investments in instructional technology or innovations in course design to promote independent learning. They must strengthen students' self-discipline and autonomy while fostering significant interactions with diverse educational components. The teacher's guidance is essential in this interactive process, fulfilling several functions. Teachers can facilitate improved disciplinary management, evaluate learning outcomes, and promote self-study. They can also aid students in formulating their own learning strategies and reflecting on their educational accomplishments. Therefore, even in a learning environment that extensively uses teaching technology, teacher guidance remains crucial for fostering independent learning.

Although the research has yielded significant insights, it is crucial to recognize limitations. The sample size was limited, perhaps restricting the ability to be generalized of the results. The initial objective was to enlist a minimum of 25 students for 5 groups, rather than 19. Moreover, while all focus groups have offered excellent insights on nearly all predetermined subjects, few discussions have demonstrated profound contemplation or profound reflection on individual learning skills or strategies. The one-hour discussion period is likely somewhat constrained. Future researchers interested in conducting similar research should mitigate these constraints by broadening the study's scope to encompass bigger and more diverse participants, as well as extending the focus group discussion duration.

Ethics Declaration

Ethical approval for conducting a “Focus Group Study” on “A Survey for Independent Learning in CUHK” was obtained from the Survey and Behavioural Research Ethics Committee of the Chinese University of Hong Kong (CUHK). The approval ID(Reference No.) is “SBRE-22-0602”.

AI Declaration

Generative AI tools have been applied solely to verify the grammar and refine the language of this paper. The content of this paper, which includes all data, concepts, research methods, research outcomes, research findings, citations and references was entirely developed or composed by the author.

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Appendix 1

A survey for independent learning on CUHK

Focus-group study

Suggested discussion questions

Understanding of independent learning (30%)

1. Some say "being able to locate suitable resources or seek help when necessary" is part of independent learning. What do you think?
    - Follow-up question: Do you think an independent learner needs to learn how to evaluate their performance?
2. How do you evaluate the effectiveness of your independent learning? (e.g. good, fair, bad etc.)
    - Follow-up question: Have you had experience in learning independently at CUHK? If yes, can you describe it and share whether it was successful?
3. It has been said that "creativity" and "language skills" are not qualities a successful independent learner needs. Do you agree? Why or why not?
    - Follow-up question: How do you understand "disciplined"? Do you think being disciplined is necessary for successful independent learning?

Independent learning at CUHK (30%)

4. From 1 to 10, please rate (1 being the lowest and 10 being the highest) the independent learning atmosphere at CUHK. Using the same scale, how would you rate your independent learning motivation? Is there a difference between the two? Why or why not?
    - Follow-up question: Do you think there are sufficient independent learning elements in CUHK's formal curriculum?
5. Some students prefer having more learning activities or getting access to more independent learning resources to being provided with more hardware. Do you agree? Why or why not?
    - Follow-up question: How do you understand "hardware"?
6. Do you think advanced technology (e.g. AR, VR, Metaverse or AI) can facilitate independent learning? Should CUHK provide more support in this area?
    - Follow-up question: Do you have experience using advanced technology (especially for educational purposes)? How do you feel about it?

The present and future of the ILC (30%)

7. Can you share with us your experience in using the learning support services provided by the ILC? Are you satisfied with our services? Why or why not?
    - Follow-up question: When did you start using ILC services (e.g. first or final year)? How often do you use our services?
8. Under the presupposition of independent learning, do you still expect face-to-face classes or on-site teaching support provided when you learn, or is online courses or self-access learning resources sufficient?
    - Follow-up question: Do you prefer the support to be provided individually or in group? Why?
9. What do you think about the future development of the ILC (e.g. any topic you are interested in, any type of learning support you would like to see)
    - Follow-up question: If the ILC intends to offer more support in academic writing or for postgraduate students (e.g. proposal, oral presentation and viva defense), will you support this? Why or why not?

Others (10%)

10. Do you have any other opinion on CUHK's independent learning or the present and future of the ILC?
    - Follow-up question: Is there anything that supports your independent learning from your faculty (or department) or college? Do you want to see more collaboration between them and the ILC? Why or who not?

Designing a Practical Course from a Gamification Perspective: Students' Insights from Informatics Education

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Abstract: Gamification is a powerful instrument in the educational process if applied with care, considering the holistic learning experience. Literature has shown that using game-based mechanisms can motivate and engage students to participate actively in the learning process. This study investigates students' motivation and engagement to participate in practical courses developed based on a holistic gamification approach. In this paper, we present the results of a case study in a Swedish university. In one of our practical courses, we designed and implemented gamification concepts (bonus points, real-life scenarios, and role-playing). The course *Software Architecture* was designed and developed from scratch with the explicit aim of integrating gamification into its structure and delivery. After each lecture, we planned a workshop (with voluntary participation) with gamification elements, applying the learning outcomes. To investigate students' insights, we distributed a research survey, complementing the general course evaluation survey, at the end of the course, during which 60% of the enrolled students were present (enrolled students:100). In total, we collected 50 responses. The preliminary results show positive statistical significance on the students' motivation to participate actively and engage in the course; moreover, it encourages positive collaboration among the students and helps students better understand the course content. However, students experience different gamification elements (e.g., bonus points and role-playing) differently, i.e., role-playing seems to make students struggle more to apply it to a real-case scenario. Moreover, there are indications that the implemented gamification approach added extra stress and pressure to the students. We also identify implications that awarding bonus points, which are collected during seminars and used on the final exam, at the group level instead of an individual level, cannot be a fair approach. Overall, the results indicated that the students are motivated and engaged to participate in courses developed with a holistic gamification approach. The study will be replicated with a different group of students and in a theoretical course to better understand how gamification designs can be applied in different types of courses.

Keywords: Gamification, Motivation, Engagement, Bonus points, Informatics

1. Introduction

A common definition of gamification is proposed by Kapp (2012,p.10), as "*using game-based mechanics, aesthetics, and gamification to engage people, motivate action, promote learning, and solve problems."* When applied correctly, gamification should encompass the entire course, e.g., engaging storytelling, realistic scenario development, and meaningful rewards. Literature has shown that gamification is a powerful instrument in the educational process. If applied with care, students are motivated and engaged to participate actively in the learning process.

Gamified designs are still very rare in higher education. The gamification concepts utilised in the courses in higher education are often implemented as pointsification (Hellberg & Moll, 2023), bonus points (Miglietti, 2021; Moll and Gao, 2022), storytelling (Csikar and Stefaniak, 2018), role-playing (Beidatsch and Broomhall, 2010), checklists (Molléri et al., 2018), and simulation (Chatzipetrou et al., 2018). However, there is a lack of studies focusing on gamifying an entire course from a gamification perspective.

To address this gap, this study has the following two objectives. The first objective is to design a practical course from a holistic gamification perspective. The second objective is to investigate students' motivation and engagement to participate in this course through a survey conducted at the end of the course. More specifically, we distributed a research survey complementing the general course evaluation survey.

Aligned with the first objective, this study presents the results from a case study at a Swedish university. In one of our practical courses, we designed and implemented gamification concepts (bonus points, real-life scenarios, and role-playing). The course*, Software Architecture,* was designed and developed from scratch to integrate gamification into its structure and delivery explicitly. After each lecture, we planned a workshop (with voluntary participation) with gamification elements applying the learning outcomes.

Regarding the second objective, a survey was designed to gain students' insights regarding the implemented practical course. First, it explores how students perceive gamification in terms of its impact on their learning,

motivation, and engagement. Furthermore, it examines whether and how gamification influences students' experiences of stress and their ability to manage time effectively. Moreover, it addresses students' perceptions of fairness, particularly how gamified elements affect grading and assessment practices. We aim to provide a comprehensive understanding of the benefits and challenges of integrating gamification into the course design of practical courses.

This study offers research-based insight into how a practical course can be developed from a holistic gamification perspective and how it impacts students' motivation and engagement. It highlights positive outcomes and challenges grounded in a real-case study. The findings are relevant for educators interested in designing engaging, student-centred, holistic learning experiences using a gamification approach.

The remainder of the paper is structured as follows: Section 2 outlines the related work. Section 3 describes the course case used in this study. Section 4 presents the research methodology of our work. Section 5 presents the results of the analysis. Finally, in Section 6, discussion and conclusions are provided.

2. Related work

Gamification has been used as an approach (Hamari, Koivisto and Sarsa, 2014) to enhance students' motivation and engagement (Rassuli, 2022) and to improve students' learning outcomes (Moll and Gao, 2022). Learning can become more interactive by integrating gamified elements, such as bonus points, badges, and role-playing. Previous studies have also found that applied gamification in education can improve students' learning outcomes (Çakıroğlu et al., 2017; Moll and Gao, 2022). For example, Çakıroğlu et al. (2017) reported that using bonus points positively influenced students' academic achievement by increasing their engagement in an ICT course. However, some potential concerns with gamification implementation in education exist, such as limited classroom time for gamified activities (Hidalgo, Astudillo, and Castro, 2023) and fairness in gamification-based grading (Moll and Gao, 2022).

One of the core concerns with gamification in education is the limited time available for gamified activities, particularly in courses with large numbers of students and limited course seminar durations. These constraints may prevent all students from participating equally in gamified activities. As a result, this can raise issues, such as fairness in the learning experience with the implemented gamification. For instance, role-playing as a pedagogical tool has been used in many different subjects in higher education, such as history (Beidatsch and Broomhall, 2010), computing (Hingle et al., 2021), and requirement engineering (Svensson and Regnell, 2017). Role-playing can create a friendly learning environment by breaking the ice among students and enhancing their motivation to learn, as demonstrated by Beidatsch and Broomhall (2010). However, its implementation within time-limited course structures can also restrict student participation. For example, Hidalgo, Astudillo, and Castro (2023) identified limited classroom time as a challenge to executing role-playing in software engineering education. The limited time on role-playing could create an unequal learning experience for students, which could affect students' perception of the fairness of the implemented role-playing.

Another critical issue relates to assessment transparency and equity in gamification-based grading. Molls and Gao (2022) reported that students perceived inequities when awarded bonus points from the implemented gamification were not distributed fairly in group settings. In such contexts, individual contributions often vary. However, bonus points may be awarded collectively or without clear assessment criteria. This would lead to students' concern about the fairness of grading and the implemented gamification. It would be interesting to explore the fairness of gamification-based grading from students' perspectives further.

Gamification can also introduce stress for students. Competition among classmates can lead to psychological reactions, such as stress (Canning et al., 2020). For instance, some students may experience increased stress when they observe classmates performing well on tasks or struggling to meet expected learning outcomes. In addition, gamified elements, such as bonus points, can introduce extra course tasks, which can be perceived as an additional study load. For instance, Domínguez et al. (2013) found that time availability was the most frequent reason students indicated for being unable to participate in gamified activities in education. Previous studies by Alsswey and Malik 2024 found that stress was reduced among students following the application of gamification tools such as Kahoot! in educational contexts. This study also aims to further investigate students' perception of stress associated with applied gamification in higher education.

3. The Software Architecture Course

The course used as the case in this study is the continuation-level mandatory methods course "Software Architecture" in the system development bachelor's program at a Swedish university. The course aims to equip students with basic knowledge and skills in software architecture and its role in developing and maintaining software systems. This understanding is critical in a digital era where software systems grow increasingly complex and interconnected. The course was given for the first time in the spring of 2025; hence, this paper focuses on the first course round.

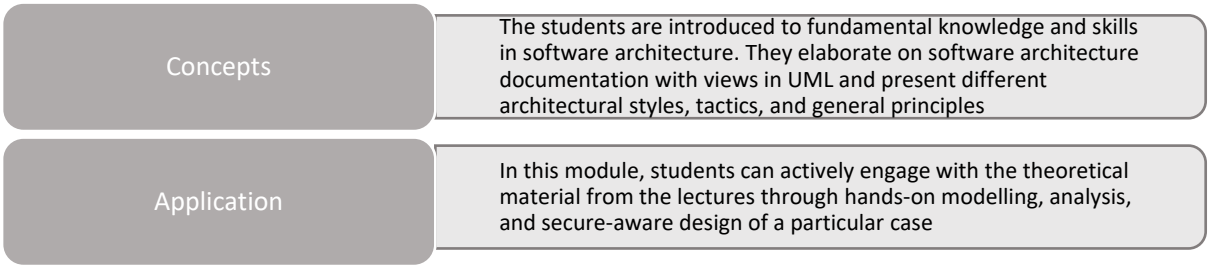


Figure 1: Course modules

3.1 Course Structure

The course design employs a holistic gamification model, comprising seven lectures, three workshops, one presentation seminar, and a concluding written examination. The above-mentioned concepts and application modules run in parallel, with lectures arranged in the concepts module and project work, including the workshops, a presentation, and a written report, in the application module.

The project is carried out in groups of 5-6 students. The workshops, which are designed to support students in their project work, are attended voluntarily; therefore, active participation is not mandatory. The project groups receive their assignments at the workshop and do not prepare in advance. However, they are encouraged to read certain chapters in the course literature before each respective workshop. Each seminar has a different setup, as described below. The focus of the workshops was:

- Identifying, capturing and organising information about class, responsibilities and collaborations.
- Identifying system components, drawing component diagrams, and introducing architectural constraints.
- Validate a software architecture by using the architecture trade-off analysis method.

The concluding written exam consists of 11 questions, each worth between 2 and 6 points. The maximum score was set at 30 points. For a passing grade, the students must earn at least 15 points (50%); 23 points are needed (80%) to pass the exam with distinction.

3.2 A Gamified Course Design

Although workshops and seminars are crucial in higher education for applying theoretical knowledge hands-on, students often prioritise studying for final exams, which typically determine their grades, leading to low attendance at voluntary sessions like workshops. This focus on exams may help students pass, but limits their deep understanding gained through practical engagement. A gamification approach (see Fig. 2) was introduced, offering bonus points—0.5 per workshop, 0.5 for the oral project presentation, and 1 for the written report, totalling up to 3 points—to motivate participation and deeper learning. Each workshop uses real-life case studies relevant to software architecture to encourage active learning. In the first workshop, students apply the Class-Responsibility-Collaboration card method to analyse scenarios by identifying actors and actions. In the second, they engage in role-playing exercises to explore system components, create diagrams, and discuss architectural constraints, gaining insight into different and conflicting roles in architectural design. Finally, in the third workshop, storytelling was applied using case-based real scenarios to validate the security-awareness of the developed architectural model.

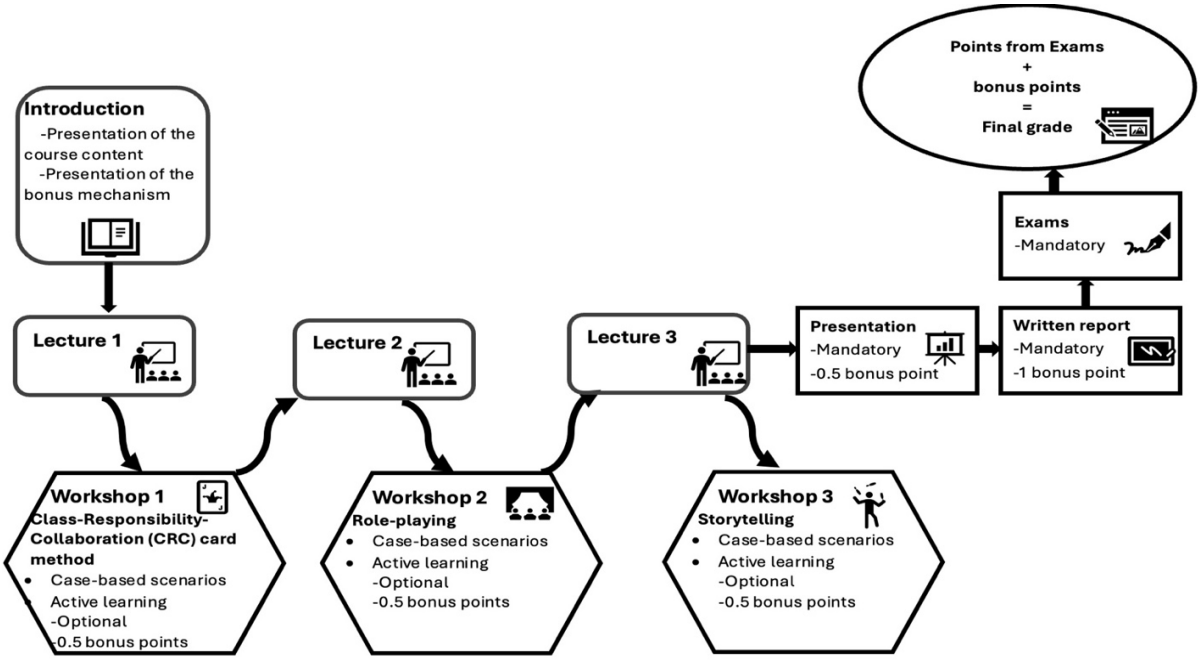


Figure 2: A diagram of the course setup, emphasising the gamification approach

3.3 Assessment and Grading

Three assessment criteria were developed for earning 0.5 bonus points from each workshop. Figure 3 gives an example from the second seminar that included the role-playing exercise. The group needs to fulfil all criteria to get the bonus points.

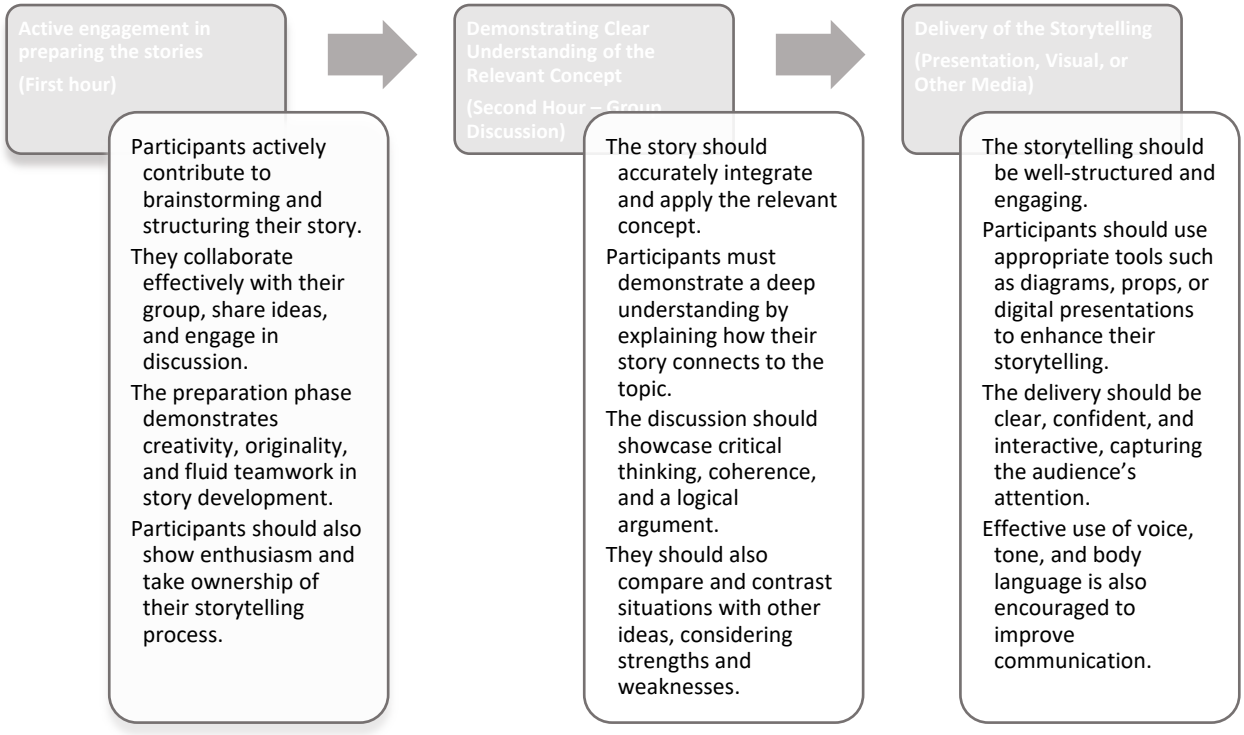


Figure 3: Bonus point criteria: Second workshop

Likewise, three assessment criteria for bonus point quality were also derived regarding the oral presentation of the projects Figure 4). As was the case for the workshops, a maximum of 0.5 points could be awarded, and all criteria needed to be fulfilled to get them. For the written project report, five assessment criteria were derived

for bonus point quality (Figure 5). If the students fulfilled all of them, they earned one bonus point; if they fulfilled 3-4 criteria, they earned 0.5 points.

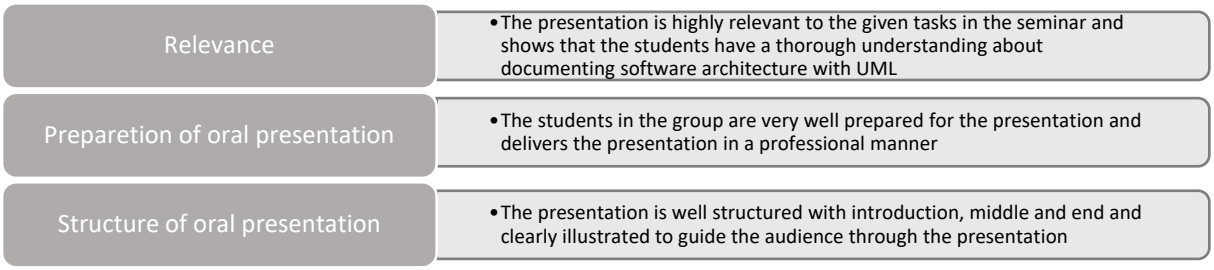


Figure 4: Bonus point criteria: Oral project presentation

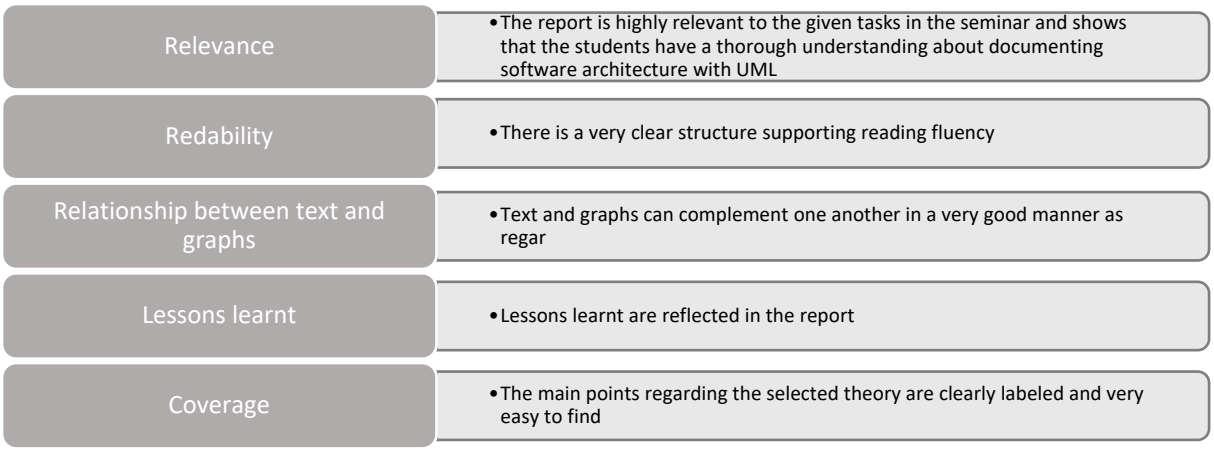


Figure 5: Bonus point criteria: Written project report

Overall, a student can get up to three bonus points, all earned at the group level and transferred to the final exam. If a student gets all bonus points from the above-mentioned course activities, 12 points will be enough for a Pass and 20 points for a Pass with Distinction (instead of 15 and 23 points, respectively). It is important to note that only whole bonus points can be transferred to the final exam. For example, a student who gets 1.5 bonus points in total, only one extra point is transferred to the final exam.

4. Research Methodology

4.1 Research Questions

In the second part of this study, we carry out a survey. The following research questions drive this survey:

RQ1: How do students perceive the use of gamification in the course, particularly in terms of its impact on their learning, motivation, and engagement?

RQ2: In what ways does gamification influence students' experiences of stress and their approaches to time management within the course context?

RQ3: How do students evaluate the perceived fairness of gamification elements, including their influence on grading and assessment practices?

4.2 Survey Design

The questionnaire consisted of 23 questions, 22 closed-ended questions, and one open-ended question. The questions are referred to as Q1-Q23 and are available in Table 1. The questionnaire contained five sections. The first section is *Demographics*, and the following sections target the *Perceptions of Gamification in the course*, *Stress and Time Management*, *Fairness in Gamification and Grading* and *Final Remarks* (open-ended). The overview of the questionnaire is available in Figure 6 and Table 1.

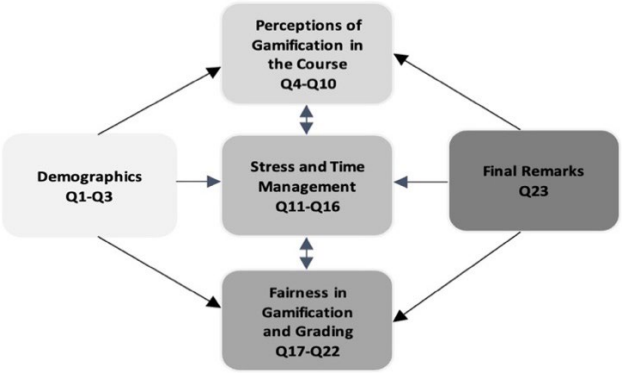


Figure 6: Overview of the questionnaire

4.3 Description of the Data Set

The survey occurred during the last session of the gamified course described in Section 3, during which 60% of the enrolled students were present (the total number of enrolled students was 100). In total, we collected 50 responses.

Regarding the demographic characteristics of the students, we considered three different factors: The subject of their study, their gender, and their experience with the use of gamification in education. Since the survey was conducted at a Business school, the students could come from different subjects. However, in our case study, 96% of the students came from informatics, and only 4% were from a different subject, which is an expected result since the course offered, *Software Architecture,* is a practical course in the software engineering field. Regarding gender, the sample was equally distributed, with 52% male and 44% female students. Furthermore, regarding their experience with the use of gamification in education, i.e., in how many courses they have experienced the gamification element, 14% have never experienced the gamification element before, 76% experienced gamification in 1-3 courses, and only 10% have experienced the gamification element in more than three courses.

Table 1: The questionnaire questions

	Questions
Q1	Which study program do you admit to the university?
Q2	What is your gender?
Q3	In how many courses have you experienced the use of gamification in education?
Q4	The gamification approaches (e.g., role-playing, bonus points) made the course more engaging (e.g., attending workshops)
Q5	The use of role-playing helped me better understand the course content
Q6	The bonus points system motivated me to participate more actively.
Q7	The gamification approaches (e.g., role-playing, bonus points) motivated me to gain a deep understanding of course content.
Q8	Gamification encouraged collaboration with my classmates.
Q9	The implemented gamified approaches contributed to my overall learning experience.
Q10	How did the implemented gamification approaches affect your willingness to complete course tasks?
Q11	How would you rate your overall stress level due to the use of gamification during this course?
Q12	The gamification approaches (e.g., role-playing, bonus points) added extra pressure.
Q13	The gamified activities helped reduce my stress by making learning more enjoyable.
Q14	I felt anxious about earning bonus points for achieving high scores on the final exam.
Q15	I planned my study schedule effectively to accommodate the implemented gamification approaches (i.e., bonus points).
Q16	The bonus points system encouraged me to complete tasks in a timely manner.
Q17	The gamification approaches (e.g., role-playing, bonus points) were implemented fairly for all students.

	Questions
Q18	The role-playing activities provided equal opportunities for all students to participate and succeed.
Q19	Awarding bonus points at the group level, rather than the individual level, was a fair approach for all students.
Q20	The bonus points system was applied in a way that fairly rewarded students' work.
Q21	Bonus points assessment from a single teacher, rather than two teachers jointly, was a fair approach for all students.
Q22	The assessment criteria were communicated clearly and consistently.
Q23	Any other comments on the use of gamification in this course or informatics education in general.

4.4 Data Analysis

To summarise overall trends and respondent characteristics, we adopted a quantitative approach and used descriptive measurements. The descriptive measurements we used were frequencies and percentages for the nominal variables, Mean value, and Standard Deviation for Likert scale variables. Moreover, to investigate if students' insights on gamification are affected by their demographic characteristics, i.e., gender or experience with gamification concepts, we used the Chi-Square test of association. To examine the strength of associations, we use Cramer's V test. Cramer's V measures the strength of the association of a nominal-by-nominal relationship. Finding an association, however, did not provide us with further details about this association (which cases are 'responsible' for this association). Therefore, following up on our statistically significant results, we performed post hoc testing using adjusted standardised residuals (Agresti, 2013). The analysis was conducted using the statistical package SPSS.

4.5 Validity Threats

The population under study, i.e., students at the Informatics Department, is large and highly heterogeneous. Consequently, we assume that the size of the population could be regarded as infinite. Under these circumstances, determining the appropriate sample size for our study is dwarfed by the importance of selecting a representative sample. Our survey was not designed to make strong quantitative conclusions about all the students belonging to the Informatics Department, but rather to identify larger trends.

Next, we discuss four aspects of validity (Runeson and Höst, 2009): *Construct validity* reflects the extent to which the operational measures represent the study subject. Our data were quantitative responses from the students, thus representing objective measures. No subjective measures were used, such as data from interviews. *Internal validity* refers to the examination of causal relations. In our study, we primarily focused on descriptive statistics. Our results are preliminary, and further analysis of potential impact factors is needed to build the resulting prediction model. *External validity* concerns how our results could be valid in another case study. The study is empirical and exploratory, and the findings cannot be generalised to an isolated department or university. *Reliability* concerns the extent to which the data and analysis depend on the specific researchers. Again, the data gathered are quantitative and independent of the influence of different research subjects or researchers' interpretations. The survey was administered in a standardised manner during the final session of the course, self-administered and anonymous, ensuring consistent conditions for all participants. Moreover, we acknowledge that more engaged or motivated students might have been overrepresented, possibly leading to a more favourable evaluation of the gamified experience. However, this limitation does not invalidate the findings, especially when the survey participation is high. concerns the extent to which the data and analysis depend on the specific researchers. Again, the data gathered are quantitative and independent of the influence of different research subjects or researchers' interpretations.

5. Results

To answer the RQs, we used a descriptive measurement and calculated the mean value of the responses.

5.1 Perceptions of Gamification in the Course

Regarding RQ1, we investigated how students perceive the use of gamification in the course and, in particular, its impact on their learning, motivation, and engagement. From Table 2, the students showed a positive perception of gamification in the course. In particular, the bonus system seems to motivate the students to participate more actively in the course (Q6, μ=3.74). Moreover, the gamified approach appears to contribute to the overall learning experience of the students (Q10, μ=3.70). However, the results showed that the use of role-

playing did not support the students to better understand the course content (Q5, μ=2.92). The gender of the students and the experience with the use of gamification in education do not seem to be related to the impact on learning, motivation, and engagement of the students.

5.2 Stress and Time Management

Regarding RQ2, we investigated the stress level and time management related to the use of gamification in the course. From Table 2, we can claim that the students experienced moderate stress during the course (Q11, μ=2.54), and especially the role-playing approach added slightly more pressure (Q12, μ=3.00). The gamified activities did not seem to help reduce the stress (Q13, μ=2.84). At the same time, the students felt quite anxious about earning bonus points for achieving higher scores on the final exam (Q14, μ=2.96) or for achieving high scores on the final exam (Q14, μ=2.96). On the contrary, the gamified activities helped to reduce stress by making the learning process more enjoyable (Q13, μ=2.92)

Furthermore, an interesting result from the chi-square test for association showed a strong statistically significant difference between gender and overall stress level due to gamification ($p<0.05$, Cramer's V=0.431). The post hoc test revealed that female students have higher overall stress levels during the course because of gamification rather than their male peers (Adj. residual > 1.96). The students' experience with gamification in education does not seem to be related to stress levels and time management.

5.3 Fairness in Gamification and Grading

Regarding RQ3, we examined the perceived fairness of gamification implementation and the grading process of the students. From Table 2, we can claim that the gamification approach was implemented quite fairly for all the students (Q17, μ=3.52), and the role-playing activities were equally provided among the students (Q18, μ=3.48). Moreover, the students reported that awarding bonus points at the group level was somewhat of a fair approach (Q19, μ=3.18) and the bonus system was applied fairly for all the students (Q20, μ=3.24). However, the students raised some concerns regarding assessing the bonus points from one teacher instead of two jointly (Q21, μ=2.84). Moreover, the students reported that the assessment criteria could have been communicated more transparently and consistently (Q22, μ=2.94). The gender of the students and their experience with the use of gamification in education do not seem to be related to the perceived fairness of gamification implementation.

Table 2: Descriptive results

Perceptions of Gamification in the Course	
Question	**Mean**
Q4	3.66
Q5	2.92
Q6	3.74
Q7	3.28
Q8	3.58
Q9	3.32
Q10	3.70

Stress and Time Management	
Question	**Mean**
Q11	2.54
Q12	3.00
Q13	2.84
Q14	2.96
Q15	2.94
Q16	3.10

Fairness in Gamification and Grading	
Question	**Mean**
Q17	3.52
Q18	3.48
Q19	3.18
Q20	3.24
Q21	2.84
Q22	2.94

6. Discussion and Conclusions

This study aimed to determine students' motivation and engagement to participate in practical Informatics courses developed based on a holistic gamification approach at a Swedish university. Gamification concepts (bonus points, real-life scenarios, and role-playing) were designed and implemented in one of our practical courses, Software Architecture.

The findings from this study showed that students generally perceived the gamification elements in the course as engaging and motivating and positively impacting their learning. The bonus point system, in particular, was viewed positively, encouraging active participation and deeper involvement with the course content. This is consistent with the findings from (Molls and Gao, 2022). In addition, While the overall experience was

favourable, role-playing activities received mixed reactions, with some students finding them less helpful or difficult to relate to. The gamified structure contributed to a more interactive and dynamic learning environment.

Moreover, students reported experiencing moderate stress towards the gamification approach, particularly about performance-based elements such as earning bonus points. While gamification was intended to enhance enjoyment and reduce pressure, it did not significantly alleviate stress for most students. Some students—especially female participants—felt additional pressure linked to role-playing and competitive aspects of the course. Time management was also reported as a challenge, suggesting that while gamification may boost engagement, it requires careful balancing to avoid unintended stress. This aligns with previous findings, which identified time availability as one of the key challenges for students engaging in gamified activities.

Furthermore, students generally perceived the gamification and grading process as fair, particularly appreciating the group-based nature of bonus point allocation and the equal distribution of activities. However, some concerns were raised regarding reliance on a single instructor for grading, implying that involving multiple assessors could enhance the perceived fairness and objectivity of the evaluation process. Additionally, students expressed a desire for more transparent and consistent communication of the assessment criteria.

Our study contributes to the existing literature by applying a holistic gamification approach to an entire practical course rather than isolated activities or modules. This study applied a holistic gamification approach to enhance a practical Informatics course, with Software Architecture as the case example. Furthermore, it also provides empirical insights into how such an integrated design can influence student engagement, motivation, and learning experiences by incorporating a gamified approach throughout the course structure. This adds to the growing body of research emphasising the importance of gamification approaches in higher education.

Several recommendations emerge from this study for teachers seeking to implement gamification in their courses. First, allocating sufficient time for planning and designing the gamified structure is crucial to ensure alignment with learning objectives and fair assessment. Second, clear instructions and transparent criteria are vital to students' satisfaction and perceived fairness. Third, while interactive methods such as role-playing can enhance learning, they should be introduced with care and supported with adequate guidance. Finally, teachers should remain mindful of diverse student experiences, particularly concerning stress and performance anxiety.

The study will be replicated in the near future with a different group of students and a theoretical course to better understand how gamification designs can be applied in various types of courses.

Ethical Declaration

The authors declare they have no competing interests or ethical conflicts to disclose.

AI Declaration

The authors acknowledge the use of artificial intelligence tools for grammar and syntax correction during the preparation of this manuscript. These tools were used solely to enhance the readability and linguistic quality of the text.

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Learning Trajectories in Hyper-Hybrid Spaces

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Abstract: This paper investigates undergraduate students' learning trajectories when working on an architectural design and building a property. The article is theoretically positioned within learning ecology and investigates the field of students' learning trajectories during the Digital Days to gain new knowledge on learning on hyper-hybrid collaboration in these learning spaces. Previous research on students' learning trajectories in hybrid spaces seems to be limited to the didactical planning of teaching activities in hybrid learning environments or to the digital solution during physical activities. The paper adds new knowledge to how students from technical education from a university, a university college in Denmark, and a university in Vietnam collaborated and navigated multiple hybrid spaces to meet the need to design a solution to the addressed challenges during the digital days. The methods included participant observations of student trajectories and collaboration in a hyper-hybrid learning environment. Based on the purpose of the study, a thematic analysis was carried out. The findings reveal that students' learning trajectories are supported by tools, resources and the students' interdisciplinary collaboration in hyper-hybrid spaces. Project management, interactions and trust among peers during the digital days seem to play a crucial role in student learning trajectories and in the progression of the assignment.

Keywords: Hyper-hybrid Spaces, Learning Trajectories, Digital Days, Learning Ecology, Interdisciplinary Collaboration

1. Introduction

This paper investigates student learning trajectories in hyper-hybrid spaces, with a special interest in students' learning trajectories in solving real-life problems. Applying hybrid learning spaces in higher education curricula provides a basis for employability (Bennett, Knight & Rowley 2020). Working with hybrid learning spaces is found to support design thinking, where different spaces hold potential for different parts of the design phases (Kohls 2019).

Hybrid learning spaces combine the physical and the digital environments and are a relatively contemporary concept aligned with the concept of blended learning. To capture the enormous complexity of the different spaces in actions during practice-based learning, the concept of hyper-hybrid learning spaces has been introduced by Nørgaard & Hilli (2022). Hyper-hybrid learning spaces appear in situations where, e.g., cross-national collaboration in online and onsite entanglements is practised (Nørgaard & Hilli 2022). Thus, a hybrid learning space is a merging of more than one form of space where the boundaries of different learning spaces are continuously crossed to expand the affordance of learning. Hybrid learning spaces give room for connectedness and dynamic integration of space and time dimensions (Trentin 2015). Eyal & Gil (2022) distinguish between three types of hybrid learning: Blended, spaces of merging interactions, and fluid, where boundaries are blurred. Hyper-hybrid learning spaces are complex as they include shifting assemblages where humans and artefacts are intertwined in different ways (Ellis & Goodyear 2016, p.149) and where borders between modalities can be more or less blurred. Cook et al. (2015) describe two types of hybridity, respectively, formal and informal social structures in an activity system and the combination of physical and digital tools mediating an individual interaction with the world and society" (Cook et al., 2015). They stress that people interact and collaborate using a hybrid network of physical and digital meetings, activating the necessary knowledge needed, and metaphorically, they conceptualise the affordances of the trajectories of spaces as "Zones of possibilities" in the interfaces between higher education and real-life workplace tasks.

Recent studies on hybrid learning spaces in higher education seem mainly to be limited to the perspective of how teachers can scaffold, design and plan for hybrid learning (e.g. Bennett, Knight & Rowley 2020; Pischetola, 2022; Kohls 2019, Wiig, Silseth & Erstad 2018) or to the different digital technologies in blended and hybrid learning environments (e.g. Raas et al. 2020) for instance related to peoples meeting, collaboration with the physical and digital tools (Cook et al., 2015). However, we have not found any observational studies investigating the hyper-hybrid interactions of students from different backgrounds. Thus, our research study will explore how the students' learning trajectories are afforded by the hyper-hybrid student learning trajectories in these kinds of hybrid spaces where students' collaboration is interdisciplinary.

2. The Hyper-hybrid Setting

Digital Days (DD) at the University College of Northern Denmark (UCN) is an interdisciplinary construction engineering, communication testing, and technological/digital experimentation event with space to explore ideas, develop solutions, make mistakes, create new discoveries, and reflect. The event helps prepare students from construction's vocational and professional courses, as well as engineering studies, for reality and gives them new perspectives to include in their careers. DD involve companies on an equal footing with students and teachers when concrete building challenges are solved in groups using dig DD is a yearly event in collaboration with the region's small and medium companies (SME), the municipality, a university, a University College and a vocational training institution. The DD is a yearly interdisciplinary event in collaboration with the region´s small and medium companies. The connections between students from different educational backgrounds and areas were organised to combine the different competencies to create a sustainable property building for people living in the neighborhoods. This is in accordance with Cook et al.´s. (2020) describes bridging social capital with people from various backgrounds to afford the learning and solve the assignment appropriately, giving the student the opportunities to work in an interdisciplinary manner, just like in the workplace. During the three days, students from Architectural Construction and Management in Denmark and Vietnam, and students working in Building Construction, Electricity, Contracting and Engineering joined the DD, trying to solve a real-life problem in creating sustainable property. During the DD, students had access to relevant tools, hardware and software for digital analysis, planning and visualisation. In connection with the group processes, all participating parties experience the complexity of the human and digital collaboration that characterises the construction of the future, and develop solutions adapted to this complexity.

2.1 The Roles of Students at the DD

The students were assigned different roles at the DD to manage the process and tasks needed. This was visualised by the shirts that the students had to wear, illustrated by Table 1 below:

Table 1: Illustration of students' role by coloured t-shirts during the DD

Project Manager (Blue)	Bim Manager (Gray)
Contractor (Green)	Project Manager Assistant (Light blue)
Engineer Construction (Red)	Engineer MEP (Orange)
Architect (Yellow)	Bim Manager (Gray)

The project manager (PM) was responsible for the assignment as a whole, and he had support from the project manager assistant (PMA). The MEP Engineer (ME) was responsible for wastewater and ventilation. The contractor (C) was responsible for the general contractor work. The BIM manager (BM) was responsible for leading the digital collaboration. The architect (A) was responsible for the planning, design and oversight of the construction, and the construction engineer (CE) was responsible for the infrastructure.

2.2 The Pedagogical Foundation

The pedagogical approaches of the participating educational institutions are based on, respectively, problem-based learning and reflective practice-based learning, which together are conceptualised as Experiential Collaborative Learning (ECL) (Jensen et al., 2022a).

2.3 Research Question

How are students' learning trajectories afforded by interdisciplinary collaboration in hyper-hybrid learning spaces during Digital Days?

3. Theoretical Positioning

The theoretical positioning is mainly related to the learning ecology. However, the concepts of learning trajectories and boundary crossing are related concepts and, in the following, are described as part of the paper´s theoretical positioning.

3.1 Learning Ecology

A theoretical perspective on learning ecology provides a conceptual framework to address the challenges of navigating a technologically rich and continuously developing society. It offers a frame for understanding people's interactions and activities across different environments. Applying a learning ecology perspective gives a nuanced perspective on blurred, multiple, and permeable boundaries and an understanding of how the environment affects people's identities and development. Therefore, it is a relevant approach to looking into student learning trajectories across spaces where technology and digital competencies are continually developed and changed. A learning ecology thus offers an adaptive and dynamic perspective on learning, where learning is regarded as ubiquitous, flexible, and contextualised. Moreover, it provides access to knowledge dimensions of habits, identity, behaviours, and narratives as relevant conditions. Accordingly, it raises possibilities to research the complexity of people's interactions with emergent technologies across different settings, spaces, and places. Hence, Barron´s (2004, p. 6) definition of learning ecology as "the accessed set of contexts, comprised of configurations of activities, material resources and relationships, found in collocated physical or virtual spaces that provide opportunities for learning, " frames our understanding of the concept. The ecological perspective gives access to investigate learning spaces through the interactions of learners in interplay with technology, tools and resources in physical and digital environments (Damsa et al. 2019).

In relation to the learning ecology perspective, affordance is understood as a mix of the physical, mental and conceptual relations that the environment offers or furnishes for better or worse. Affordance is also determined by humans' preconditions, prior experiences, and capacity, as well as their previous engagement with the environment, tools, people, and artefacts (Dau, 2021).

3.2 Learning Trajectories as Wayfinding and Mapmaking

Learning trajectories are multidimensional and include peoples' pathways in and across different contexts (Membrive et al., 2022), affording the learning process. Thus, the learning trajectory is related to people's participation in different learning activities and their engagement with the environment and the artefact. From a learning ecology perspective, the learning trajectories are a process of mapmaking and wayfinding. Ingold (2000) describes these kinds of learning trajectories as trajectories of motions and becoming: "…in wayfinding, people do not traverse the surface of the world whose layout is fixed in advance - as represented on the cartographic map. Rather, they 'feel their way' through a world in motion, continually coming into being through the combined action of human and non-human agencies" (Ingold 2000, p. 55). Ingold (2000) differentiates wayfinding, mapmaking, and navigation and juxtaposes wayfinding and mapping as an ongoing cartography process which can also involve mental representations. However, navigation is compared to map use and thus following paths already made or represented. Map-making is related to humans' capacity to make a map. Nevertheless, it is not about drawing a cartographic map on paper but about remembering, sensing, structuring, consolidating, and comparing processes. Moreover, questions of "Where am I?" and "Which way should I go?" are found in narratives of prior movements. How people find their way is thus characterized as complex structures holding complex processes (Dau 2020). For instance, research on campus students' orientation reveals that it is formed by their prior study trails, practices, habits, and movements. The students seem to find their academic and professional way based on instructions, the peers' movements and approaches, artefacts, and the teacher's acting and guiding. Social connections and co-constructed knowledge are parts of a common mapmaking process that affords students wayfinding and professional identity development (Dau 2015). Therefore, in this paper, trajectories are framed as processes of mapmaking and wayfinding.

3.3 Boundary Crossing and Ecotones

Boundaries are part of any learning process (Akkerman & Bakker 2011). Boundaries are stressed to hold different learning potentials in relation to identification, coordination, reflection, and transformation (Ibid.). Boundary crossing is typically described as a person's transitions or interactions across and between different settings. Similarly, boundary objects are often described as transition, bridging artefacts (Ibid.). Contrary to the transition concept, the concepts of boundary crossing and boundary objects include interactions between contexts and people and between artefacts and people across time (ibid.). This is aligned with the combined action between human and non-human agencies, as described in wayfinding (Ingold 2000). Applying a learning ecological approach seems to give room for understanding students' learning trajectories during boundary crossing and working in ecotones. The concept of ecotones originates from biology and is described as a transition zone between two relatively different kinds of entities or areas (van der Maarel 1990). The term ecotones have

recently been applied to studies of the humanities to understand post-digital thinking (Ryberg et al. 2021) and students' navigation in blended learning environments (Dau & Ryberg 2014). The conceptualization of ecotones contributes to a nuanced investigation of students' learning trajectories during transitions and border crossing.

4. Method

Qualitative studies are typically applied to fully understand students' learning trajectories in hyper-hybrid learning spaces and, thus, the complexity (Bennett, Knight & Rowley 2020). Thus, the method applied was participant observations (Glaser 1996) of the digital days in 2022. Two groups of students were observed. The students were selected by snowballing, where the teacher in charge of the days was to find two voluntary groups of students who agreed to be observed during the digital days. The data collection method was based on observations of two groups of students working on solving a real-life assignment for two days. Data collection consisted of pictures and field notes, including citations. Participants had signed a consent form before the observations took place. In total, 42 students were observed, divided into two groups of 21. From each group, 17 students were physically present, and four were online. The findings from the observations of one of the groups are included in this article. The observations took place in the autumn of 2022.

An observation scheme was conducted beforehand based on the ECL-related concepts. Thus, the observation scheme included subcategories related to the pedagogical approaches used at the educational institutions involved to see if they were practised (Jensen et al. 2022b). The subcategories are presented in Table 2.

Table 2: Subcategories in Observations Scheme

Student oriented
Collaborative
Nonlinear/linear
Iterative processes /or not
Disruption of activities/or not
Reflective dialogues
Self-efficacy
Experimental/inquiry-based

Furthermore, attention was paid to the focus of the content of the learning process in relation to students' problem orientation, theoretical immersion, value-based choices, professional judgment, and academic competencies.

5. Analysis

A thematic analysis was applied to identify patterns of relevance in relation to the research question and structures of the main subcategories presented in Table 1. Inspired by Braun and Clarke´s (2006) analytical process, we followed the six steps in the thematic analysis. Get familiar with our data, 2. Initial coding, 3. Searching for themes, 4. Reviewing the themes. 5. Naming the themes and reporting. In Table 3 below, the coding and themes are presented.

Table 3: Analytical codes and themes

Observations Categories Based on ECL	Codes	Themes
Student oriented	Division of labour – seeking balance	Professionalism in action -Supported by role taking and peer-learning
	Overview of roles and actions	
	Peer-learning	
Collaborative	From mono-disciplinary to cross-disciplinary	Hyper-hybrid collaboration -Design processes scaffolded by input and structure
	Structure support collaboration	
	SME representative shares knowledge	

Observations Categories Based on ECL	Codes	Themes
Nonlinear/linear	Revise and change	In time, revision and progression
	Time is essential	
	Dialogue across disciplines scaffolds linear progressions	
Iterative processes /or not	Sharing resources	Knowledge sharing and tools fostering iterations
	Tools inform and disrupt iteration	
	Dialogue flows between disciplines	
Disruption of activities/or not	Disruptive inquiries from SME representatives trigger reflection	Disruptive practice relevant input resources trigger reflections
	Teachers' disruptions do not contribute to the activities	
	VR visualise mistakes and failures in design	
Reflective dialogues	Questions and reflections support interaction	Questions and immersive VR actions trigger reflection
	SME representative asking questions	
	VR supports troubleshooting and further reflection	
Self-efficacy	The project manager's solutions are supported by different input from the group members	Interdisciplinary collaboration affords decision-making
	Navigating in VR supports students' decision-making	
	Interdisciplinary discussions support students' experience of agency and professionalism	
Experimental/inquiry-based	Searching the Internet for tools	Navigating Digital tools in Interdisciplinary Investigation
	Cross-disciplinary investigations and inquiry on screen	
	Experimenting in VR qualifies for further actions	

Besides the code categories and themes revealed, a drawing of student navigation in the group work area is illustrated below in Figure 1:

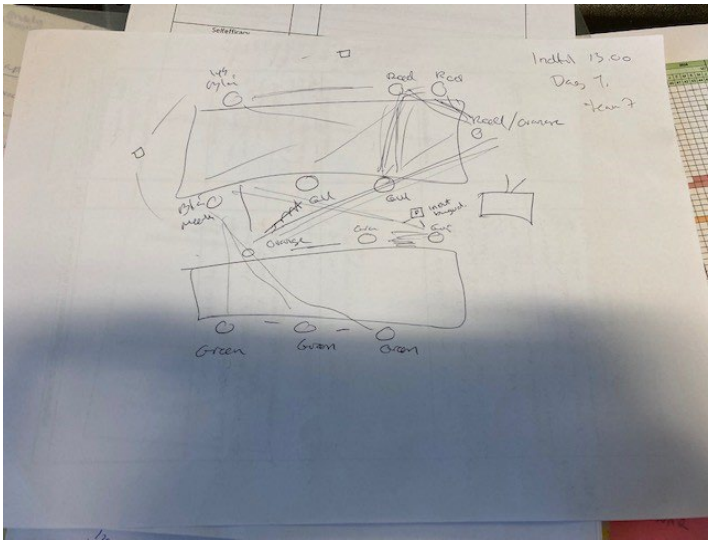


Figure 1: Illustration of the students' navigation and interaction across the different roles.

6. Findings

The findings are structured in relation to the themes retrieved from the analysis. The interpretation is made on the basis of the research questions investigating how students' learning trajectories are afforded by collaboration in hyper-hybrid learning spaces.

6.1 Professionalism in Action

In general, the student division of labour afforded the real-life project collaboration, supported by participants from SMEs and their knowledge sharing and questions.

The predefined different roles exemplified by the t-shirt colours supported the student's immersion in the role of a professional. Moreover, the PM´s scaffolding of the interplay and structure seemed to afford the flow of the work during the DD. The PM and the APM took notes and looked at the different roles and responsibilities to gain an overview before they structured the processes by giving the students in the group access to a Teams group where they could follow the progression of the assignment based on continuous updates from the different professions involved. The PM also managed to balance the interplay with the students (A) from Vietnam:

“We must also think of them in Vietnam” (PM).

The PM followed up later with the PM in Vietnam, asking the constructors (C) about their contact with the Vietnamese PMs, which made them pay attention to the computer to test it.

“They are on chat and Teams” (C).

The cross-national interaction across different time zones made the students aware of how to navigate international collaboration, but at the same time, this blended hybrid collaboration also made them aware of differences in competencies and culture and their own professionalism. This was addressed during their work, where a couple of the Danish Cs mentioned that the Vietnamese did not have the specific knowledge needed, thus challenging the hyper-hybrid learning. Nevertheless, the Vietnamese were included as part of the group during the DD, and the students from Denmark managed to navigate differences, distance and online-onsite collaboration.

6.2 Hyper-hybrid Collaboration

Students' blended hyper-hybrid collaboration is characterised as an interplay between people from different professions and countries and the available or searched artefacts and technologies. The hybridity in the group is, however, also afforded by the project manager's (PM) overview and continued questions and input to merging actions exemplified by this quote from the PM:

“We must have control over the construction, and it has to be sustainable – we have to talk together quickly if design and the sustainable construction are not in place.”

Also, the PM orientation toward the needs of the peer student in performing the tasks seemed to support collaboration and progression.

PM: *“Do you need one to change to MEP engineer?”*

ME: *”Cool, if we can be two MEs”*

Based on the experienced need of ME, the PM mapped the situation and thus the need for more resources to solve the ME tasks. Therefore, a CE changed its role to an ME by changing t-shirts and engaging in interactions with the original ME.

The use of different technologies seemed to give students access to the needed information for further progression. Thus, the students work on different software programs used in SMEs, whereas some are new to the students, and some are familiar. They also apply a TV screen for collaboration on the task and different 3D programs suitable for testing the solutions on screen and in VR. The affordance of VR is illustrated by the following dialogue between the architect(A), the MEP engineer (MEP) and the construction engineer (CE):

“So, we can enter in VR and look it through”.

The student discussed the indoor task for the architect, including corridors and room distribution. There was a loud discussion between the different professions on possibilities and limitations, triggering students' individual reflections. The interaction, students' wayfinding, and attention to visible failures in VR were afforded by the communication.

The fluid hyper-hybrid interaction navigation was afforded by access to different online and physical spaces with different resources available, illustrated by the student's trajectories between spaces and tools. In this situation, learning was scaffolded during their wayfinding online and onsite, both in regard to the use of the VR facilities and the available online programs for managing collaboration and solving professional tasks by applying relevant engineering and digital solutions. Furthermore, students' interaction between different professions, transversing a variety of spaces and crossing boundaries in interplay with technology, tools and resources illustrated the learning ecology in action.

6.3 In Time, Revision, and Progression

Time seemed to be essential for the progression and decision-making, and the student's mapping furnished problem-solving during DD and limited revision, as illustrated by the quote:

"It does not make sense – I am starting now… the construction will look different in half an hour" (Dialogue between A and CE).

Students' awareness of the interactions and continuous follow-up with different professions to meet the need for thought-out solutions seemed to support the progression of the tasks. Moreover, the progressions were also supported by the 3D stretching, the immersive VR technologies available and the interplay between students:

"It is the great this; here we edit at the same time without it fucks up" (CE).

"The plan is to finish the building today – so we can walk around in it" (PM).

As quoted above, setting goals also supported students' learning trajectories during the DD. The PM's ability to keep an overview, supported by the online progressions scheme, became essential for timely collaborations, revisions, and progression.

Hence, the student's learning trajectories were structured by the PM setting up deadlines for the peers in relation to their specific partial assignments. This scaffolded students' commitment and engagement in the project. The interplay between different professions during the days became more and more interdisciplinary, crossing borders between the roles. For instance, the BM asked which software to use and what it should be used for later, and the CE confirmed it while raising a loud question about why he could not buy less than ten meters of steel plate. Also, loud reflections took place between ME, A, PM and two Cs. The merging of competencies supported students' wayfinding and, thus, their individual learning trajectories.

6.4 Knowledge Sharing and Tools Fostering Iterations

The interdisciplinary knowledge sharing and bridging of different perspectives and artefacts was afforded by the setup and questions raised during the DD. For instance, A asked PM about building regulations and solar panels, and they discussed how to make a flat roof green. CE asked questions in relation to Building Information Modelling (BIM) and how to work and analyse using BIM. A dialogue between C and ME took place about the plan at the same time. The border crossing of different perspectives was also afforded by the openness of students' own limitations:

"…we have actually never learned it" (CE)

Also, questions raised by the SME representatives seemed to foster knowledge acquisition:

"Do you have an overview of where it does not work?" (SME representative).

This was followed up by sharing knowledge on calculations and demands. BM tried to get an overview of the applications while he interacted with the SME representative, who asked about demands in relation to light and heat. At the same time, A and PM discussed the size of the elevator shaft based on the calculation among the CEs. All the work was shared at a joint meeting, where the dependence of the different roles and their progression became visible:

"I cannot start to draw it before they are finished" (ME).

At the joint meeting organised by the PM, with a representative from each of the roles, different problems were addressed, and possible solutions were suggested. The student shared their reflections and how to gain help from others. They agreed to share knowledge before they decided on the final solutions.

"We must talk together before we decide the final solutions" (PM).

Together, they discussed the opportunity to make an offset roof and talked about living rooms and following the local plan. They agreed to ask a teacher about the requirements for the foundation of the building, and ME presented the calculations in relation to ventilation and heating, supplemented by two SME representatives' input on thermostat control. The joint meetings thus seemed to foster renewed engagement and trust in the group. The engagement became visible in the observations where students became loudly eager to contribute and laughed at their challenges, triggering ideation and commitment.

The entanglement and mapping of different perspectives during the knowledge-sharing process joint meeting supported the student's upcoming navigation in the available shared online and physical rooms, giving them an idea of how to progress with the assignment.

6.5 Disruptive Practice Relevant Input Triggers Reflections

Appropriate disruptions are one of the teaching principles at UCN based on the signature pedagogy of Reflective Practice-based Learning. During the DD, two kinds of disruptions took place: disruptions that triggered reflection and progressions and disruptions without any affordances. An example of disruption triggering reflection was when the SME representative asked the students about quality requirements, resulting in a discussion of AutoCAD (a program for 2d and 3d modelling) and Revit (a building information modelling software) supported by the SME representative's knowledge of the use and their experience in using the programs. The disruptions paved the way for a closer collaboration between students and the SME representatives. The SME representative's engagement became more visible when they were able to share their expert knowledge, and the questions fostered students to investigate and reflect on their work.

"I don't know if it (Revit) can handle it…What about the sealings and the steel construction? We must have a pillar here in the middle, and what about the kitchen? How do you visualise it in 3D" (SME representative).

The questions were followed by ideas and suggestions and discussed with the SME representative in relation to the specific dimensions. The interplay with the SME representatives also disrupts some of the other students' work, and they join the mapping of the problems raised with different viewpoints, adding further knowledge to the discussions. For example, C turns his screen to the SME representatives, ME, A and CE, and they engage in a common dialogue.

Students also trigger their peers' reflection by addressing challenges and asking questions:

"The problem is just that it is heavier" (A).

"How about the light boxes?" (CE).

"I do not know if there are other rules when there is a deflection?" (A).

"Can it be double?" (CE).

During the discussion fostered by the SME representatives, several new questions were raised, triggering students to look at their designs and redesign part of the building. Following the paths of SME representatives' experiences in working with different systems and the construction of buildings in an interdisciplinary environment seems to help students' own mapmaking and wayfinding.

Questions and immersive VR actions trigger reflection

The use of immersive VR gives the students the opportunity to navigate and traverse the surfaces in their created 3D building. For instance, the students C, PM, BM and ME went to the VR room. PM and ME took place at the PC, and C and BM each put on the VR glasses and navigated the immersive building. BM and C investigated the windows. There was a hyper-hybrid conversation between the four in the room, two at the PC station and two in the immersive VR space. The quotes below illustrate the conversations between MB and PM where PM followed MB's navigation in VR:

"Yes, the steps are too low" (BM)

"Is there a hole in the floor?" (PM)

"I don't know if there is a mistake" (BM)

"Wait a minute- yes, yes, it is huge windows, there are red lines all over" (PM)

" It is a creative process" (BM)

"Let's continue" (PM)

"I am not sure the model is updated" (BM)

"There is something with the balconies again, can you see?" (PM)

"I really think it works well" (PM)

"I look at the two bars, they are overlapping" (BM))

"They are extremely close to each other" (PM)

"Ahh there" (BM)

Working in the hybrid spaces supported the students' design thinking during the interplay with the VR tool. The interplay was supported by the PMs observation on screen and BMs navigation in VR and their shared communications. The crossing of onsite, online, and immersive technologies seemed to add an extra dimension to their design process and provide a realistic experience of their drawn building and its limitations. Thus, the blurred hyper-hybrid VR actions triggered student reflections and thus gained insight into their redesign of the constructions and the building as a whole. Testing the solutions in VR became central to the success of the assignment.

"I cannot fly out of the building" (C).

The affordance of the VR setting created seamless navigation and student language, illustrating how the immersive environment has its own language, illustrated by the term "flying out". The crossing of borders and the extended possibilities in VR support students' mapping of the building, and the mistakes become more visible. The online onsite entanglement offers new forms of interdisciplinary collaboration and reflections.

Interdisciplinary collaboration affords decision-making

The students' interdisciplinary collaboration supported their decision-making and continued the progression of the assignment. For instance, when students across disciplines continuously look into the description of the assignment and the affiliated requirements. Also, the PM's attention to the roles and support of changing roles during DD helped to get a better balance between the tasks to be done and the design challenges to be solved. The interdisciplinarity afforded a synergy between the students and between the SME representative and the student. The dialogue, discussions and common reflections between students were the" glue" that supported interdisciplinary wayfinding and problem-solving. For example, when an SME representative talked with the PM, A and CE about the roof's construction while studying the construction drawing on TV and sharing previous experiences.

The examples and quotes from the VR setting in the section above also highlight how students with different roles are intertwined with tools and resources to find common ground and necessary solutions. The blurred and messy navigation between online and onsite students across different levels, educational practices, and countries seems to mirror real-life scenarios on a construction site. The cross-disciplinary navigation and negotiation support students' wayfinding and learning trajectories across spaces and places in the design process.

6.6 Navigating Digital Tools in Interdisciplinary Investigation

Navigating digital tools supported student learning trajectories by collaboration across disciplines. For instance, during the DD, C found a bin on the internet, and CE and ME discussed the technical solutions for ventilation by looking at the shared 3D model on the television screen. The visibility created a common ground for students' interdisciplinary investigation and mapmaking while exceeding existing borders.

The VR setting also supported students' interdisciplinary investigation. At a time when the two Cs wore VR glasses and a PM and a BM sat in front of the computer screen following the Cs on screen, the investigation became fluid hyper-hybrid during the entanglement of different kinds of presents.

"I can see where you point with your right hand" (PM to C)

"I am on the second floor now" (C)

At the same time, a dialogue took place between PM, C and BM

"Can you not hop over the door?" (PM to C)

"There is a mistake in the system" (PM to C)

"Maybe we should print and read the report" (C to PM).

"Okay, I am outside now" (C no. 2 – now wearing the VR glasses)

"Can you see there is a window there? Can you mark it?" (C to PM)

The other C no 1 sits by the computer with PM and asks him how to take a picture. PM help C no. 1 to take a picture and walks toward the other C to guide him and inform him of the mistakes already documented by the VR system.

"I have a lot of mistakes – this door is one out of three" (C no. 2)

"There is a slide-door" (C no.1 by the screen)

"There is grass, where there is supposed to be a lift" (C no. 2)

During the collaboration in the VR room, students experienced how their common investigations helped them understand the system and the mistakes they made as a group. This triggered their reflections and further progression. The students supported each other in navigating to mark the failures and guide the movement in the VR-created building. Thus, their learning trajectories were supported by the interdisciplinary investigations taking place.

7. Discussion and Conclusion

The study's use of a learning ecology approach has demonstrated its relevance in capturing the complexity of students' learning trajectories and border crossing in interaction with different settings, tools, resources and people. The study has contributed with additional knowledge on students' learning trajectories in interplay in a hyper-hybrid interdisciplinary environment where cross-country collaboration, structure, tools, technologies and practitioners play a central role in students' wayfinding. It has been illustrated that different hyper-hybridity mirrors real-life complexity and engages students in a collaborative learning journey.

It reveals how students' learning trajectories are afforded by interdisciplinary work, the tools and resources available or found on the internet, and the disruptions created by SME representatives or peers. However, structuring the communication, the goal, and group meetings played a central role in student design making and the ability to learn new competencies as they faced huge complexity in relation to the design process. The complexity of navigating was characterised by an entanglement of different onsite digital and physical tools and students from different educational institutions, both nationally and internationally. These hyper-hybrid learning environments forced the students to make in-time knowledge sharing across disciplines to meet the need for creating a new and sustainable building for citizens in the area. Students' learning trajectories were facilitated by the SME representatives who had experience with similar situations from their work life, and the student's gained insight into the complexity and how interdisciplinary collaboration is similar to what happens in real life. Students' learning trajectories were thus afforded by the interdisciplinary collaboration in a hybrid setting, where software systems and hardware tools played a significant role in supporting student reflections and troubleshooting. Students not only followed paths already made by, for instance, SME representatives, but during the DD, students created their own physical and probably also mental maps, which were furnished by the setup and the access to different tools, artefacts and people.

The study, however, is limited to investigating just one out of several groups of students and cannot be generalised, as it seemed that some of the other groups did not receive the same experience during the DD. Nevertheless, the study constitutes the limited empirical research available on hyper-hybrid spaces and their impact on student learning trajectories when students are in charge of their own design process. Future studies would benefit from including a larger population of students to strengthen the evidence on how collaboration in hyper-hybrid learning spaces can support students' learning trajectories. Also, future studies investigating the support of a generative AI assistant during the hyper-hybrid collaboration could be relevant, as generative AI has disrupted most educational practices today.

Ethics Statement

Ethical clearance was not required for the research.

AI Declaration

AI has not been used in the creation of this paper

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Evaluating the Impact of Online Mentoring Sessions on Student Engagement

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Abstract: Asynchronous learning offers flexibility but often struggles to maintain high levels of student engagement, particularly among first-year undergraduates. This study examines the impact of online mentoring sessions on student engagement in an asynchronous course delivered to first-semester students enrolled in the Bachelor of Information Technology (BIT) programme at the University of Moratuwa. The BIT programme, conducted in the open and distance mode, does not provide synchronous live lectures for any of the modules. However, the students have often shown interest in getting more assistance with live interactions. Taking the increasing student concerns into consideration, an online mentoring session was proposed. An instructor would conduct a 1.5 hour online synchronous session for each module starting from the first semester. Instructors were selected based on their specialization on the module content. From the logistics perspective, this introduced additional burden on the resource persons who are already loaded with work. The need for an evaluation of the effectiveness of the newly introduced programme was identified. In that regard, a mixed-methods approach was employed, combining LMS activity data with student surveys and feedback. The intends to provide insight on the effects on student engagement following the introduction of online mentoring, particularly in areas such as student view content in around the first three weeks. The delivery of mentoring sessions provides insights of student engagement: enhancing comprehension, confidence, and inclusivity. The study underscores the potential of culturally and linguistically responsive online mentoring to improve student engagement in asynchronous learning environments, particularly in diverse educational contexts. The preliminary results indicate that students with access to the online mentoring program exhibited higher engagement, with an increase in the number of content views and interactions. Specifically, the presence of a mentor led to an approximate 5% increase in student engagement, suggesting that personalized support positively influences students' interaction with course materials. The findings highlight the importance of mentorship in enhancing student participation in online learning environments.

Keywords: Online Mentoring, Student Engagement, Asynchronous Learning

1. Introduction

The Bachelor of Information Technology (BIT) programme at the University of Moratuwa, administered by the Centre for Open and Distance Learning (CODL), is a three-year undergraduate degree tailored for students who have completed the (General Certificate of Education) GCE Advanced Level examination in Sri Lanka. This programme is delivered entirely through asynchronous methods via the Moodle learning management system, offering access to recorded lectures, digital course materials, and both formative and summative assessments. While the asynchronous format provides flexibility and accessibility, students—particularly those in their first semester have frequently voiced the need for more direct interaction with instructors to clarify concepts, engage in discussions, and receive timely academic support. Accordingly, this study focuses specifically on first-semester students, as the structured online mentoring sessions were introduced only for this group.

In response to these concerns, the programme introduced a structured online mentoring initiative, wherein each module was supplemented with a 1.5-hour synchronous session conducted by subject-matter experts. These sessions aimed to bridge the interaction gap inherent in asynchronous learning by providing a platform for real-time engagement, discussion, and personalized support. While the implementation of these sessions introduced additional responsibilities for instructors, the potential benefits in enhancing student engagement warranted a thorough evaluation.

This study aims to assess the effectiveness of the online mentoring sessions in improving student engagement within the BIT programme. Employing a mixed-methods approach, the research analyses data from the Learning Management System (LMS) to track student interactions and complements this with surveys and feedback to capture student perceptions.

In line with the aim of the study, the following research objectives were identified.

1.1 Research Objectives

1. (RO1) To evaluate the effect of online mentoring sessions on student engagement in an asynchronous learning environment.
2. (RO2) To explore how online mentoring contributes to various aspects of student engagement, focusing specifically on students' interaction with content, levels of intrinsic motivation, and frequency of participation in academic tasks.
3. (RO3) To compare engagement levels between students who participated in online mentoring sessions and those who did not.

2. Literature Review

The integration of digital technologies into education has reshaped how student support is delivered, particularly in online and distance learning. One of the most promising strategies for enhancing learner engagement in these settings is online mentoring. By providing flexible, personalized academic support, online mentoring helps bridge the gap between asynchronous content delivery and active student participation (Enwereji and Van Rooyen, 2024).

Despite its benefits, student engagement with mentoring services remains uneven. Enwereji and Van Rooyen (2024), in a study at the University of South Africa, discovered significant behavioural differences between individuals who participate in e-tutoring and mentoring and of those who don't, identifying gaps in awareness and service design. This suggests that beyond content delivery, structured support services are critical to increase participation and preventing dropouts in virtual learning environments.

The importance of mentoring in supporting students emotionally and academically is well documented. Andersen and West (2021) identified four core domains through which online mentoring benefits learners: emotional support, academic goal setting, role modelling, and technological guidance. The most effective support was found to be emotional and psychological, especially for non-traditional or transitional students who frequently experience uncertainty and loneliness in digital environments.

Peer mentoring is another approach that contributes meaningfully to student engagement. Edwards et al. (2021) examined an online peer mentoring initiative at the Open University, where student-led design and co-creation fostered a sense of ownership and empowerment. The program helped reduce feelings of isolation, created learning communities, and supported academic progress, underscoring the social dimensions of engagement that mentoring can support.

Mentoring programs have also shown significant results among first-year undergraduates. Queiruga-Dios et al. (2023) reported that structured mentoring activities at Spanish universities promoted critical thinking, proactivity, and self-awareness. In particular, the mentoring program at Universidad Francisco de Vitoria resulted in apparent increases in motivation and academic confidence, both of which are significant measures of engagement.

The COVID-19 pandemic provided a natural stress test for online education. Spitzer et al. (2021), using survival analysis, showed that while platform enrolment spiked during school closures, sustained engagement was harder to maintain. These findings support the idea that mentorship, particularly with constant, structured interaction, may help maintain continuity and motivation in unpredictable or completely remote learning environments.

The design and delivery of mentoring programs matter greatly. Sherman and Camilli (2014) emphasized that clearly defined mentoring responsibilities (e.g., feedback, planning, support logs) contributed to more effective learning outcomes. Similarly, Maré and Mutezo (2021), applying the Community of Inquiry framework, found that e-tutoring with mentoring components improved academic performance and reduced learner isolation in open and distance learning settings.

Collectively, these studies highlight that online mentoring plays a central role in fostering student engagement, particularly in asynchronous and distance education contexts. It supports emotional well-being, promotes academic responsibility, and facilitates meaningful connections between learners and mentors. However, the success of such initiatives depends on mentor training, technological infrastructure, and strategic program design (Andersen and West, 2021). Mentoring should be viewed as a basic component of student engagement efforts as universities expand their digital learning offerings.

3. Methodology

3.1 Data Collection

Student activity and performance details of a Semester 2 module (ITE1223) were collected from the Moodle LMS. This module had one mentor who conducted the online mentoring sessions.

Group A includes students who did **not attend** any online mentoring sessions, while **Group B** consists of students who **participated** in online mentoring. This classification helps compare engagement levels based on the presence or absence of mentoring support.

Table 1:

Module	Group A		Group B	
	Views per registered students - 720		Views per registered students - 1283	
1st Lesson	1642	2.281	2958	2.306
2nd Lesson	996	1.383	1832	1.428
3rd Lesson	656	0.911	2024	1.578

This diagram presents engagement data from two distinct student groups: Group A with 720 registered students and Group B with 1,283 registered students. The analysis focuses on the average number of views per student for the first three lessons. In Group A, the 1st Lesson received 1,642 views, resulting in an average of 2.281 views per student. The 2nd Lesson garnered 996 views (1.383 views/student), while the 3rd Lesson had 656 views (0.911 views/student), indicating a gradual decline in engagement across lessons.

In contrast, Group B displayed consistently higher engagement, with 2,958 views for the 1st Lesson (2.306 views/student), 1,832 for the 2nd Lesson (1.428 views/student), and 2,024 for the 3rd Lesson (1.578 views/student). This group not only maintained stronger engagement over time but also exhibited a noticeable increase in 3rd Lesson views compared to Group A.

The data suggest that Group B presumably the group that experienced online mentoring interventions demonstrated greater and more sustained engagement with the learning materials. This supports the notion that online mentoring has a positive effect on student motivation and involvement, fulfilling the objective of identifying its impact on engagement within the target group.

3.2 Data Analysis

Tableau is a powerful and user-friendly data visualization and analytics software that enables users to analyze large and complex datasets with ease. It is widely regarded as one of the leading tools in the field of data analytics due to its ability to transform raw data into interactive, insightful visualizations such as charts, graphs, dashboards, and maps. Tableau supports a wide range of data sources, including Excel, SQL databases, cloud services, and big data platforms, making it highly flexible and adaptable to various research and business needs. One of Tableau's key strengths is its drag-and-drop interface, which allows even non-technical users to explore data and uncover patterns, trends, and correlations without needing to write code. Additionally, Tableau enables real-time data analysis and provides tools for predictive analytics, helping users make data-driven decisions efficiently. Its ability to present findings in a clear, visual format enhances understanding and communication of insights, making Tableau an excellent tool for both quantitative and qualitative data analysis in academic, business, and research environments.

A key contribution is its guidance on interpreting the statistical summaries generated by Tableau. The analysis is grounded in a dataset that includes Market Risk Premium data from seven Latin American countries Argentina, Brazil, Chile, Mexico, Peru, and Uruguay—spanning from 2012 to 2018. The paper is structured in three sections:

an overview of the dataset, a detailed explanation of how to create and analyse trend line models in Tableau, and a concluding section summarizing key insights. (Salgador, 2018)

RO1: To evaluate the effect of online mentoring sessions on student engagement in an asynchronous learning environment.

To evaluate the effect of online mentoring sessions on student engagement, viewership data for the 4th and 5th lessons both covered during online mentoring sessions were analysed. The comparison between engagement levels before and after the mentoring sessions reveals a substantial increase in both the number of views and unique users. For the 4th lesson, the number of views rose from 585 to 1,416, while unique users increased from 262 to 456. Similarly, the 5th lesson experienced an increase from 327 to 890 views and from 166 to 363 users. These figures represent more than double the engagement in both lessons after the introduction of mentoring. This suggests that the presence of mentors encouraged more students to revisit and interact with the learning content. The notable growth in views and unique participation indicates that online mentoring sessions had a significant positive impact on student engagement, supporting the objective of enhancing student interaction and motivation through structured academic support.

Table 2:

Module	Before the Introduction of Online Mentoring		After the Introduction of Online Mentoring	
4th Lesson	585 Viewers	262 users	1416 views	456 users
5th Lesson	327 viewers	166 users	890 views	363 users

RO2: To explore how online mentoring contributes to various aspects of student engagement, focusing specifically on students' interaction with content, levels of intrinsic motivation, and frequency of participation in academic tasks.

Analysis of the attendance who participate in the online mentoring session by Questionnaire and looking here how can students' attitude pertaining to the online learning environment be influenced by e-mentoring.

- self-paced,
- teacher as assisted mentor
- multimedia instruction

Online mentoring is essential for improving many facets of student involvement, especially for adult learners enrolled in distance learning programs. A study was carried out at the School of Distance Education, University Sains Malaysia, to investigate how students' perceptions of various aspects of the online learning environment like multimedia instruction, teacher-assisted tutoring, and self-paced learning influence their engagement, contentment, and perceived worth of working with e-mentors.(Omar et al., 2012) To achieve the objective of exploring how online mentoring contributes to various aspects of student engagement particularly learners' interaction with content, intrinsic motivation, and participation frequency the study examined three key elements of the online learning environment: self-paced learning, teacher as assisted tutor, and multimedia instruction. Each of these dimensions aligns with different facets of engagement and offers insight into how online mentoring enhances learner experience.

Self-paced learning allows students to engage with content on their own schedule, accommodating individual learning preferences and personal responsibilities. This flexibility supports intrinsic motivation by empowering students to take ownership of their progress. When paired with online mentoring, students are more likely to remain consistent in their academic tasks, as mentors provide direction, accountability, and encouragement, thus reinforcing sustained participation.

Teacher as an assisted tutor plays a crucial role in maintaining students' connection to the course. Online mentoring in this model ensures timely feedback, personalized guidance, and emotional support. This interpersonal interaction enhances students' sense of belonging and commitment to their studies. With a

mentor available for academic and motivational support, students feel less isolated in an online environment and are more engaged in content discussions, forums, and assignments.

Multimedia instruction increases interactivity and caters to diverse learning styles, which directly influences content engagement. Videos, animations, and interactive modules make learning more stimulating and enjoyable, especially when mentors guide students on how to navigate and interpret these resources effectively. Online mentors can further contextualize multimedia content, fostering deeper cognitive engagement and a richer understanding of material.

Together, these three elements when facilitated through structured online mentoring demonstrate a synergistic effect that enhances students' engagement levels. Students not only interact more frequently with academic content but also exhibit higher motivation and greater consistency in their academic participation. Thus, online mentoring proves to be a valuable approach in supporting student engagement in a digital learning environment.

The pie chart generated using Tableau software illustrates the perceived impact of online mentoring sessions on students' course understanding, based on responses from a questionnaire. The participants were asked to rate the level of help they received from the online mentoring sessions. The questionnaire was conducted anonymously. According to the chart, 38.10% of students indicated that the sessions "greatly helped" them in understanding the course material, showing a strong positive response to the effectiveness of online mentoring. The largest segment, 47.62%, responded that the sessions "somewhat helped", suggesting that nearly half of the participants found the support beneficial, though not transformative. Only 14.29% of respondents remained neutral, indicating minimal impact or uncertainty regarding the value of the sessions.

These findings suggest that the online mentoring sessions were largely effective in enhancing course understanding for a majority of the students. When combined with insights from self-paced learning, teacher-guided instruction, and multimedia use, the mentoring support appears to play a significant role in fostering content engagement and improving academic clarity. The data supports the value of structured online mentoring to strengthen students' learning outcomes and motivation in a distance education setting.

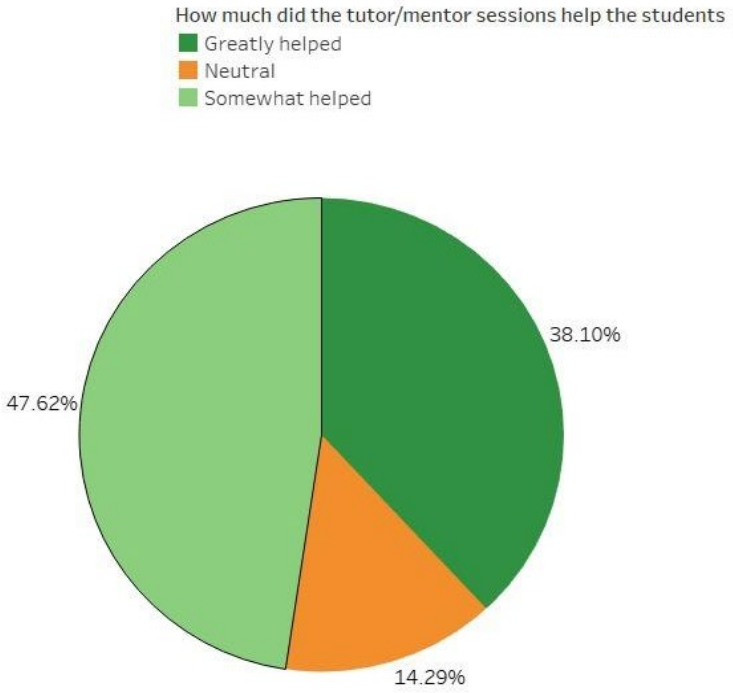


Figure 1: Impact of sessions on the learning experience

RO3: To compare engagement levels between students who participated in online mentoring sessions and those who did not.

To achieve the objective "To compare engagement levels between students who participated in online mentoring sessions and those who did not", the bar chart generated using Tableau clearly illustrates the relationship between session attendance and practical performance outcomes in module ITE 1223.

The data shows that students who attended 4–5 sessions achieved the highest average practical marks (68.75), indicating a strong correlation between moderate engagement in online mentoring sessions and academic success. Students who attended more than 5 sessions also performed well with an average of 62.40 marks, reinforcing the value of sustained engagement.

Interestingly, students who did not attend any sessions still managed a relatively high average score of 59.13, suggesting they may have relied on other learning methods such as self-paced or peer-supported study. In contrast, students who attended 2–3 sessions scored the lowest average (35.63), possibly indicating that minimal or inconsistent engagement is less effective than either full commitment or independent study.

This comparison highlights that active and consistent participation in online mentoring sessions significantly enhances student engagement and practical performance. The results support the idea that structured support through mentoring can improve outcomes, especially when students engage meaningfully and regularly.

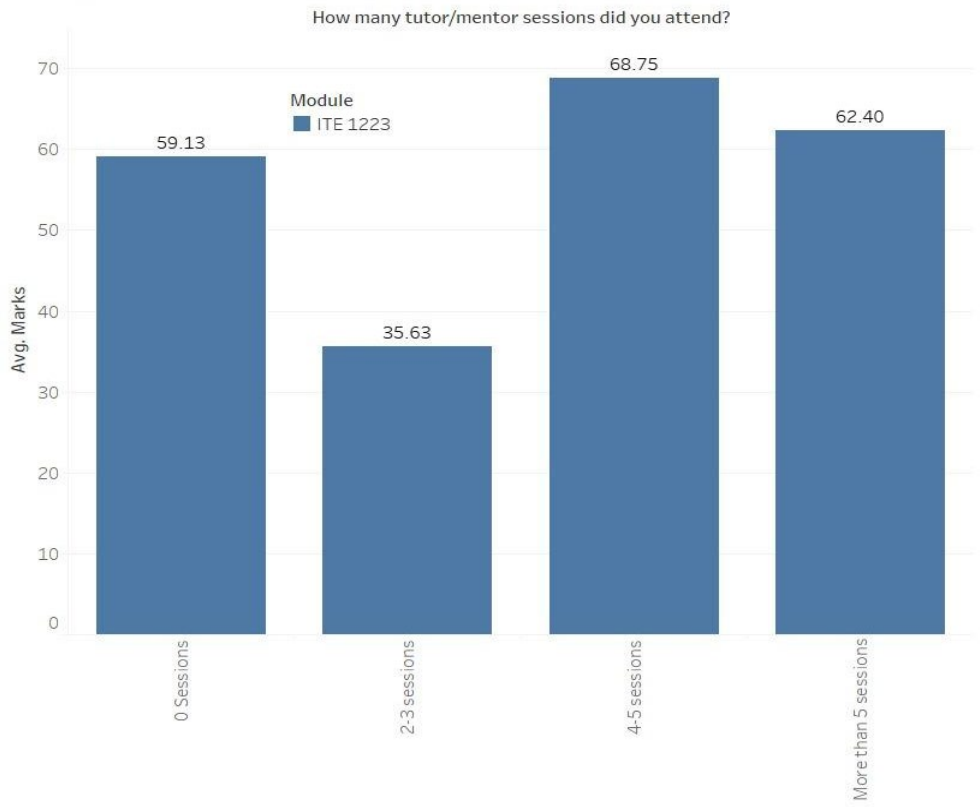


Figure 2: Average practical marks by online mentoring session attendance

4. Conclusion

This research comprehensively evaluated the impact of online mentoring sessions on student engagement within a self-paced, mentor-assisted, multimedia learning environment. The findings across all three objectives consistently highlight the positive role of structured mentoring in enhancing both academic engagement and performance.

Firstly, the analysis of login activity revealed a marked increase in student participation immediately following online mentoring sessions, particularly for the lessons directly addressed during these sessions. This indicates that online mentoring not only reactivated student interest but also provided the clarity and encouragement needed to re-engage with course content.

Secondly, insights from student feedback and target group segmentation confirmed that mentoring fostered deeper interaction with learning materials, boosted intrinsic motivation, and increased participation frequency. The real-time guidance, alongside multimedia content, created a learning environment that was more inclusive, responsive, and psychologically engaging key elements for sustained academic participation in distance learning settings.

The combination of real-time guidance and multimedia resources created a learning atmosphere that was both supportive and stimulating, ultimately contributing to heightened psychological investment in the course.

Thirdly, academic performance analysis showed that mentored students performed better in final practical assessments than those who did not attend the sessions. This improvement reflects not only better comprehension and confidence but also a stronger ability to apply knowledge effectively demonstrating deeper cognitive engagement.

Beyond academic metrics, the influence of mentoring on students' future career development is notable. By nurturing key skills such as self-regulation, problem-solving, and the ability to seek and apply feedback, mentor sessions helped students cultivate habits essential for workplace success. The approximately 5% increase in engagement further validates the influence of structured, culturally and linguistically responsive mentoring on student motivation and interaction.

In conclusion, the introduction of synchronous online mentoring into an asynchronous educational model significantly improved student engagement. The findings support the integration of structured mentor support as a sustainable strategy for enhancing student outcomes in distance and asynchronous learning environments, particularly among first-year undergraduates in diverse educational contexts.

Ethics Declaration

Ethical clearance for collection of data was obtained as per the university regulations.

AI Declaration

AI-based tools were used solely for formatting assistance and language refinement. All intellectual content, analysis, and conclusions presented in this paper are the original work of the authors.

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How Early Can We Identify At-Risk Students? An Analysis of LMS Interactions

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Abstract: The switch to online learning in higher education brought about by the Covid-19 pandemic has had lingering effects – most notably, continued higher levels of usage of learning management systems (LMS) such as Moodle for assessment and sharing of course materials. This has enhanced the potential for learning analytics even for courses that are delivered in a face-to-face mode. This is because the design of the course page on the LMS and how it is utilized for assessments over the semester necessarily affect the nature of student interactions with the LMS. There is already a sizeable literature that links student interactions with the LMS, selected student characteristics, and learning outcomes, highlighting that it is indeed possible to detect at-risk students using data sources such as course logs and click streams. However, there is less research on how early a student who is at risk of not completing or failing the course can be detected. This paper uses LMS logs, student characteristics, and learning outcomes of six cohorts of undergraduate students (over 500 students in total) taking a compulsory second-year module in a Sri Lankan university to detect the earliest point in the semester at which at-risk students can be identified. Due to the weekly modeling structure, the dataset expands to over 8,000 records, with each entry corresponding to a unique combination of student index number and week number. This paper employed a cumulative modeling approach, where several machine learning models including Random Forest, Decision Tree, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN) are assessed for performance. Random Forest consistently outperformed other models, achieving an accuracy of 78.51% in Week 16. Notably, performance metrics stabilized above 70% by Week 8, suggesting it as the optimal point for early prediction. The analysis revealed that prior academic performance and consistency of LMS engagement were stronger predictors than total LMS clicks. These findings support the development of data-driven early warning systems tailored to the Sri Lankan higher education context, emphasizing the value of consistent behavioral monitoring and historical academic data for effective intervention strategies and it provides insights on how effectively utilizing an LMS can improve learning outcomes even for courses that are offered in face-to-face mode.

Keywords: At-Risk Students, Early Warning system, LMS Interactions, Machine Learning, Learning Analytics

1. Introduction

Learning Management Systems (LMS) are now a core part of modern higher education, revolutionizing how educational institutions deliver and manage learning experiences. The COVID-19 pandemic worldwide significantly accelerated the adoption of the Learning Management Systems (LMS), triggering an unparalleled historical transformation of educational paradigms to e-learning modes. In this context, the necessity for digital and innovative technology to support teaching tasks, manage classes, and track learners has become a critical component in education (Zabolotniaia, 2020; Simanullang and Rajagukguk, 2020). This rapid transition has brought to light opportunities and challenges in terms of digital learning spaces, especially monitoring and supporting the success of learners.

This growth in digital learning spaces has created some unique challenges, particularly in developing countries. In Sri Lanka, for instance, aside from problems relating to access to the suitable infrastructure for online learning (World Bank, 2020), studies have highlighted lack of opportunities for interactive communication between teacher and student, the impossibility of asking a question as soon as some specific issue occurs and the slowdown in development of social skills (Rupasingha and Haththotuwa, 2021). These concerns have highlighted the need to identify students in distance learning environments who are falling behind academically in a timely manner.

In the aftermath of the Covid-19 pandemic, universities resumed normal operations but heightened use of learning management systems for instruction persists (Uthsari et al., 2024). Given that these systems generate vast amounts of behavioral data based on student interactions with course material, assignments, and discussions, they are now being increasingly used to derive insights on learner behaviours (Nguyen, 2015). While much of the literature focuses on the use of LMS data for the study of distance and online learning (e.g Arizmendi et al., 2022; Kaensar and Wongnin, 2023), there are several papers that investigate outcomes of university students who learn in face-to-face settings too (Uthsari et al., 2024; Biktimirov and Klassen, 2008; Baugher, Varanelli and Weisbord, 2003).

In the case of distance learning courses, the prediction of course completion receives a major focus, given the high levels of non-completion in these courses (Hayes et al., 2024; Latif et al., 2022). Even for courses operating with specific start and end dates (like courses offered in undergraduate or postgraduate degree programs), there is a large literature that connects student learning outcomes with student interactions with the LMS **(**Kaensar and Wongnin, 2023; Simanullang and Rajagukguk, 2020). Recent advances in educational data mining have leveraged machine learning (ML) approaches to predict student performance using algorithms such as logistic regression, decision trees, support vector machines (SVM), and random forests, which have shown effectiveness in analyzing behavioral patterns and academic histories to support early predictions (Arizmendi et al., 2022; Shayan and van Zaanen, 2019). These methods have the advantage of large and complex datasets, identifying hidden patterns in student behavior and enabling timely interventions to support at-risk students.

Given this established relationship between interactions with the LMS and learning outcomes, another key question arises from the point of view of the educational manager: how early can this data be effectively utilized to identify students at risk of poor academic performance? This is particularly pertinent because even though the use of later-semester data can yield more precise predictions, early identification is the most crucial method of effective intervention to a student. The use of LMS-generated data for addressing this question is also suited for large-class environments where instructors face challenges in closely monitoring individual progress. AI-based tools that analyze early LMS behaviors offer promising solutions by enabling institutions to detect academic risk at earlier stages and initiate support before students fall behind (Latif, 2022).

The existing research on this specific area suggests that the predictive value of different features varies throughout a course. For instance, Shayan and van Zaanen (2019) analyzed data from 426 students across five blended learning courses using Moodle LMS data, student characteristics, and academic performance with a decision tree algorithm and found that prior academic records such as GPA play a significant role in the early weeks, while mid-course performance data and LMS activity metrics (e.g., session counts, clicks, quiz attempts) become more predictive later on. Hayes (2017), in a similar analysis based on LMS behavioural data and predictive modeling finds that the initial six weeks of a course are a critical period in which intervention can have the most impact on student performance. These papers highlight how meaningful insights early in the course are vital for timely interventions though the features used and optimal timing for accurate predictions can vary depending on the context.

Despite advancements in educational data analytics globally, Sri Lankan higher education institutions have yet to effectively utilize LMS behavioral data for early risk prediction. Existing local studies predominantly focus on LMS adoption and student perceptions (Subashini et al., 2022) or examine correlations between LMS usage and academic performance, without offering frameworks for real-time, early-stage interventions (Uthsari et al., 2024; Bandarigodage et al., 2024). Consequently, behavioral indicators available in the initial weeks of a course remain largely untapped for predicting at-risk students. This underutilization limits opportunities for timely academic support and proactive student retention efforts.

Accordingly, this study addresses the following research questions: (i) Can LMS behavioral data and prior academic records predict end-of-semester academic performance in a face-to-face learning environment? (ii) What is the earliest point in the semester at which at-risk students can be identified with acceptable accuracy? (iii) What LMS interaction features most significantly contribute to the prediction of at-risk students? The broader aim of the study is to investigate how predictive models based on early semester data can support the design of effective early intervention strategies within the Sri Lankan higher education context.

To answer these research questions, we analyze LMS interaction data collected during the entire 16 weeks of the semester in a core undergraduate module, together with data on students' end-semester and prior academic performances. A cumulative weekly modeling approach is applied using several machine learning algorithms, incrementally assessing model performance from the first week through the sixteenth week of the semester. Through this design, the research aims to establish an empirical basis for determining the earliest feasible prediction point for academic risk detection, to identify key behavioral indicators associated with performance outcomes, and to propose timely, data-driven intervention strategies that can be operationalized within the Sri Lankan higher education system.

2. Data and Methods

This study investigates the early prediction of academic risk using LMS behavioral data combined with prior academic performance. The analysis workflow includes detailed data collection aligned with weekly course activities, comprehensive data preprocessing to prepare features and address imbalances, and a cumulative

predictive modeling approach that evaluates model performance week-by-week throughout the semester. Each step is designed to address the key research questions concerning the feasibility, timing, and features important for early risk identification in Sri Lankan higher education contexts.

2.1 Data Collection

This study utilizes behavioral and academic performance data from the Faculty of Business, University of Moratuwa. The dataset comprises six cohorts of students (Intakes 17 to 22), focusing on a core module taught in Semester 3, Introduction to Econometrics. The final grade in Introduction to Econometrics serves as the target variable. The grade obtained from its prerequisite subject, Probability and Statistics for Business – II (Semester 2), is included as a predictive variable.

The initial dataset included over 500 unique students. To ensure consistency and avoid duplicate records, students who had repeated attempts in the introduction to Econometrics module were excluded from the analysis. Due to the weekly modeling structure, the dataset expanded to over 8,000 records, with each entry corresponding to a unique combination of student index number and week number. This structure enabled a realistic simulation of ongoing monitoring and prediction throughout the semester.

Behavioral data were extracted from the Moodle Learning Management System (LMS), which records detailed logs of student interactions over the 16-week semester. Weekly clickstream features were derived, including clicks on learning materials, course pages, non-continuous assessment (non-CA) activities, quizzes, and assignments. Each student was identified using an index number, from which the batch prefix was also derived. Week numbers were determined from activity timestamps. These behavioral features were then merged with the final grade and the prerequisite module grade using index numbers as the linking key.

In addition to raw click counts, derived features were engineered to enhance the dataset. These included: (i) the proportion of clicks per activity type within each week, relative to total weekly clicks; and (ii) the week-by-week standard deviation of clicks per activity type, capturing consistency in LMS engagement. All data extraction and feature engineering tasks were performed using Python.

Table 1 provides an overview of the weekly academic activities and the corresponding LMS behavioral features derived from Moodle log files. The weekly breakdown ensures transparency in how student learning behavior was monitored, with LMS interactions captured through event logs (*event name*, *component*, and *event context*). The table is based on the latest course design, with only minor adjustments across different student cohorts.

Table 1: Weekly course structure and LMS interaction mapping

Week	Weekly Activities	LMS Interaction Logs Captured
01	Revision quiz, lecture notes, R code, dataset	Clicks on learning materials, course page, non-CA activities, quizzes
02	Quiz, lecture notes	Clicks on learning materials, course page, quizzes
03	Quiz, lecture notes	Clicks on learning materials, course page, quizzes
04	Lecture notes, R code, dataset	Clicks on learning materials, course page, non-CA activities
05	Lecture notes, R code, dataset, quiz, R activity	Clicks on learning materials, course page, non-CA activities, quizzes
06	Lecture notes, R code, dataset, assignment details	Clicks on learning materials, course page, non-CA activities, assignments
07	Lecture notes, assignment	Clicks on learning materials, course page, assignments
08	Lecture notes, recordings, R code, dataset	Clicks on learning materials, course page, non-CA activities

Week	Weekly Activities	LMS Interaction Logs Captured
09	Lecture notes, R code, dataset, recordings	Clicks on learning materials, course page, non-CA activities
10	In-class test	Clicks on course page, non-CA activities, quizzes
11	Assignment progress presentations	Clicks on course page, non-CA activities, assignments
12	Lecture notes, R code, dataset, recordings, assignment submissions, peer assessments	Clicks on learning materials, course page, non-CA activities, assignments
13	Lecture notes, R code, dataset, quiz, R activity	Clicks on learning materials, course page, non-CA activities, quizzes, assignments
14	R activities	Clicks on course page, non-CA activities, assignments
15	Quiz, Revision questions	Clicks on course page, quizzes
16	Make-up test	Clicks on course page, quizzes

2.2 Data Preprocessing

Several preprocessing steps were performed to prepare the dataset for modeling. Appropriate data types were assigned to each variable, and missing values were handled accordingly. In particular, missing values in the consistency features calculated as the standard deviation of weekly click counts by activity type were observed in Week 1 for all students. This was expected, as standard deviation cannot be computed from a single observation. These values were imputed with zero, indicating the absence of variability in the initial week. Categorical variables were encoded to support downstream modeling. The target variable (final grade) and the prerequisite course grade were ordinally encoded, while batch identifiers were one-hot encoded. All numerical features were standardized to ensure comparability across scales.

Correlation analysis was conducted to identify relationships among features. It provides some interesting insights. Among the LMS interaction variables considered, most are positively correlated with final grade, though the correlations are not strong. The prerequisite course grade was found to be most strongly correlated with the final grade (r = 0.63), as shown in Figure 1.

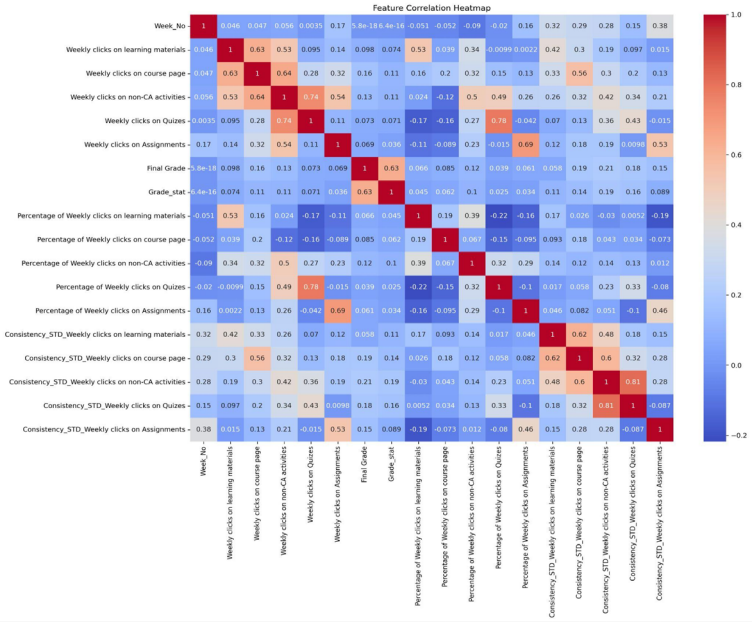


Figure 1: Correlation heatmap of the variables

An analysis of the final grade distribution revealed class imbalance, as shown in Figure 2. To mitigate this, the Synthetic Minority Over-sampling Technique (SMOTE) was applied to balance the dataset. To ensure reliable evaluation of model performance, the dataset was divided into a training set and a testing set, where 80% of the data was used for training and 20% was reserved for testing. This split allows for objectively evaluating how well the models generalize to new unseen data and forms the foundation for the modeling approaches discussed in the next section.

2.3 Modeling Approach

To evaluate the feasibility of early prediction of student performance, a cumulative modeling approach was adopted. Beginning with data from Week 1, models were trained incrementally by adding one week of behavioral data at a time (e.g., Week 1 only, Weeks 1–2, Weeks 1–3, ..., up to Week 16). This enabled performance comparison across different points in the semester and allowed for the identification of the earliest stage at which reliable predictions could be made.

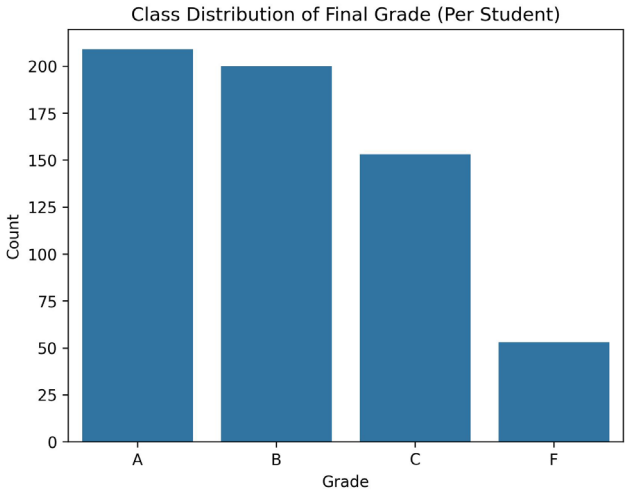


Figure 2: Class imbalance of final grade

The task was framed as a multiclass classification problem, given that the target variable, final grade, is categorical with more than two classes (A, B, C and F). Four classification algorithms were evaluated: Random Forest, Decision Tree, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN). Each model was trained and evaluated on the cumulative datasets using standard multiclass performance metrics, including accuracy, macro-averaged precision, recall, and F1-score. Accuracy measures the proportion of the total number of correct classifications to the sum of classifications. Precision reflects the proportion of students predicted to be at risk who are actually at risk, while recall measures the model's ability to identify all students who are truly at risk. The F1 Score, which is a compromise of both precision and recall, offers a balanced assessment, especially useful when both false positives and false negatives are important to consider. This score is typically an effective metric for measuring the quality of an approach (Shayan and van Zaanen, 2019). The best-performing among these tested models based on these metrics was then selected for further refinement using hyperparameter tuning.

To determine the earliest point of stable prediction, a line graph of model accuracy over time (by week) was plotted. This visualization facilitated the identification of the optimal prediction week—the earliest week in the semester when the model achieved sufficient accuracy to meaningfully differentiate between student performance levels. This point serves as a benchmark for enabling timely and targeted academic interventions.

3. Results

3.1 Model Comparison and Identification of Optimal Week

In the first stage, different models were fitted to the data to predict the final grade and each model was assessed using standard classification metrics to evaluate its performance in predicting at-risk students. The performance metrics across different models are summarized in Table 2.

As Table 2 shows, other than in Week 1, the Random Forest algorithm consistently outperformed other algorithms in classification metrics. Accordingly, to further enhance performance, hyper parameter tuning was applied to the Random Forest model.

Table 2: Comparison of selected models' performance metrics at week 1, week 8 and week 16

Model	Week 1 Perfomance Metrics	Week 8 Performance Metrics	Week 16 Performance Metrics
Random Forest	Accuracy: 0.5447, Precision: 0.5490, Recall: 0.5447, F1 Score: 0.5359	Accuracy: **0.6972**, Precision: **0.6949**, Recall: **0.6972**, F1 Score: **0.6953**	Accuracy: **0.7373**, Precision: **0.7357**, Recall: **0.7373**, F1 Score: **0.7362**
Decision Tree	Accuracy: 0.5041, Precision: 0.5067, Recall: 0.5041, F1 Score: 0.5026	Accuracy: 0.6524, Precision: 0.6591, Recall: 0.6524, F1 Score: 0.6549	Accuracy: 0.7154, Precision: 0.7202, Recall: 0.7154, F1 Score: 0.7169
Support Vector Machine (SVM)	Accuracy: **0.569**1, Precision: 0.5891, Recall: **0.5691**, F1 Score: **0.5694**	Accuracy: 0.6209, Precision: 0.6285, Recall: 0.6209, F1 Score: 0.6216	Accuracy: 0.6037, Precision: 0.6091, Recall: 0.6037, F1 Score: 0.6056
K-Nearest Neighbors (KNN)	Accuracy: 0.4634, Precision: 0.4929, Recall: 0.4634, F1 Score: 0.4725	Accuracy: 0.5528, Precision: 0.5802, Recall: 0.5528, F1 Score: 0.5625	Accuracy: 0.5574, Precision: 0.5688, Recall: 0.5574, F1 Score: 0.5617

Figure 3 shows the trend of model performance measures throughout the semester of 16 weeks. The model performance shows a clear improvement over time, with the Accuracy (solid blue line) increasing from 0.5366 in Week 1 to 0.7851 in Week 16. While similar improvements were seen in precision (solid orange line) from 0.5490 to 0.7857, recall (solid green line) from 0.5366 to 0.7851, and F1-score (solid red line) from 0.5273 to 0.7846 followed a comparable upward trend, stabilizing around Week 8 and achieving their highest values in the final weeks. This trend in performance is to be anticipated, since each week's model was trained on cumulative behavioral features. That is, more precise LMS interaction data were available later in the semester. As such, the model's ability to distinguish between student final grade categories (A, B, C, F) inevitably improves over time.

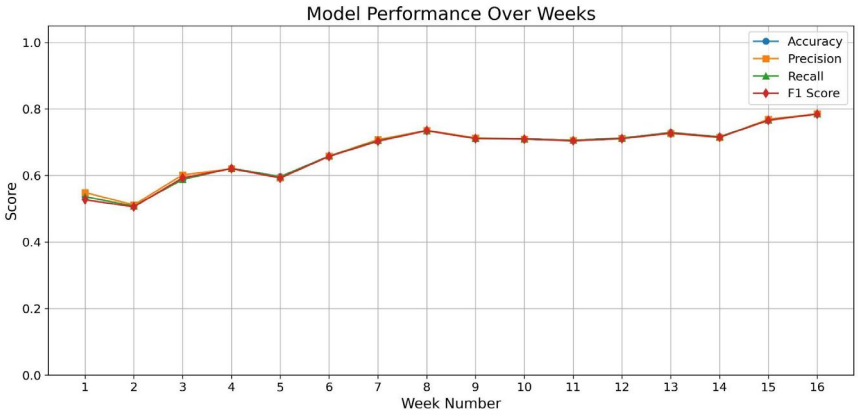


Figure 3: Model performance metrics (Accuracy, Precision, Recall, and F1 Score) across 16 weeks.

Despite relatively modest predictive power during the first few weeks (especially Weeks 1–5), model performance began to increase significantly from Week 5 onward. Most strikingly, by Week 8, all performance metrics exceeded the 0.70 threshold and remained consistently high throughout the remainder of the semester. This stabilization indicates that mid-course, the model has accumulated enough behavioral evidence to yield stable predictions and that Week 8 represents a possible threshold for early detection of at-risk students and intervention planning.

These results confirm the idea that behavioral data extracted from the LMS and aggregated across weeks, is an effective proxy for both academic success and engagement. Yet they also underscore the value of temporal variations showing that while there are some signals in the early weeks, reliable predictions require several weeks of interaction data.

3.2 Feature Importance Analysis

In order to determine which behavioral indicators were most predictive of final grades, feature importance scores were calculated from the best-performing Random Forest model at Week 8, the earliest reliable prediction point identified previously.

As shown in Figure 4, the most valuable feature was Grade_stat (importance score: 0.2625), which assesses previous academic performance in the prerequisite statistics course. It accounts for 26.25% of the model performance, whereas LMS interaction variables jointly explain 73.75%. This indicates that although past academic performance is highly influential, behavioral data from the LMS collectively contribute more to the predictive power of the model.

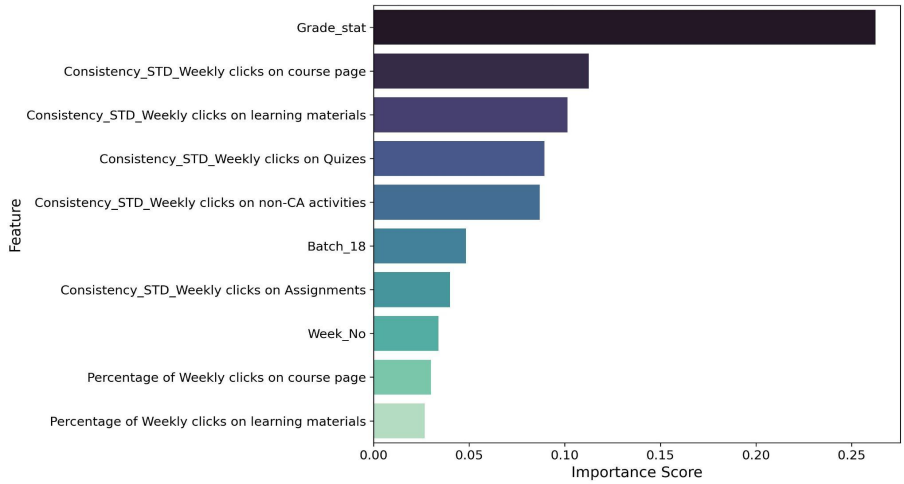


Figure 4: Top 10 most important features identified in Week 8 model for predicting final grades

However, in addition to historical grade information, several features related to consistency in weekly LMS usage have become top-level predictors. These include the standard deviations of weekly clicks on key elements such as course pages, learning materials, quizzes, and non–continuous assessment (non-CA) activities. Their modestly high importance values suggest that students with unstable or highly variable engagement are more likely to be identified as at-risk than students who consistently engage—despite low overall click totals. On the other hand, raw click counts and percentage-based distributions of clicks across activity types showed lower importance, highlighting that sheer volume of activity is less predictive than the pattern or regularity of that activity over time.

These results provide several key implications for early warning systems: first is that prior performance is a key predictor. Second, rather than simply assessing how much a student is utilizing the LMS, it may be more beneficial to track how consistently they use it from week-to-week.

4. Discussion and Conclusions

This study sought to establish how early in a semester behavioral data from an LMS can be used to differentiate between weaker and performing students, with a view to providing timely academic interventions using data from a Sri Lankan university. The findings demonstrate that, aside from prior performance, student usage patterns on Moodle LMS, and particularly those reflecting consistency of engagement, can serve as effective predictors of end-of-term academic performance. These results directly address the first research question, confirming the predictive value of LMS behavioral data combined with prior academic records. The cumulative modeling approach employed in the study demonstrated enhancing model performance measures—accuracy, precision, recall, and F1-score—gradually and consistently with growing quantities of weekly behavior data. Although predictive performance was comparatively modest in the initial weeks, there was a marked improvement starting from Week 5, with the level of performance plateauing above 70% from Week 8. This result indicates that at the mid-point of the semester, there is enough behavioral evidence to effectively distinguish between students who have a likelihood of success and those who may be at risk and it answers the second research question about the timing of at-risk student identification

The importance of behavioral consistency was further highlighted by feature importance analysis, which revealed that week-over-week fluctuation in LMS activity was more predictive of final outcomes than click

counts. Inconsistent or highly variable interaction patterns were associated with poor performance among students, indicating that participation quality and consistency may be more important than activity counts. In addition, prior academic performance, as captured by the grade in the prerequisite course, emerged as the single most influential predictor of final grade, reaffirming the importance of historical academic data in early risk detection. These findings are consistent with the previous research, which has shown that prior ability strongly influences student performance (Ruiperez-Valiente et al., 2018), and that consistent engagement patterns are more predictive than raw activity volume (Bitkimirov and Klassen, 2008; Baugher, Varanelli and Weisbord, 2003). This analysis provides a clear answer to the third research question by identifying the most significant LMS interaction features contributing to predicting at risk students.

These findings have significant implications for Sri Lankan institutional practices. The identification of Week 8 as a cutoff for stable and accurate prediction offers a handy benchmark for developing early warning systems. Universities can use this insight to develop predictive monitoring tools that automatically flag students showing erratic engagement patterns by mid-semester. Academic support units can deliver focused interventions, like personalized feedback or mentoring, thereby providing students a chance to recover prior to the final assessments.

In conclusion, this study demonstrates that LMS behavioral data, when analyzed cumulatively and combined with prior academic performance, can effectively distinguish between weaker and better-performing students in higher education. Findings confirm that reliable predictions of student outcomes can be made as early as Week 8 of the semester, allowing for a valuable window of opportunity for the early detection of at-risk students. This early prediction capability supports the design of timely, data-driven academic interventions that are both scalable and relevant to the Sri Lankan higher education context. The study further indicates that it is not the quantity of activity in LMS usage, but consistency of usage that more strongly predicts academic performance, and therefore the value of monitoring behavior patterns over time.

This study only addresses one module so is perhaps not generalizable across courses. Though focused on LMS use, instructional approach, course design, and lecturer interaction have the potential to influence learning behaviors that are not quantified directly here. Furthermore, extraneous variables such as economic status or psychological traits were not employed. Future research could extend this analysis to multiple subjects, where LMS usage may vary depending on discipline and instructional methods. A broader study would help assess generalizability and support development of an early intervention framework based on real-time LMS analytics.

Ethics Declaration

This study received ethics approval from the University of Moratuwa Ethics Review Committee under approval number EDN/2023/008. Data collected were de-identified and stored securely. There was no access to individual identifiers such as student names or their contact information at any point in the research process.

AI Declaration

One AI tool (ChatGPT) was used exclusively to aid in enhancing the manuscript's writing quality, grammar, and clarity. The AI tool was not employed to generate content, analyze data, or aid in research design.

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From Lecture Notes to Videos: The Impact on Learning in a Distance-Learning Program

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Abstract: The key challenges in the delivery of distance learning programs include maintaining student engagement and ensuring that students achieve intended learning outcomes. While video content has the advantage over lecture notes in being able to hold a student's attention more effectively and improve comprehension, the preparation of high-quality pre-recorded content can involve a large initial time investment, while infrastructure constraints such as availability of devices and network connectivity may also hold, especially in developing countries. This research studies the transition of two course modules offered in the first year of a distance learning program in Sri Lanka from a 100% notes-based delivery style to the incorporation of pre-recorded videos for each of the topics in the modules. Specifically, the study investigates the impact of the inclusion of video content into the course content on learning behavior measured by interactions with the LMS and learning outcomes measured by continuous assessment and written examination marks. The study uses data from 12 cohorts of students and two modules, where the first five cohorts did not have access to any videos, while the remaining cohorts did. The impact of the availability of video content is assessed using a repeated-cohort multiple regression model where changes to the examiner of the module can be controlled for. Results of this study show that marks for non-formative quizzes and summative continuous assessments are positively and significantly associated with the minutes of video content in both modules. However, the impact on end-semester examinations and submission of formative assignments varies across modules and is even negative for one subject. These findings suggest that the incorporation of video content perhaps has a more substantial short-term effect on learning outcomes, helping with immediate retention of content, though the evidence about longer-term effects, as observed in final examinations, is mixed. While further work is needed to incorporate additional course modules and perhaps use detailed topic-wise marks from final examinations, the findings of this research provide a case study for the use of data-driven strategies for content design and development.

Keywords: Course Design, Video Lectures, Student Interactions, Online Courses, Learning Materials

1. Introduction

Online and distance learning programs are now a crucial means of expanding access to higher education and fostering lifelong learning. While such programs allow students the flexibility to access educational materials at their own pace remotely, they come with their own set of challenges. Such challenges include uneven access to technology, low student engagement, limited feedback from both students to teachers and teachers to students, and a lack of motivation among students (Ucar and Saritepeci, 2022; Culduz, 2024). These problems are especially pronounced in situations where there are differences in digital literacy, device availability, and internet reliability (Ndibalema, 2022). However, given that the objective of these programs is to instill skills and knowledge among the learners, the biggest challenge in such settings is ensuring that students are engaged and achieving the desired outcomes (Gaskell and Mill, 2017).

Many strategies are adopted to enhance student engagement in online and distance learning, such as providing feedback on time, creating a sense of community among students, and improving the effectiveness of learning materials through interactivity and gamification, etc. (Chakraborty and Nafukho, 2014; Hew, 2014; Pakpour et al., 2021; Young and Bruce, 2011). The use of video-based learning to enhance interaction and engagement in online settings is a commonly employed strategy to address the challenge of developing effective learning materials, although evidence supporting its effectiveness is mixed. On the one hand, video content has been found to considerably boost student engagement and understanding by making difficult lessons simpler and increasing student interest (Anie and Faustino, 2024; Simi, 2025; Zhu et al. 2022). Several studies focusing on student perceptions about learning materials also note that video materials improve the student experience and improve the grasp of difficult subjects (Albalawi, 2024; MacDonald and Thompson, 2005; Yang, 2017). While increased engagement and interest are known to improve academic performance, there is not as much work directly evaluating the impact of video content on final learning outcomes, as this requires a longer time frame of data to compare outcomes of students with and without access to the video content. Given that considerable

costs are involved in developing high-quality video content, as well as creating content that is engaging for learners, evaluations of this nature would be very useful for educational planners and content developers.

The Centre for Open and Distance Learning (CODL) of the University of Moratuwa offers a three-year, fully online Bachelor of Information Technology (BIT) external degree program. The program is delivered through Moodle, a popular learning management system (LMS) for online teaching and learning management. All subjects in the program include continuous assessments (CA), which take the form of quizzes and assignments, and a written examination (WE), conducted physically at the university at the end of the semester. Eligibility for sitting for the WE is based on passing the CA component.

At its inception in 2006/07, the main components of the course materials were text-based content, including lecture slides and PDF notes. However, in 2018, along with a major curriculum revision, video recordings of lectures were incorporated into the learning materials as a way to improve student interaction, understanding, and the quality of lesson delivery. This was rolled out gradually over several years for several courses. At the time of writing, most of the modules offer video lectures alongside the other learning materials. However, no empirical research has been conducted yet to assess its effectiveness in improving student engagement and achieving learning outcomes.

Therefore, in order to determine whether the addition of video lectures has improved student engagement with the course materials, this study evaluates LMS logs and students' grades on continuous assessments and semester-end exams from two modules in the BIT program for which video content was introduced. By using data on 12 cohorts, some of whom were exposed to the video learning materials and some of whom were not, this study's primary goals are to:

- Compare the academic performance of students in a fully video-based, partially video-based, and non-video-based module.
- Assess the effect of video lectures on student engagement by examining Moodle LMS logs.
- Determine whether video-based content increases student grades in comparison to traditional text-based materials.

Given the limited empirical evidence on this topic in the Sri Lankan context, this study provides some insights on how e-learning and teaching can be adapted to the local context. Moreover, while this study focuses on selected modules within a particular degree program, the research provides a case study for the use of data-driven strategies for designing curricula and course content for online and distance learning program.

2. Data and Methods

This study investigates the impact of incorporating video lectures in two first-year modules of the University of Moratuwa's Bachelor of Information Technology (BIT) external degree program. Using data from twelve student intakes from 2018 to 2023 (the program enrolls two intakes per year), we examine the potential effects of this design change on academic performance and student engagement with the LMS.

2.1 Selected Courses

This study uses data on two modules: Visual Application Programming (ITE1112) and Mathematics for IT (ITE1812), both of which are offered during the first year of the BIT degree program. While the BIT program's curriculum revision took place in 2018, the shift from text-based content to video-based content occurred from 2020 onwards. Accordingly, we study 12 cohorts (from Intake 2 of 2018 to Intake 2 of 2023), covering cohorts with and without access to these video materials. It should be noted that the introduction of video content was a single intervention - there were no changes in module content or structure of formative or summative assessments at the same time. Accordingly, Moodle course page structures are consistent before and after the introduction of videos, allowing for the comparison of student behavior and results over time.

2.2 Modelling the Introduction of Video Content

Initially, the course materials in both modules were limited to text-based PDFs and PowerPoint decks, with video lectures added starting with Intake 2 of 2020. We calculate the total number of minutes of video content uploaded to the Moodle page for each topic for each intake for each module (this is zero for all cohorts up until Intake 2 of 2020). It should be noted that for ITE 1112 the video content was introduced gradually with videos

introduced for half the topics in the course for Intake 2 of 2020 and the remaining half included for Intake 1 of 2021 onwards. For ITE 1812, video content for all topics was introduced in a single semester, Intake 2 of 2020.

We also create a dummy variable to indicate the change in the course instructor. This allows us to control for possible changes in final results caused by changes in lecturing staff who set the summative assessments.

2.3 Student Interactions and Outcomes

The Moodle logs for every cohort were used to gather information on student interactions with the LMS. Specifically, we do the following: For ITE 1112, we take the number of student submissions for each of 16 ungraded learning activities and the average number of clicks per student on each of the 16 course learning activities of ITE 111 (given weekly for all of the 12 cohorts) to measure engagement. To enable aggregate analysis across students, submissions were transformed into a binary variable: 1 for submitted, 0 for no submission. Given that the grades of these activities were not included in the final grade, we do not have the marks for these activities; hence, the use of submission as the outcome variable. For ITE 1812, the formative assessments were quizzes rather than assignment submissions. Accordingly, for this subject, we use the marks from 19 formative assessment quizzes given over 16 weeks to study students' engagement with the course content and Moodle page.

Both written exam (WE) scores and continuous assessment (CA) marks, which are scaled to percentages, were used to capture academic achievement. These scores were averaged across all students and recorded for each cohort (intake). The reason for this is that while the video content was prepared per topic, the only information we have on topic-wise engagement and learning outcomes are the interactions with formative assessments. So cross-topic variation in video content can only be exploited against formative assessment completion. For the summative assessments (WE and CA) it is the total count of video minutes that matter, which means that the only source of variation there is across the cohorts.

Descriptive statistics for the variables used in the study are provided in Table 1.

Table 1: Descriptive statistics

Variable	ITE 1112		ITE 1812	
	Before Video	After Video	Before Video	After Video
Video minutes	0	600	0	471
Average CA marks	66.49	47.25	54.66	59.32
Average WE marks	49.72	43.50	30.57	27.88
Average clicks per LA	4.98	4.75	NA	NA
Average submission rate for LAs	0.65	0.47	NA	NA
Average marks for quizzes	NA	NA	8.97	8.86

2.4 Statistical analysis

To examine the association between the introduction of video content and student performance and engagement, we used a regression-based methodology. Specifically, multiple linear regression models were also estimated in order to assess the impact of video lectures. These models looked at the link between the amount of video minutes and the following outcomes:

- Average clicks per learning activity and average submission rate (as a proportion) for ITE 1112
- Marks for formative assessment quizzes in ITE 1812
- Aggregate CA marks and WE marks for both modules

A dummy variable was incorporated into each regression to account for change in examiners that took place during the time period considered. This enables the separation of the instructor's influence from the impact of the educational format.

The regression models are estimated separately for each module at two different levels: when CA or WE marks are the dependent variable, the regressions are estimated at the student level, and video minutes are fixed for the pre- and post-video cohorts. The specification is as follows:

$$y_{it} = \beta_1 VideoMinutes_t + \beta_2 LecturerChange_t + \epsilon_{it}$$

where the grades for student i in intake t are represented by y_{ijt} , and the error term is represented by ϵ_{ijt}.

When interactions with learning activities (for ITE 1112) or formative assessment marks (for ITE 1812) are used, we estimate the regressions at the activity or topic level with the video minutes varying across both pre- and post-video cohorts and topic. The specification is as follows:

$$y_{jt} = \beta_1 VideoMinutes_{jt} + \beta_2 LecturerChange_t + \epsilon_{jt}$$

where the grades or interaction metric for topic **j** in intake **t** is represented by y_{ijt} .

3. Results

Regression analyses were performed to assess the effect of video lecture content on students' academic performance and engagement with the Moodle learning management system (LMS) across two core modules: ITE1112 (Visual Application Programming) and ITE1812 (Mathematics for IT). The empirical results are discussed in this section. Quiz marks (out of 10), Written Exam (WE) and Continuous Assessment (CA) scores (out of 100), and LMS engagement metrics (clicks and submissions) are evaluated by the models, to examine the impact of "video minutes" as the main explanatory variable.

3.1 Academic Performance in ITE1112

Figure 1 plots the average CA and WE marks before and after the introduction of video minutes for ITE 1112. As the figure shows, there is a reduction in both CA and WE marks after the introduction of video content. However, this figure does not control for the effect of the change in the lecturer, which could drive differences in overall grades.

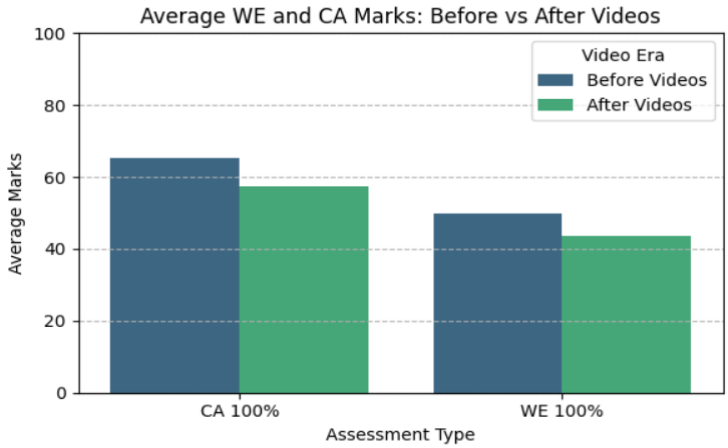


Figure 1: Average WE and CA marks for ITE 1112 before and after the introduction of video content

Table 1 shows the regression estimates of the impact of video minutes on student outcomes and engagement after controlling for changes in the lecturer. Note that the outcomes regressions (CA and WE marks) are estimated at cohort-student level whereas the engagement with learning activities regressions are estimated at the cohort-learning activity level explaining the difference in sample size across the models.

Table 2: Impact of video minutes on student outcomes and LMS interactions, ITE 1112

ITE 1112	CA marks	WE marks	Clicks on LA	Submissions per LA
Constant	55.2845***	49.7236***	4.9761***	0.6525***
	[0.772]	[0.755]	[0.293]	[0.014]
Video minutes	0.0124***	0.0125***	-0.0082***	-0.0004***
	[0.003]	[0.003]	[0.001]	[0.0001]
Lecturer change	-16.4845***	-13.0244***	1.6243***	-0.1047***
	[1.944]	[1.986]	[0.496]	[0.024]
R-square	0.041	0.032	0.156	0.409
N	3105	1942	192	192

Contrary to Figure 1, the regression results show a statistically significant positive relationship between continuous assessment grades of ITE1112 and video material duration ($\beta = 0.0124$, $p < 0.001$) after controlling for variations in average marks caused by the change to the examiner. In particular, the provision of a minute-long addition of video material to the Moodle course is related, on average, to an increase of about 0.012 percentage points in continuous assessment marks. The lecturer change effect is also large: the dummy variable for the lecturer had a large negative coefficient ($\beta = -16.48$), indicating a significant drop in continuous assessment grades after a change in the course examiner. Similarly, the video minutes variable shows a statistically significant and positive association with WE marks ($\beta = 0.0125$, $p < 0.001$), consistent with the findings based on the CA model. These results support the assumption that instructional videos increase students' understanding of course content, especially in technical courses that require visual interpretation.

Interestingly, however, we do not find a positive effect on the LMS interactions with learning activities or submission of learning activities - instead, the estimated coefficients are significantly negative, suggesting that fewer clicks and fewer submissions are made for subjects with more video minutes. However, given that these learning activity assignments are not graded or counted for the final grade, this may not be particularly concerning as students may be attempting the activity themselves even if they do not do the submission.

3.2 Academic Performance in ITE 1812

Figure 2 summarizes the CA and WE marks for ITE 1812 before and after the introduction of video lectures. Unlike for ITE 1112, we see an increase in the average CA marks after the introduction of video content, even without controlling for the change in examiner. However, the average final examination shows a reduction following the change like in ITE 1112.

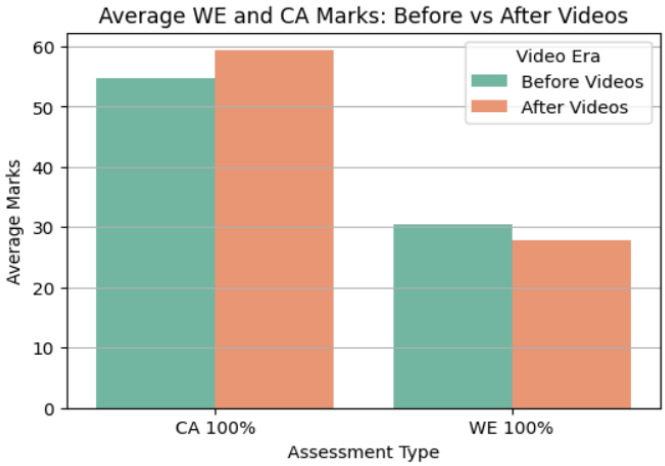


Figure 2: Average WE and CA marks for ITE 1812 before and after the introduction of video content

Table 3 provides the regression results. Consistent with Figure 2, we see a positive and significant effect of video minutes on CA scores (beta = 0.0099, p < 0.001) again affirming the claim that video-based delivery aids learning outcomes. The value of coefficient is a little smaller in magnitude than in ITE1112 but not significantly so. However, WE marks show a negative association with video minutes (beta = -0.0057, p = 0.008), and is statistically significant, even after accounting for the change in the examiner for the module. This finding appears unexpected, especially given the positive associations observed with both CA marks and formative quizzes (0.0095, p < 0.001), which rule out the possibility of insufficient practice or interaction. However, it is possible that the WE tests different learning outcomes or skills that are not assessed in the continuous or formative assessments provided during the semester.

4. Discussion and Conclusion

This study examines the impact of the introduction of video lectures on two first-year modules offered in an online, distance learning program offered by a Sri Lankan university. Using data from 12 cohorts which cover populations with and without access to video content, we estimate the impact of videos (measured by the duration of video content) on student learning outcomes as well as interactions with the LMS.

Table 3: Impact of video minutes on student outcomes and LMS interactions, ITE 1812

ITE 1812	CA marks	WE marks	Quiz marks
Constant	54.6610***	30.5758***	8.9713***
	[1.025]	[0.873]	[0.037]
Video minutes	0.0099***	-0.0057***	0.0095***
	[0.003]	[0.002]	[0.003]
Lecturer change	0.00002***	-0.0001***	-0.3392***
	[0.0000]	[0.0000]	[0.086]
R-square	0.004	0.002	0.071
N	3476	3476	209

Considering the results from both modules together, we see some interesting features. It is possible that the negative impact of video content on LMS interactions and submissions observed for ITE 1112 are due to the assignment nature of the learning activities. When the formative assessment takes the form of a quiz (as in ITE 1812), where there is feedback to the student and the feedback is obtained immediately, it is likely that the students have more motivation to complete them, with the video content positively affecting the learning outcomes. This then reflects in the overall CA marks, suggesting that the learning taking place during the semester is positively influenced by the video minutes. The negative impact on clicks could also be explained by limitations with using conventional LMS log indicators, as also put forward by Macfadyen and Dawson (2010), where clicks and log-ins alone are not really an accurate measure of the real time involvement or understanding of students.

However, when it comes to the final examination, which takes place as a physical, proctored examination, the estimated effect of the video content is mixed. In ITE 1112, the written examination marks also correlate positively, whereas in ITE 1812, the estimated effect is significantly negative. While there could be many explanations for this result, one could be that the final examination and continuous assessments test different learning outcomes. If, for instance, the quizzes and CA test more basic learning outcomes whereas the written examination tests higher order thinking skills, it may be students are preparing insufficiently for these higher level questions. This distinction suggests that video by itself is not a perfect solution, but a supplemental instrument, the usefulness of which is amplified when combined with proper instructional design and assessment strategies.

The analysis in this study could be extended in different directions to improve on the findings. One obvious direction is to increase the number of modules included in the study - this will help with the generalizability of the findings as well as highlight any difference in the impact of videos across disciplines (e.g. mathematics,

statistics, programming etc.). Another would be to further drill down into the CA and WE marks - if marks breakdown per question are available, we could map the marks against the topics in the course to obtain a more detailed picture of which topics ultimately benefit from the provision of video content. Accordingly, while this study provides a case study for the data-driven strategies for informing course design and delivery, the need for continuous self-monitoring, evaluation and re-design are key for improving maintaining student engagement and learning, particularly in distance learning programs.

Ethics Declaration

This research was conducted in accordance with ethical guidelines and approved by the University of Moratuwa Ethics Review Committee, with approval number EDN/2023/008. All data utilized in this research were de-identified before they were analyzed and kept within secure systems. Individual student identifiers like names, registration numbers, or contact information were not accessed or utilized at any stage of the research.

AI Declaration

AI software was not used in the design of the research, preparation of data analysis, or writing the manuscript. All scholarly findings, interpretations, and conclusions contained in this paper are the property of the authors.

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Student Performance Prediction Using Virtual Learning Environment (VLE) Interactions

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Abstract: Technological advancements have reshaped the education landscape through the introduction of digital learning platforms. Although higher education institutions are striving to increase the learning outcome and reduce the dropout rates, they still face challenges. Virtual Learning Environments (VLEs) have become essential platforms for delivering instructional content and assessing student engagement. This study aims to predict the students' learning outcomes for the database management subject using VLE log data. This study utilised 78,175 VLE click events generated by two hundred and forty-seven (247) students in a distance learning environment from a state university in Sri Lanka. The study utilised seven behavioural features, number of unique components, average hour, standard deviation of the hour, average number of days, number of weekend interactions, number of session count, peak study hour and thirty-four learning activity features to predict the learning outcome. From the Exploratory Factor Analysis (EFA) session count, the number of weekend interactions, and the unique components are selected as the most influential behavioural features, grade user report viewed, discussion created, discussion viewed, course viewed, a file has been uploaded, feedback viewed and course module viewed have been selected as the most influential learning activity features. The study utilises traditional Machine Learning approaches such as Random Forest Regressor, Support Vector Machines (SVM), and Deep Learning approaches, Multilayer Perceptron (MLP) and Long Short-Term Memory (LSTM) to perform the prediction. Among this approaches the Long Short-Term Memory (LSTM) model, a type of RNN outperform other approaches in terms of accuracy, Mean Absolute Error (MAE), and F1 score. The LSTM model achieved 97% accuracy.

Keywords: Deep Learning, Learning Activity, Log Data Analysis, Machine Learning, Performance Prediction, Virtual Learning Environment (VLE)

1. Introduction

Technology advancements introduced during the COVID-19 pandemic introduced a new norm in education. Traditional pedagogical systems are being replaced by the increasing integration of digital platforms like learning management systems (LMSs). Educational institutions have transformed the traditional learning environment into modern digital environments (Rizwan et al., 2025). According to the global statistical report, 77% of higher educational institutions have incorporated digital platforms to teach their core curriculum (Maaliw, 2021). However, low learning outcomes (Rogers et al., 2025), less engagement (Jawad et al., 2022) remain as core challenges for educational institutions using LMSs.

Though the Virtual Learning Environment (VLE) and the LMS have the same features, they however differ from the way they are used (Pinner, n.d.). VLE serves as the basis of most of the e-learning platforms and makes positive impacts on learners and teachers alike (Maaliw, 2021). VLE changes the teaching and learning environment from a physical classroom to online (Ryani Kusumawati, 2024). VLE supports content sharing, learning activities and assessment (Ryani Kusumawati, 2024) . Even though e-learning platforms follow the "one size fits all" style, it has failed to understand the individual needs (Maaliw, 2021). However, learners have different learning needs and learning behaviours, and these impact learning outcomes. Further, lower engagement (Jawad et al., 2022), abnormal participation and different adaptability among the learners reduce their learning outcomes (Ryani Kusumawati, 2024). In addition, poor curriculum design and minimal interactivity create more challenges (Ryani Kusumawati, 2024). Digital divide and digital literacy also influence the learning behaviours of the learners (Zakir et al., 2025). These challenges create the necessity to understand the influencing factors in learning outcomes and the early prediction of learning outcomes.

VLE contains a huge volume of student interaction data with the students' details. Machine Learning (ML) and Deep Learning (DL) are subsets of Artificial Intelligence (AI) and have emerged as powerful tools to predict hidden patterns and make predictions. Understanding how students interact with VLEs can provide valuable insights into their learning behaviours and performance. The available literature mainly relies on statistical analysis (Jo et al., 2018)) and applying ML and DL may provide more details of learner's performance (Borna et al., 2024). Unlike the traditional statistical models, ML and DL can also learn from data-making predictions.

In the literature, researchers commonly utilised course design data and LMS data to predict the performance (Liu et al., 2023). The frequently used data include demographic, academic background and learning behaviour to predict the performance (Liu et al., 2023). The challenges in the reusing model build using course related data are difficult to be applied to another course since the course data is heavily dependent on the course design (Liu et al., 2023). However, the clickstream data contains the details of student activity and navigation during the course (Liu et al., 2023). This study used clickstream data to predict the learners' performance. This study utilises VLE log data collected from a module followed by distance learning students from a state university in Sri Lanka. The study utilises the Random Forest Regressor, Support Vector Machines (SVM), Multilayer Perceptron (MLP) and Long Short-Term Memory (LSTM) to predict the learning outcome. Therefore, this study applies ML and DL techniques to analyse VLE log data to predict learners' learning outcome, enabling timely interventions and personalised learning strategies.

UNESCO's Sustainable Development Goal 4, namely "…ensure inclusive and equitable quality education and promote lifelong learning opportunities for all," intends to provide quality education for all. This study aligns with the Sustainable Development Goal 4. This study aims to improve the education quality by analysing the learners' learning behaviours in the digital environment along with the learning outcome to improve the learners' learning outcome.

2. Literature Review

The Online Learning Platform is capable of storing vast amounts of students' learning data (Borna et al., 2024). VLEs store students' interaction data (Borna et al., 2024), learning resources and activities. The VLE log data contains students' click interactions with the VLE. These details offer the opportunity to predict student performance. However, the difficulties in accurately identifying at-risk and high-achieving students remain a challenge (Borna et al., 2024). VLE logs contain details about students' learning behaviour. However, current literature has a very limited understanding of how these log events represent the learners' learning behaviours (Fazil et al., 2024). By understanding the students' learning patterns, the teachers can support them with more personalised content.

Learners' behaviours in online learning platforms differ from traditional learning environments, where motivation plays a key role in performance (Borna et al., 2024). However, on average, the learners' engagement contributes to predicting learning outcomes (Al-Tameemi et al., n.d.) and engagement plays a significant role compared to personal information. Student behavioural measurements can be divided into device-based or activity based (Borna et al., 2024).

The available studies in the literature used different approaches and different features to predict the learning outcome. They predict and analyse student performance based on different features. These features have been divided into the following groups (Rizwan et al., 2025): first, academic performance features (previous and current education background features such as courses studied, assignments, quizzes, course grade, final grade, course details, exam scores and GPA etc.). Second, demographic features (student's personal biodata information, which consists of the student's details, family details and social data, such as gender, age, job detail, number of family members, study hours, number of friends etc.). Third, behavioural or clickstream features (login time, online spending time, submitted assessments, web page clicking and web page visiting, discussion forums and video interactions, etc.). Fourth, facial and emotional features (facial expressions, head movements, head poses, eye contact and recognition etc.). Fifth, learning activity features respectively (interaction in VLE, learning behavioural and LMS activity data based on click frequency information, etc.).

In the literature, several features are used to predict the learning outcomes. They are, namely, demographic features, assessment grading, number of clicks and final marks (Al-Tameemi et al., n.d.). Researchers used several VLE features discussion forum (Rogers et al., 2025), course material, HTML material, Home page, quiz (Rogers et al., 2025), for their final result to predict the learning outcome (Al-Tameemi et al., n.d.). VLE resources, files, links and forum discussions have positive impacts on learning outcomes (Rogers et al., 2025). The most influential learning behaviour is submission, and the least influential feature is delete in performance prediction among the following features: submission, quiz, forum create, read, update, and delete days logged (Rogers et al., 2025). Course module activity design, collaboration, student engagement with VLE, features use, and adaptability features positively impacted learning outcomes (Ryani Kusumawati, 2024). Among these features, the most influential and the second influential features are the course module activity design.

Learning analytics is a relatively young research field (Alasalmi, 2021). Educational Data Mining (EDM), ML, and DL help to understand the learners' behaviours (Al-Tameemi et al., n.d.). In the literature, the widely used

techniques in the performance predictions are Random Forest (RF) (Rogers et al., 2025; Yağcı, 2022a), Nearest Neighbour (Yağcı, 2022a), Support Vector Machine (SVM) (Yağcı, 2022), Logistic Regression (Altabrawee et al., 2019; Yağcı, 2022b), XGBoost (Rogers et al., 2025), Decision Tree (DT) (Altabrawee et al., 2019; Rogers et al., 2025), Artificial Neural Networks (ANN) (Altabrawee et al., 2019; Ryani Kusumawati, 2024b) and K-Nearest Neighbour(Yağcı, 2022a).

Random Forest, Decision Tree, and XGBoost are used to predict the learning outcome. As per prior literature, Random Forest outperformed the other two (Rogers et al., 2025). When Random Forest is used with Synthetic Minority Oversampling Technique (SMOTE), it predicts the pass and fail students in the class, and this helps learners to work proactively (Jawad et al., 2022). Another study applies Artificial Neural Network, Logistic Regression, Naïve Bayes, and Decision Tree are used to predict the poor performance in computer science courses, where ANN outperforms the other approaches (Altabrawee et al., 2019).

Nowadays researchers utilize DL techniques on learning analytics to predict the students' learning outcome. DL techniques are capable of finding insights from raw data. Waheed et al predict the students' performance using deep artificial neural network, logistic regression and SVM, where deep artificial neural network outperforms with 84% - 93% accuracy (Waheed et al., 2020). Liu et al (2023) applied LSTM and One-dimensional Convolutional Neural Network (1D-CNN) along with traditional ML approaches to predict the learning outcome, where Long Short-Term Memor (LSTM) outperform with 90.25% accuracy. However, the application of DL to Learning analytics is still in the preliminary stages (Aljohani et al., 2019). Further, only a very few studies have applied the DL techniques to analyse and evaluate the learning behaviours in VLE (Aljohani et al., 2019).

3. Methodology

This study aims to predict the learner's performance using their interaction with VLE using ML and DL techniques.

3.1 Data

This study utilises two data sets, VLE log data and students' marks data. The VLE log data is collected from an asynchronous online course module offered in distance mode to external degree undergraduate students from a state university in Sri Lanka. The module was offered during the second year first semester of the degree programme. The module is followed by two hundred and forty-seven (247) students. The data contains 78,175 VLE click event records that are generated by the course administrators, instructors and learners. The course module discusses fourteen (14) topics using different resources. The module contains resources such as lecture materials and activities such as quizzes, forum discussions and assignments. The module was offered from August 2022 to December 2022. The module contains twenty (20) lessons, six (06) quizzes, and seven (07) activities. Table 1 shows the VLE log data attribute with description.

In addition to VLE log data, researchers utilise marks data which contains user, and the marks obtained by students.

Table 1: VLE Log data attributes and description

Attribute	Descriptions
Time	Timestamp of each interaction
User Full Name	User
Affected User	Other users involved in
Event Context	Resources or activity type
Component	Learning objectives
Event Name	Specific activity the user performs
Description	User event description
Origin	Client source
IP address	Users' IP address

3.2 Preprocessing

As a first step, the researchers removed the click events that are not generated by the students. The researchers removed 5,216 records generated by the instructors and administrators of the course module. The students generated 72,950 records used for the study. In the next step, two datasets were merged to generate a single file. Researchers removed the user's full name (for anonymisation) and replaced it with a unique ID to uniquely identify each student. Next, the time attribute is converted into a date and time format. Following that, the available numerical features were normalised using StandardScaler. In the next step, relevant attributes were extracted, and irrelevant features such as the IP address and origin were removed. At the subsequent step, the following details were extracted: (a) number of interactions per user, (b) weekday and weekend interactions, (c) extracted interactions per unique event type, (d) temporal features (average time and day of the interactions) and (e) extracted interactions per unique event type.

3.3 Method

After pre-processing, the study utilises the students' seven (7) behavioural or clickstream and thirty-four (34) learning activity features. Table 2 lists the behavioural or clickstream features used for the study with a description. Table 3 lists the learning activity features used by the study. The study utilises eighty (80) percent of the data for training and twenty (20) percent of the data for testing.

Table 2: Behavioural or Clickstream Features

Attribute	Description
unique_components	The number of distinct VLE components (e.g., quizzes, forums, videos) a student interacts with.
avg_hour	The average hour of the day when a student engages with the VLE.
std_hour	The standard deviation of the hours at which the student accesses the platform, indicating variability in study time.
avg_day	The average number of days per week that the student interacts with the VLE.
weekend_interactions	The total number of interactions occurring on weekends.
session_count	The total number of study sessions recorded for the student.
Peak study hour	The most frequent hour of the day when the student is active on the platform.

Table 3: Learning Activity Features

A file has been uploaded.	Quiz attempt updated
Comment created	Quiz attempt viewed
Comment deleted	The status of the submission has been viewed.
Course module instance list viewed	Tour started
Course module viewed	User list viewed
Course user report viewed	User profile viewed
Course viewed	User report viewed
Discussion created	Video module viewed
Discussion subscription deleted	Read tracking disabled
Discussion viewed	Remove submission confirmation viewed.
Feedback viewed	Role assigned
Grade overview report viewed	Some content has been posted.
Grade user report viewed	Submission created.
Post updated	Submission form viewed.
Quiz attempt auto saved	Submission updated.
Quiz attempt reviewed	Subscription created
Quiz attempt started	Quiz attempt summary viewed

The study utilises several prediction models, namely (a) traditional machine learning approaches: Random Forest Regressor (RF) and Support Vector Machines (SVM) and (b) Deep Learning Approaches: Multilayer Perceptron (MLP) and Recurrent Neural Networks (RNN). The RF model builds multiple decision trees and merges their prediction. The model used hundreds of trees to reduce the overfitting by using bootstrap aggregation. SVM uses high high-dimensional space to separate the classes. This study uses the Radial Basis Function as a kernel. The MLP model used hidden layers, batch normalisation and dropout to overcome overfitting. The model used the Adam optimiser. LSTM is a special RNN introduced to overcome the vanishing gradient problem. This study used Long Short-Term Memory (LSTM) with the Adam optimiser. The traditional ML approach RF is selected as the baseline for the study based on the literature (Borna et al., 2024). The study performed the result prediction with all the features after removing the absent student data. Further, the researchers performed the Exploratory Factor Analysis (EFA) to select the most influencing features and reduce the redundancy.

4. Results and Analysis

This section discusses the results obtained from the descriptive analysis and the model. Figure 1 shows the number of hits performed by different students. This shows that some students engaged more with the VLE while they were following the course. On the other hand, some did not. The maximum number of hits performed by students is 1,093, minimum number of hits perform by the student is two (2) and on average, students perform 295 hits. Figure 2 shows the number of hits performed on different activities. The Figure shows the system with the most influential activity, followed by a quiz. The very first place that the students enter is the system. The next most influencing activity is quiz, which shows that learners move more towards the path to growth.

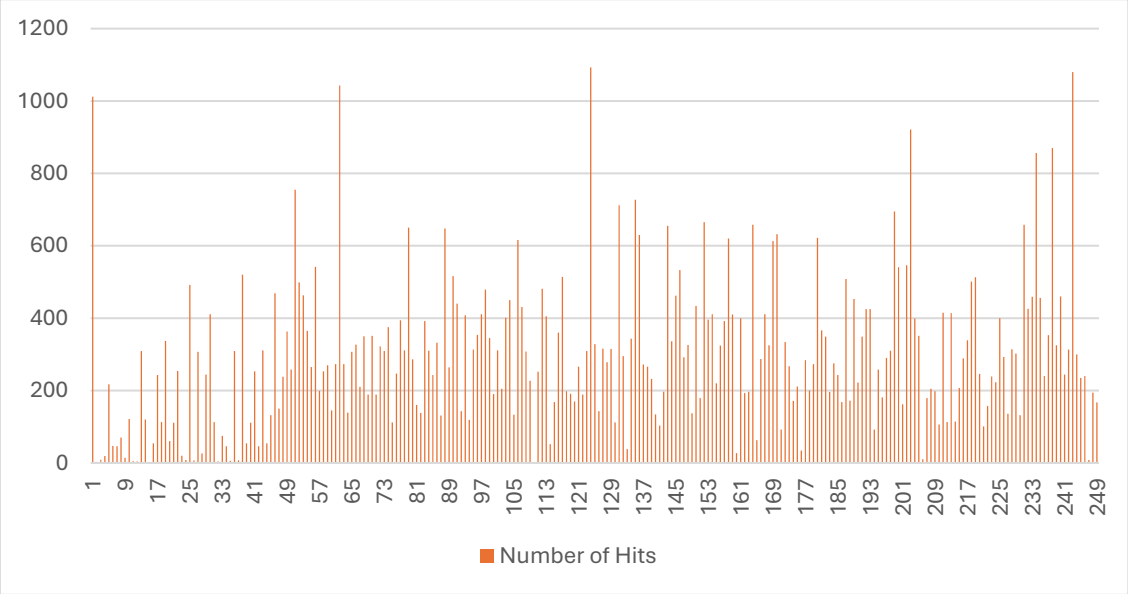


Figure 1: Number of hits by the students

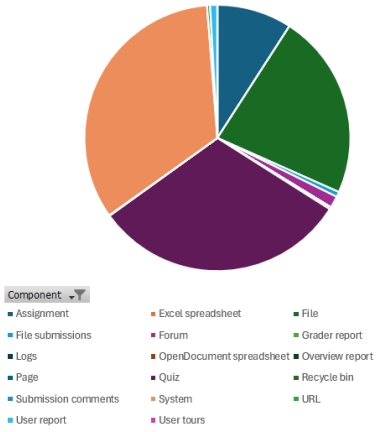


Figure 2: Different activities offered by the module and interaction

Figure 3 shows the number of events by hour of the day. This shows a higher number of interactions happening at night, ten (10) to eleven (11), and day ten (10) to eleven (11). Further, most of the user activity is happening in the evening from 6.00 pm to 12 midnight. This shows that students engaged more in their learning activities during late evening. This is shown in Figure 4. Figure 5 shows the activity distribution by the day of the week, where Wednesday is the most active day, followed by Saturday, Sunday Tuesday, Friday, Thursday and Monday. Weekdays have more interactions (70.3%) than on weekends (29.7%). Figure 6 shows the transition probabilities between the events. This Figure shows the highest transition probability between the quiz attempt submitted and the user graded.

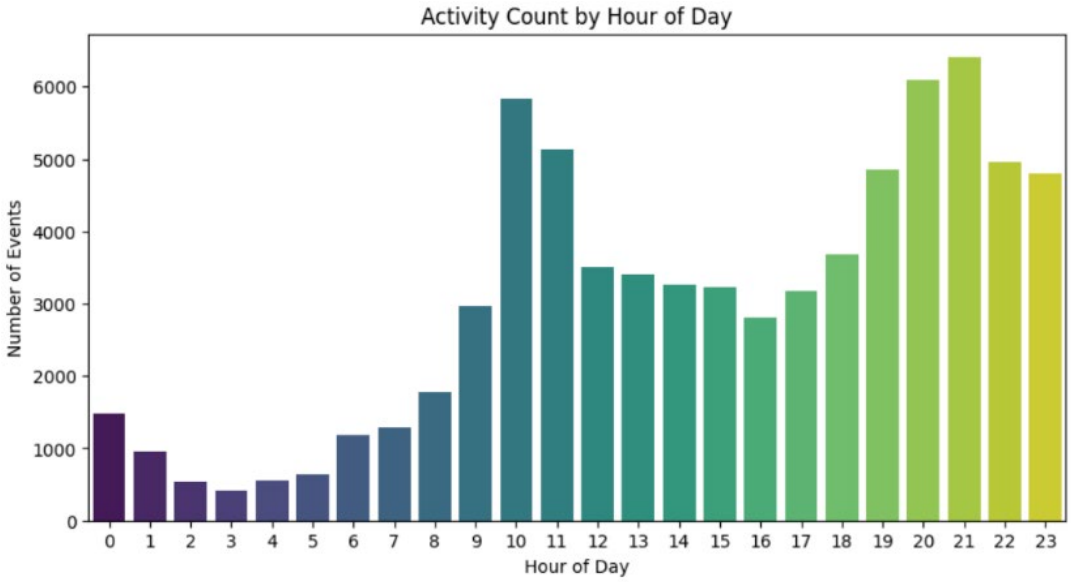


Figure 3: Activity count by hour of the day

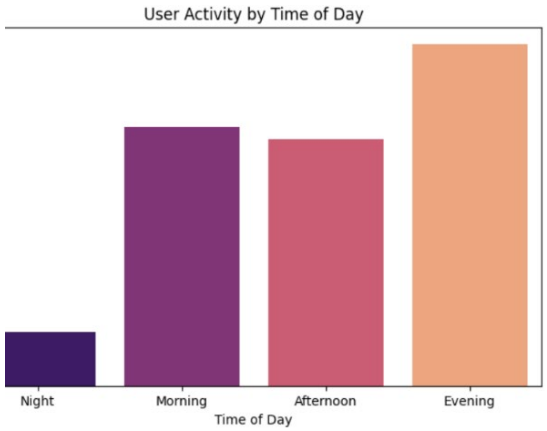


Figure 4: Activity by time of the day

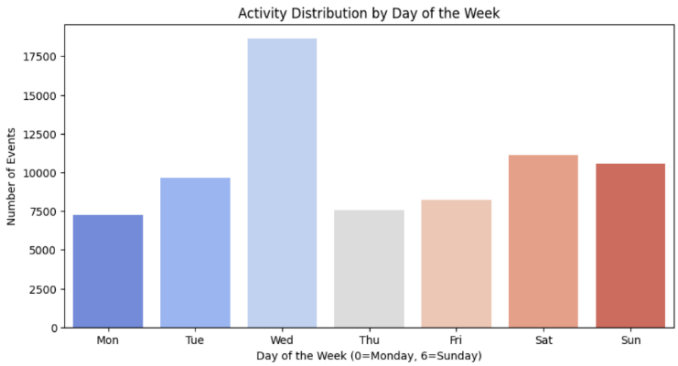


Figure 5: Activity distribution by day of the week

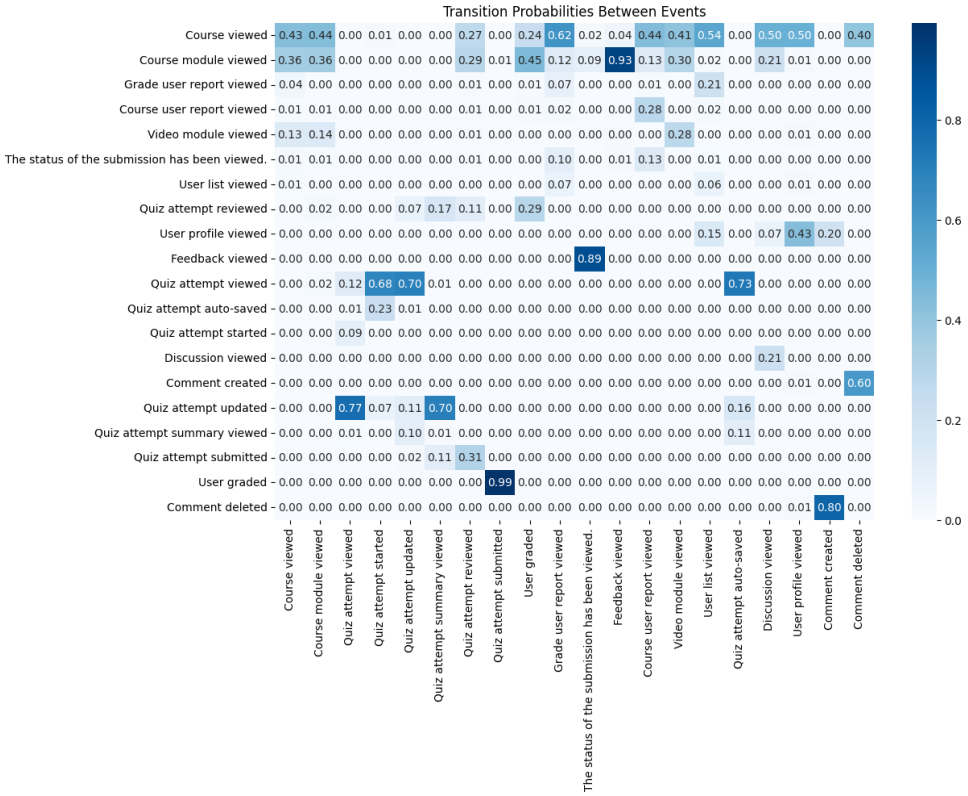


Figure 6: Transition probabilities between the events

The Model performance was evaluated using accuracy, F1-score and Mean Absolute Error (MAE). Table 4 shows the F1 score for different techniques where LSTM outperforms in terms of F1 score for pass and fail classes. Further, Table 5 lists the accuracy and Mean Absolute Error (MAE). The best model was the LSTM with 97% accuracy with 0.062 MAE. Even though MLP archived good accuracy, it failed to predict the failure class correctly.

Table 4: Approaches with F1 score

Technique	Class	Precision	Recall	F1 score
MLP	Pass	0.97	1.00	0.99
	Fail	0.00	0.00	0.00
RNN (LSTM)	Pass	1.00	0.97	0.99
	Fail	0.75	1.00	0.86
Random Forest	Pass	0.95	1.00	0.97
	Fail	1.00	0.33	0.50
SVM	Pass	1.00	0.58	0.74
	Fail	0.17	1.00	0.29

Table 5: Approaches with accuracy and Mean Absolute Error (MAE)

Technique	Accuracy	MAE
MLP	0.9744	0.0640
RNN (LSTM)	0.9744	0.0620
Random Forest	0.95	0.0512
SVM	0.62	0.051

Feature importance was analysed using the EFA. From the EFA, the most influential behavioural or clickstream features are the number of sessions count, number of weekend interactions and the number of unique

components. The most influencing learning activities are grade user report viewed, discussion created, discussion viewed, course viewed, a file has been uploaded, feedback viewed, course module viewed.

5. Discussion

The study analyses the learning behaviours of the learners along with their learning outcomes. It uses the number of hits to analyse the learner's engagement since the number of hits and hours spent on the activities have similar patterns (M.S. Faathima Fayaza & Supunmali Ahangama, 2024). The results show that students have more interaction on weekdays than on weekends. Furthermore, students engage more at night than during the day. The highest transition probability is between the "quiz attempt submitted" and the "user graded". The second highest transition probability is shown between "course module view" and "feedback viewed". After that, "the status of the submission has been viewed" and "feedback viewed" have the highest transition. These show that students expect feedback immediately when they perform their activity. Effective feedback motivates and encourages students to plan and monitor their learning strategies.

The study investigates several ML and DL approaches to predict the performance. The RF is used as the baseline model. However, the LSTM outperformed other approaches, possibly because the LSTM can handle sequential observations. Similar results have been reported by other researchers as well. For example, Aljohani et al. and Liu et al., reported that LSTM outperformed the ML approaches. (Aljohani et al., 2019; Liu et al., 2023)

Further, the study elaborates on the most influential behavioural and learning activity features in the performance prediction among distance learning students. The number of sessions, number of weekend interactions, number of unique components, grade user report viewed, discussion created, discussion viewed, course viewed, a file has been uploaded, feedback viewed and course module viewed are the most influential features in the performance prediction. This shows the active involvement of the students' impact on the learning outcomes, and these findings can be used to design and create the course module.

However, this study has some limitations. Clickstream data contains non-continuous data and results in the sparce data. The study used the data with the imbalance sample. This can be address in the feature by using the SMOTCK techniques. Future studies need to focus on predicting the performance in the granular grade level. Further, future research can also focus on the multimodal data such as assignment interaction and quiz to analyse the learning pattern.

6. Conclusion

Online learning provides flexibility in terms of time and place though the system suffers from a high dropout ratio and low retention rate. VLEs have become an increasingly popular platform for delivering online courses. VLE is designed as course centric. This study utilises the behavioural or clickstream features and learning activity features to predict and analyse the students' performance. The Random Forest Regressor, SVM (Traditional Machine Learning Approaches) and MLP and LSTM (Deep Learning Approaches) are used for performance prediction. Among these approaches LSTM outperforms with 97% accuracy. From the Exploratory Factor Analysis (EFA) session count, the number of weekend interactions, and the unique components are selected as the most influential behavioural features. Grade user report viewed, discussion created, discussion viewed, course viewed, a file has been uploaded, feedback viewed, and course module viewed have been selected as the most influential learning activity features.

Ethics Declaration

This study obtains ethical clearing from the University of Moratuwa for the data used in the study.

AI Declaration

This paper does not use any AI tools in its development.

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Understanding and Supporting Student Problem Solving in Mathematics Exams with Artificial Intelligence

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Abstract: This paper presents the findings of a pilot study aimed at gaining deeper insights into student errors in solving mathematics tasks from the Czech national school-leaving examination (*maturita*), while also exploring the potential of artificial intelligence (AI) to support error analysis and provide targeted feedback. The study began with an analysis of publicly available CERMAT data, focusing on tasks that have consistently shown low success rates over the years. Based on this analysis, a subset of tasks was selected and further tested on students preparing for the exam. The results were compared with national statistics to validate the relevance of the identified difficulties. A revised version of the test was then developed and administered to a new cohort of students, enabling the collection of a dataset of real student solutions for qualitative error analysis. The study adopted a nuanced framework for error classification, distinguishing between "slips" (minor, often procedural errors) and "true errors" stemming from a lack of conceptual understanding. Emphasis was placed on understanding the nature and origin of these errors, their recurrence, and implications for learning. Student work was analysed in all phases of the error-handling process, including detection, diagnosis, explanation, and correction. At the same time, the study evaluated selected AI tools, primarily ChatGPT 4.0—for their potential to solve exam-level mathematics tasks at the university level and identify errors in student solutions. Multiple test items were processed through the AI system, and its responses were compared with those of students. Particular attention was given to the AI's behaviour when confronted with incorrect or incomplete answers. The results revealed both the promise and limitations of current AI models in supporting formative assessment, particularly with respect to misinterpretation of task wording, difficulty in recognising alternative valid strategies, and occasional inconsistency in the quality of feedback. The findings contribute to the broader discussion on how AI can be effectively integrated into educational practice—not as a replacement for teacher judgment, but as a supplementary tool to enhance student understanding, develop metacognitive skills, and improve preparation for high-stakes assessments such as the *maturita* exam.

Keywords: Mathematics Education, National high-stakes assessment, Error Analysis, Student Misconceptions, Artificial Intelligence in Education, Diagnostic Feedback, Conceptual Understanding, Secondary Education, Test Validation, Educational Technology

1. Background

1.1 Errors in Mathematics and Their Classification

An error is generally understood, both in pedagogical and psychological contexts, as a deviation from the desired or expected performance (Průcha et al. 2009). In mathematics education, an error can be perceived not only as a failure but also as an opportunity for learning—provided it is approached with appropriate didactic intent (Borasi 1994, Brodie 2014).

The academic literature offers various approaches to classifying errors. They can be categorized according to the following:

- Cognitive value: meaningful vs. meaningless (i.e., based on some form of reasoning vs. random)
- Organisation: regular (systematically recurring) vs. sporadic
- Bearer: individual vs. collective (e.g., an entire class repeating the same mistake)
- Typicality: common vs. unusual
- Severity: significant (indicating serious misunderstanding) vs. insignificant
- Nature of deficiency: declarative (knowledge-related) vs. procedural (process-related)
- Cause: e.g., inattention, poor strategy, lack of understanding, etc. (see, e.g., Kulič 1971, Průcha et al. 2009, Heinze 2005)

From a didactic perspective, we are particularly interested in classifications that relate errors to mathematical thinking and the level of understanding demonstrated by the student in a given situation. Here, we draw inspiration from Reason's distinction between slips and mistakes, or more broadly, errors (see Pilous 2014).

Slips are errors that result from inattention, computational mistakes, or carelessness. They are usually insignificant in terms of mathematical thinking and understanding.

Mistakes, by contrast, indicate deeper issues—such as a lack of understanding of concepts, procedures, or problem-solving strategies. These errors tend to recur in similar situations and require a targeted intervention. They may be viewed as obstacles, in the sense described by the theory of didactic situations (Vondrová 2019).

This basic two-level classification allows us to analyse student errors not only in terms of their occurrence, but more importantly, in terms of their significance for the learning process.

1.2 Constructive Work with Errors

In mathematics education, errors have traditionally been perceived as failures, deviations from the norm, or signs of ignorance or misunderstanding. However, this view has been superseded by a modern constructivist approach, which regards errors as a natural part of the learning process and an opportunity for deeper understanding (Průcha et al. 2009, Brodie 2014). When approached with appropriate pedagogical guidance, working with errors can lead to genuine insight, encourage student self-reflection, and support the development of mathematical thinking. The key is to create a safe learning environment—one that does not penalise errors but instead deliberately uses them as a didactic tool.

Working with errors involves four fundamental steps: detection, identification, interpretation, and correction (Průcha et al. 2009). These phases can become part of everyday teaching if the teacher actively integrates them into instructional design. Importantly, the teacher does not need to be the sole actor in this process. Students should be guided to recognise, analyse, and correct their own errors. In doing so, they learn to take responsibility for their learning and develop metacognitive skills.

Research in cognitive science confirms that working with errors is one of the most effective strategies for fostering deep learning. Booth et al. (2017) summarise findings from cognitive psychology demonstrating that analysing incorrect examples can be more effective in acquiring mathematical concepts than working solely with correct ones. When students identify the nature of the error, its cause, and how it can be corrected, they engage more actively in the learning process and develop stronger mental models.

Similar conclusions are drawn in Rushton's (2018) study, which found that working with mathematical errors improves long-term knowledge retention and supports metacognitive development. The findings show that students who learn through error analysis not only understand the content better but also feel more involved in the learning process and become more aware of their own thinking. According to the author, this experience is more valuable than simply acquiring the correct procedure.

Jo Boaler (2016) has also made a significant contribution to this topic with her concept of mathematical mindsets, emphasising that an error is not a threat, but a signal that the brain is learning. Boaler stresses the importance of fostering a growth mindset in students—that is, the belief that mathematical ability is not fixed or innate, but can be developed through effort, feedback, and reflection. A classroom environment that allows for experimentation, tolerates errors, and provides constructive feedback supports not only improved performance but also a more positive attitude toward mathematics. Boaler warns that a traditional emphasis on speed and accuracy can cause anxiety and a loss of confidence, whereas a learning environment that embraces errors as part of learning promotes creativity and perseverance.

A recent Czech study (Janíková, Janík & Pavelková 2024) confirms that most teachers still perceive errors primarily as indicators of insufficient knowledge rather than as learning opportunities. However, the study also shows that teachers who view errors as part of the learning process are more likely to create supportive classroom environments and contribute to deeper understanding. Their instruction is characterised by openness to errors and encouragement of student participation in analysing them.

Constructive work with errors is thus not merely a teaching strategy, but part of a broader learning culture. It requires an approach that respects individual learning pace, fosters self-reflection, creates opportunities to discuss thought processes, and provides meaningful feedback. The studies cited above make it clear that such a culture has the potential not only to improve students' academic performance, but also to strengthen their relationship with mathematics as a subject.

1.3 Artificial Intelligence in Education: Adaptive Systems, Personalisation, and the Role of Language Models

The use of artificial intelligence (AI) in education has evolved rapidly in recent years, transforming how students engage with learning content and how educators approach instruction and assessment. Particularly important

in this context are AI-powered adaptive learning systems, generative language models, and interactive feedback tools, which together form the foundation for personalised and self-regulated learning.

In a meta-analysis of 45 independent studies published between 2010 and 2022, Wang et al. (2024) demonstrated that AI-enabled adaptive learning systems have a medium to large positive effect on students' cognitive learning outcomes (g = 0.70). The effectiveness of these systems was significantly moderated by factors such as the duration of the intervention, student level, subject area, and study design. Interestingly, the type of AI used in the adaptive engine did not significantly influence learning outcomes. Instead, the most impactful elements were the extent to which the systems adapted to students' cognitive, affective, and behavioural characteristics, and the targeting of adaptive features, such as navigation and assessment.

Building on this line of inquiry, Yaseen et al. (2025) examined the impact of adaptive learning technologies and AI tools that provide personalised feedback on student engagement. Their findings suggest that such technologies improve student motivation and involvement, particularly among students with higher levels of digital literacy. The study emphasises the importance not only of the technological tools themselves, but also of students' ability to use them effectively.

A more specific example of AI integration in education is the use of generative language models, such as ChatGPT, which enable interactive dialogue, task creation, lesson planning, and formative assessment. In a scoping review, Pepin, Buchholtz, and Salinas-Hernández (2025) concluded that ChatGPT holds significant potential to support personalisation, collaboration, and the development of instructional design skills among teachers. However, the review also highlights concerns regarding the accuracy of responses, the possible erosion of critical thinking, and the need for pedagogical guidance when implementing such tools in practice.

This ambivalence is echoed in experimental research by Kumar et al. (2023), who investigated the effect of LLM-generated explanations on learning in high school mathematics. Their findings suggest that LLM explanations can facilitate learning—particularly when students attempt to solve problems independently before consulting the AI. Even when the explanations contained errors, they still yielded learning gains, indicating that interaction with incorrect outputs can be cognitively stimulating, especially when paired with appropriate instructional support.

1.4 The School-Leaving Examination in Mathematics in the Czech Republic

The school-leaving examination (*maturita*) in the Czech Republic represents a standardised method for completing upper secondary education. It consists of two parts: a common (state-administered) component and a profile (school-based) component. The common part is organised by the Ministry of Education, Youth and Sports through the Centre for the Evaluation of Educational Achievement (CERMAT), while the profile part is prepared and assessed by the individual secondary schools.

The examination in Czech language and literature is mandatory for all students. In addition, students choose one elective subject—either mathematics or a foreign language. Thus, in the current model, mathematics is an optional subject. However, for certain groups of students (e.g., those in technically oriented study programmes), mathematics may be made compulsory within the profile component, based on the decision of the school.

The didactic test in mathematics, which constitutes the state component of the examination, follows a standardised structure and assessment criteria. The test includes a combination of closed-ended and open-ended tasks. In closed-ended tasks, students select the correct answer from multiple choices, whereas in open-ended tasks, they are typically required to provide not only the final answer but also the full solution process. This format enables verification not only of students' ability to identify correct answers but also of their conceptual understanding, reasoning skills, and the ability to apply acquired knowledge in unfamiliar contexts. The test duration is 135 minutes, and the content is based on the publicly available Catalogue of Requirements for the Mathematics Examination (CERMAT, 2023a).

The mathematics exam is taken by final-year secondary school students who have chosen this subject. In addition to the standard spring term, former students who did not pass in previous years—or who wish to improve their scores—may also take the test. The test is centrally evaluated through a system managed by CERMAT. Each item has a predetermined point value. Students receive their results in the form of both raw scores and percentage evaluations. To pass the exam, students must reach a minimum threshold set by the Ministry of Education.

To support exam preparation, the Catalogue of Requirements for the Mathematics Examination outlines the scope of knowledge and skills to be assessed. It also includes sample tasks with solutions, helping both teachers and students to understand the test structure and expected performance. Furthermore, full versions of previous years' tests—including answer keys and scoring schemes—are published annually on the official website: https://maturita.cermat.cz.

For analytical and research purposes, summary reports of school-leaving examination results are also available. These documents, published by CERMAT, present statistics on student success rates, failure rates, average scores, and other indicators. Results are provided at both national and regional levels and further broken down by school and examination type. As such, they provide valuable data for monitoring educational trends, identifying problematic areas, and improving exam preparation at individual schools (CERMAT, 2023b).

2. Design of Our Study

When designing the test and selecting the tasks, we relied on publicly available data published by CERMAT. Specifically, we selected tasks from the spring 2024[1] school-leaving mathematics examination. The tasks were ranked in ascending order based on their success rates—that is, the average score achieved per task as a percentage of the maximum possible score. We then selected the 14 tasks with the lowest success rates at the national level.

Performance (or lack thereof) on these tasks corresponded to the results of the autumn tests conducted at School 1, the institution where the study was carried out. To this initial set, we added three additional tasks. Although tasks in the areas of statistics and probability showed high success rates in the national data (90.2% and 75.3%, respectively), students at School 1 performed significantly below average on them in the initial autumn test (27.3% and 0.0%, respectively). We also included a task on trigonometric functions. The test used in the autumn session was based on the 2022 version, which included a similar task with an extremely low success rate (0.0%). Since no comparable item appeared in the spring 2024 test, we included an analogous one from the spring 2022 test.

2.1 Analysis of Results

For each task, student responses were categorised according to the following status codes:

U = Task solved correctly, full marks awarded.

N = Task not attempted.

R0 = Task attempted or started, but the solution was incorrect or incomplete, no points were awarded.

R1 = Task attempted; a mistake was made, but partial credit was earned.

Figure 1 presents an overview of the task-solving outcomes in the observed schools, including achieved scores and comparisons with national performance data.

		Task 1	Task2	Task3	Task4	Task5	Task6	Task7.1	Task7.2	Task8	Task9.1	Task9.2	Task13	Task14	Task18	Task20	Task22	Task24	Task25	Task22*
School 1	Score (%)	83,3	79,2	70,8	50,0	41,7	27,1	54,2	41,7	29,2	58,3	66,7	83,3	66,7	87,5	70,8	62,5	66,7	62,5	29,2
	U	20	19	17	11	10	5	13	9	8	14	15	20	15	21	17	15	16	15	7
	N	1	0	2	1	0	6	3	5	7	4	5	0	0	0	0	1	0	0	1
	R0	3	5	5	12	11	11	8	10	9	6	4	4	7	3	7	8	8	9	16
	R1	0	0	0	0	3	2	0	0	0	0	0	0	2	0	0	0	0	0	0
School 2	Score (%)	25,0	54,2	41,7	20,8	33,3	22,9	20,8	20,8	33,3	20,8	45,8	45,8	29,2	45,8	25,0	25,0	37,5	27,1	16,7
	U	6	10	9	4	6	4	5	4	8	5	10	12	5	11	6	6	8	6	4
	N	2	0	5	1	0	4	4	9	7	5	5	2	4	2	5	4	3	4	5
	R0	9	1	3	9	7	6	8	4	2	7	2	3	4	4	6	7	6	6	8
	R1	0	6	0	3	4	3	0	0	0	0	0	0	4	0	0	0	0	1	0
National score		59,0	68,9	60,9	47,0	58,8	62,8	44,9		34,8	59,3		90,2	64,7	75,3	70,4	59,8	64,8	64,0	not available

Figure 1: Summary of the task response status in the observed schools

[1] Due to a reduced time allocation for the autumn testing (90 minutes, i.e., approximately 66.6% of the standard time limit), we decided to include 17 out of the 25 total tasks, with a combined maximum score of 32 points out of a possible 50.

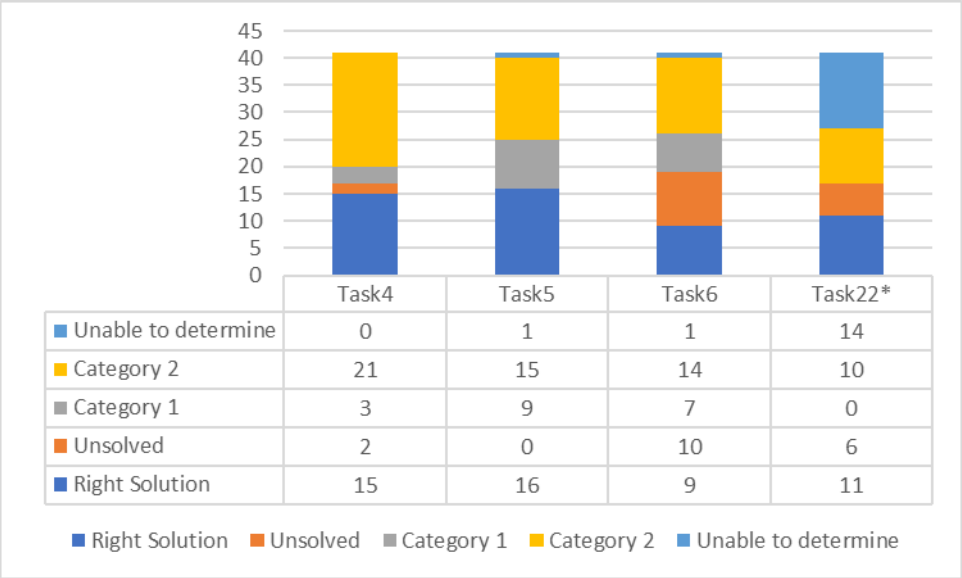
Based on the data analysis, four tasks were selected using the following two criteria:

1. Tasks with low average scores in both schools.
2. Tasks with a high proportion of attempted but incorrect solutions (i.e., categories R0 and R1).

Tasks 4, 5, 6, and Task 22* (on trigonometric functions) were selected for an in-depth analysis of student problem-solving strategies. The errors were classified into two categories:

Category 1: Slips: numerical mistakes, large leaps in reasoning, inattentiveness, or mistakes due to incorrect transcription.

Category 2: True errors, stemming from conceptual misunderstanding, a lack of grasp of fundamental ideas, processes, or an inability to apply or integrate knowledge into a coherent solution.



	Task4	Task5	Task6	Task22*
Unable to determine	0	1	1	14
Category 2	21	15	14	10
Category 1	3	9	7	0
Unsolved	2	0	10	6
Right Solution	15	16	9	11

Figure 2: Distribution of Student Solutions by Error Categories

Figure 2 illustrates the distribution of student errors across the defined categories. Overall, a greater number of true errors were observed. These most often involved incorrect procedures resulting from a lack of understanding of fundamental mathematical principles (e.g., solving an equation instead of an inequality, or incorrectly determining a common denominator for rational expressions). In many cases, students were unable to complete the task due to such conceptual gaps.

In some cases, such as Task 6, students failed to solve the problem because of an inappropriate strategy. For example, some did not identify the least common denominator of rational expressions. Even when the remainder of the procedure was correct, this led them to work with unnecessarily complex expressions involving higher powers and large numbers they could not manage.

In some cases, it was not possible to clearly interpret the nature of the error. In one response to Task 5, it was unclear whether the errors resulted from a series of numerical errors and carelessness, or from misunderstanding of basic arithmetic rules. In Task 6, a student correctly followed each procedural step but failed to complete the final simplification. Because the overall approach was sound, it was uncertain whether this omission was due to oversight or a lack of knowledge.

The final task analysed (Task 22*) contained a higher number of similarly ambiguous cases. In this task, students were asked to determine the value of a function, with the condition that the solution must be within a specific interval. The task was a multiple-choice question, with the answer options including tangent values from both intervals. Based on students' responses alone, it was not clear whether the error stemmed from inattentive reading of the question—corresponding to category 1—or from a failure to understand how to evaluate the function within a specified interval, which would indicate a lack of understanding of the basic principles and rules related to periodic functions—i.e., category 2.

3. Working with AI

This section explores the potential of artificial intelligence (AI) tools in helping students solve test problems, critically assessing both the benefits and limitations of such use. The investigation was divided into two parts, reflecting two ways in which students might engage with AI:

1. To solve an entire test, including the presentation of solution procedures.
2. To identify errors in their own solutions to test problems.

3.1 Solving the Test Using AI

For this analysis, the selected test was uploaded to the ChatGPT environment (version 4.0), and the model was asked to solve the individual tasks. Because the tasks were presented in an image-based format, the user was informed at the outset that optical character recognition (OCR) would be required due to the model's reliance on converting visual inputs into readable text before processing them.

The first three tasks were correctly recognised and solved without error. However, with the fourth task—focused on inequalities—the model misinterpreted the task prompt, resulting in an incorrect solution method. In five subsequent tasks, the model generated multiple solution approaches and invited the user to choose their preferred method. This reflects the way AI learns from patterns in human understanding and provides various interpretative frameworks.

During the interaction, the model twice prompted the user to confirm whether it should continue solving the test—likely an optimisation measure related to token usage, which regulates the computational resources allocated per response.

Out of the seventeen tasks, eight were incorrectly recognised. In two additional cases, the model slightly simplified the task wording, although the overall meaning was preserved. Furthermore, the model generated two tasks that were not part of the original test. When asked about their origin, the AI claimed they were drawn from official CERMAT sources. After being informed that these tasks did not appear in the actual test, the model acknowledged that they had been "randomly included" based on similar test formats.

In conclusion, while AI demonstrated a capacity to accurately recognise and solve certain types of tasks, the overall results were inconsistent and cannot be considered a reliable solution model for students without further oversight.

3.2 Detecting Errors in Student Solutions

The second part focused on AI's potential to identify errors in student solutions. Again, this analysis concentrated on four selected tasks that had proven most challenging, providing a sufficiently rich sample of incorrect student responses for review.

3.2.1 Case 1 – Task 4

A handwritten, incorrect solution to Task 4 (including the task prompt) was photographed using a mobile phone. The image was then uploaded to the AI system, and the model was asked to evaluate the solution.

The AI correctly identified the error: the student had treated an inequality as if it were an equation. The model highlighted the mistake, provided commentary, and presented a revised solution. However, its final result was incorrect. We then uploaded a second image showing a correct student solution and asked the model to compare it with its previous output. Upon detailed review, the AI recognised its own mistake, acknowledged it, and then provided a corrected final result.

3.2.2 Case 2 – Task 5

Task 5 was also submitted as a photo, showing a student's incorrect attempt at solving an equation. This time, the AI failed to accurately recognise the problem statement. We then reformulated the task in a linear textual format—similar to how a student might enter the problem into an advanced calculator.

This enabled the model to correctly identify and solve the task. However, it did not relate its solution to the student's original work. When prompted with a follow-up question whether its own calculation was correct, the model recalculated the problem and confirmed its accuracy. Only after explicitly pointing out that the original

solution appeared in the first image did the AI respond appropriately. It identified the error, and—despite noting the low legibility of the work (see Figure 3)—was able to extract the equation used by the student. However, this equation differed from the one the model considered correct.

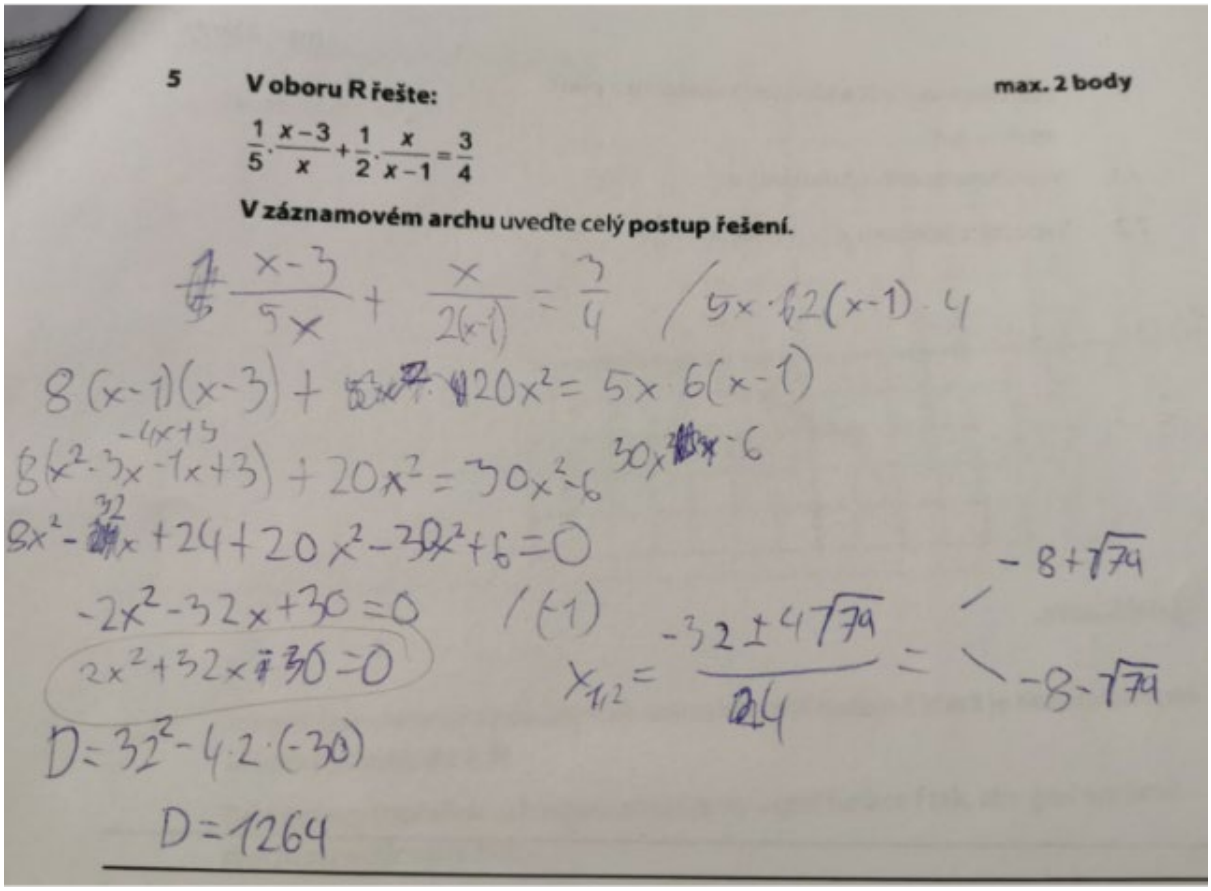


Figure 3: Student's solutions with error

This case highlights two key issues: the extended interaction required to evaluate student errors, and the potential for the AI to identify a different—though mathematically valid—intermediate equation, which it may incorrectly flag as erroneous. This shows the need for thorough verification of AI-generated outputs and careful pedagogical oversight, particularly when evaluating non-standard solution strategies.

3.2.3 Case 3 – Task 6

Task 6 involved simplification of an algebraic expression. Both the task prompt and the student's solution were uploaded as a photo taken with a mobile phone. Initially, the AI failed to correctly interpret the task from the image. To resolve this, we only uploaded the problem prompt, without the solution. At this point, the model accurately recognised the task and proceeded to solve it.

In this instance, the model remained focused on the original instruction to find an error. While simplifying the expression, it discovered a mistake in one particular step, based on a mismatch with its own intermediate result. Ironically, the student's solution was entirely correct—it was simply incomplete, with the final step (factoring out an expression that would lead to cancellation) omitted.

This case also indirectly supports the hypothesis outlined in Case 2: While AI tools are effective at identifying computational errors, their evaluation is guided by their own solution paths. As a result, they may fail to recognise alternative (yet valid) approaches or incomplete solutions. Once again, this highlights the importance of expert interpretation and consistent pedagogical oversight when integrating AI tools into education.

*3.2.4 Case 4 – Task 22**

In the final case, we analysed Task 22*, in which students were required to solve a trigonometric equation and determine the correct value of the tangent function for a given angle, constrained to a specific interval. The task

prompt and the student's incorrect solution were uploaded via a mobile phone photo. The AI correctly solved the problem, identified the student's mistake, and provided a clear explanation of the error.

In this case, the AI fully met expectations—offering precisely the kind of support that would be highly beneficial to both students and educators.

4. Discussion

The analysis of student strategies in the selected tasks clearly indicates a high prevalence of true errors when working with equations and algebraic expressions. These errors stem from a lack of knowledge or insufficient mastery of fundamental principles that students are expected to know by the time they take the school-leaving (*maturita*) exam. Therefore, it is essential that the preparation for the exam includes thorough assessment of students' knowledge and skills in this area. If significant gaps are identified, emphasis should be placed on re-teaching and reinforcing foundational skills—e.g., by including simpler tasks that guide students through each step required for solving complex exam problems.

When working with trigonometric functions, we recommend including more exercises that require students to determine values across various intervals. This approach serves a dual purpose: it helps reinforce the importance of paying close attention to interval constraints specified in the task and provides students with valuable practice in interpreting and applying periodic properties of trigonometric functions. Such targeted practice supports effective remediation whether student errors stem from carelessness or a lack of understanding.

The case analyses described in Chapter 3.2 reveal several key findings that should be considered when integrating artificial intelligence (AI) tools into classroom instruction and assessment.

One of the most significant limitations observed is the inconsistent accuracy with which AI models recognise problem prompts—particularly when tasks are uploaded as images or when mathematical notation is generated using an equation editor in DOCX format. This may stem from limited exposure to such formats during training as the equation editor language is less familiar and less legible to the model. Consequently, misinterpretation or omission of task components can occur, leading to incorrect solutions or a failure to understand the task. In contrast, when the same files were converted to PDF format, the AI's recognition accuracy improved notably. This is likely because PDF formats render equations as fixed graphical elements, which the AI is better equipped to process using optical character recognition (OCR).

A second limitation lies in the AI's method of evaluating student responses based on internal solution algorithms. The model typically validates solutions by checking whether the intermediate steps and final answer align with its own procedural pathway. As a result, student responses that use alternative—but mathematically valid—methods may be incorrectly flagged as incorrect. A similar issue arises with incomplete solutions that are headed in the right direction but, for instance, omit a final step such as factoring or simplification.

Finally, a recurring usability issue was observed: interruptions in the flow of problem-solving, as the model frequently requested confirmation to proceed or clarification of instructions. While this behaviour is related to computational efficiency (i.e., token management), it can be distracting for users and impede the continuity of the task-solving process.

5. Conclusion

Based on these observations, several practical recommendations can be made. When submitting digital tasks, it is advisable to use PDF rather than DOCX format—particularly for mathematical content. Task prompts and student solutions should be uploaded separately, presented clearly, and provided in machine-readable form whenever possible.

AI-generated outputs should be considered a starting point for further discussion, rather than definitive evaluations. All assessments must remain under the supervision of a teacher, who can determine whether deviations from standard approaches represent alternative, but still valid, solution strategies.

AI can serve as a valuable assistant, especially for routine problem types with well-defined structures, such as algebraic manipulations, equations, or inequalities.

Ethical Statement

The submitted manuscript is original, has not been published elsewhere, and is not under review by another journal or conference. All authors contributed significantly and all sources are properly cited. The research is based solely on anonymous or publicly available data. In accordance with Czech legislation and institutional guidelines, no ethical approval was required.

AI Statement

This paper examines and analyses the role of artificial intelligence in education. Accordingly, AI tools (specifically ChatGPT 4.0 by OpenAI) were used during the research and preparation of this manuscript. These tools supported selected analytical tasks, data interpretation, and language refinement. All AI use was conducted under the supervision of the authors, and the final content reflects their independent critical judgment. The authors take full responsibility for the accuracy, originality, and integrity of the manuscript.

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Education 4.0 as a Driver for Institutional Change in Higher Education: A Qualitative Study of Educational Transformation in a Danish HEI

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Abstract: In recent years, the concept of "Education 4.0" has emerged as a response to the technological, social, and economic transformations that have accompanied the rise of Industry 4.0 (Rienties, 2023; Miranda et al., 2021; Salmon, 2019). As industries increasingly integrate advanced technologies such as AI, big data, and the Internet of Things, institutions of higher education (HE) are similarly compelled to rethink their structures, methods, and objectives. Education 4.0 aims to equip learners with the skills needed in an evolving digital economy, promoting critical thinking, adaptability, and digital literacy (Oliveira & Souza, 2022; Alenezi, 2021). This paper presents a study of a program aimed at building capacity for Education 4.0 through a targeted and strategic organizational program in a higher education institution in Denmark. For two years, researchers applied a formative dialogue research-approach, where the activities were studied in real time without direct involvement of the researchers in the activities. Through interviews with stakeholders across three organisational tiers (the strategic, the tactical, and the operational level), our study explores to which extent, and by which means, the targeted program enhanced institutional capacity, contributing to the broader goal of integrating Education 4.0. The main research question was: "How can a targeted organizational change program enhance capacity building at strategic, tactical, and operational levels to support the implementation of Education 4.0 in higher education?" Through analysis of a series of in-depth interviews, we find that the program takes a technology-driven approach despite intentions of the opposite; that management of the institution sees great potential for change in the program; and that participants in the program's experimental activities can get caught between innovation, everyday practices, and educational culture.

Keywords: Educational Transformation, Education 4.0, Emerging Technologies, Learning Design, Formative Dialogue Research

1. Introduction

Across the globe, digital transformation is reshaping the way societies work, communicate, and learn. In higher education, this transformation is not merely about adopting new technologies - it is about rethinking educational practices, structures, and cultures to align with the rapidly evolving demands of the digital age (Rienties et al., 2023; Miranda et al., 2021). In this context, "Education 4.0" has emerged as a strategic framework that responds to these shifts by promoting digitally enriched, learner-centred, and innovation-driven educational models (Oliveira & Souza, 2022; Alenezi, 2021). Education 4.0 extends beyond e-learning platforms or digital tools. It encompasses the development of new pedagogical formats, integration of emerging technologies such as AI, and greater alignment with workplace competencies and lifelong learning (Salmon, 2019). However, achieving this vision is not simply a matter of implementing new technologies or policies. It requires deep organizational change - particularly in how institutions build capacity among staff, create enabling structures, and foster cultures that support experimentation and collaboration.

This paper examines how a targeted and strategic organisational change program, labelled "Education 4.0.", can enhance institutional capacity to support the implementation of Education 4.0 at a University College in Denmark. In the paper, we present findings from a study of an initiative that aims to create educational change as well as a changed mindset of teachers, management, learning designers, and support staff towards the process of experimenting with new and emerging technologies to change the organization. The institutional program in question involved a multi-level approach, engaging key stakeholders at the strategic, tactical, and operational levels of the institution. Each level was assigned a crucial role in steering the organisation toward an adaptive, future-oriented educational model that aligns with the local assumption of the Education 4.0 phenomenon.

The paper contributes to ongoing debates about digital transformation, organisational learning, and educational innovation by addressing the research question: How can a targeted organisational change program enhance capacity building to support the implementation of Education 4.0 in higher education?

The program in question is an attempt to develop a new path to educational and teaching development – a design-oriented and experimental approach to educational development, inspired by the phenomenon of Education 4.0. The basic assumption behind the program was that many digital innovations that are changing society will also change how institutions will offer education in the future. Over a three-year period, the program has engaged educators, consultants, and managers in an institutional program that aimed to gain experience with the opportunities and barriers that current digital innovations offer in relation to education and learning. The article brings forward the perspectives of both steering committee members and program leaders. Their experiences give insight into how higher education institutions can navigate the complex interplay of strategic intent, operational realities, and pedagogical innovation.

2. Background and Context of the Study

The study was conducted at a Danish University College from 2022 to 2024. In 2022, the Institution's board of management decided to launch a targeted organisational program called "Education 4.0", and the authors were invited to study the implementation of the program. The program was highly inspired by a paper by Christiansen et al. (2018) discussing the relationship between Industry 4.0 and educational design in the future. Based on this, two fundamental assumptions shaped the program from its inception: 1. The assumption that the influence of digital technologies on society will change how education will look in the future, and 2. That the path to developing the education of the future involves challenging and disrupting the current logic and rationale of educational practices.

From the onset, a principal value in the Education 4.0 program was co-creation, meaning that initiatives in the program are conceived and implemented by users, i.e., teachers and other staff at the Institution. The program aims to give this co-creation process a common direction by introducing two things: 1. Thematic tracks, into which ideas must fit, and 2. Design principles, on which ideas must be based. To encourage a user-driven approach, twice a year, staff at the institution could submit their ideas for educational experiments or development activities which they believed was within the scope of the Education 4.0 themes. The term "idea" was carefully chosen to give emphasis to the exploration and experiments. Ideas were selected by the leaders and the steering committee of the program, and resources were allocated in terms of time and technical and pedagogical support for the owner of the idea. As illustrated in figure 1 below, participants in the program were expected to carry their idea through as many of the phases as possible. However, implementation was not always the goal, as a possible consequence of the explorative approach was that some ideas turned out to be immature, too difficult to implement into existing study programs, or simply to not give sufficient additional value to teaching or learning. To support staff in developing their ideas, the program offered guidance from pedagogical or technological consultants, which were at first named "track leaders". As the significance of the initial thematic tracks diminished over time, the name of this role was changed. Not all ideas were formulated by teachers, also administrative departments had ideas on how to integrate digital technology in their ways of working.

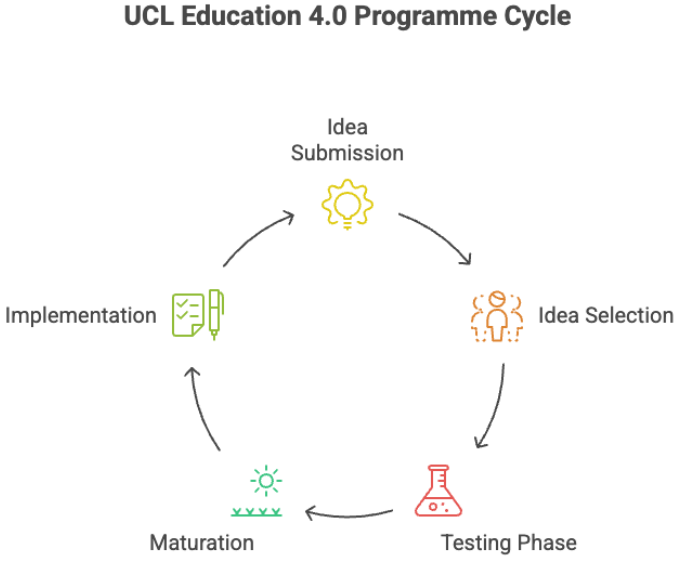


Figure 1

In a Danish context, Education 4.0 came into focus when Christiansen et al. (2018) set out to examine how the influence of Industry 4.0 technologies might transform educational designs. Their study was based on the premise that technological innovations have consequences of social, economic, and cultural character, and it is expected that they will also influence education, hence the term Education 4.0. For the present project, we carried out a literature review of research on how educational development can be achieved through digital transformation (using the concept and / or term education 4.0) in higher education. We found that very little has been published where the concept Education 4.0 is clearly defined and used as a framework or in other ways is seen to influence the educational design process. Overall, the concept is widely used as a general reason for the use of technology in educational design, in curriculum, and in teaching techniques. Often, the term education 4.0 is used in parallel with other generic terms such as 21st Century skills or digitalization in society.

3. Education 4.0 as Driver for Digital Educational Transformation

A literature review was carried out in 2023, targeting peer-reviewed research publications only. 453 studies were identified and subjected to screening. This led to the exclusion of 403 studies, and 48 studies were retrieved and assessed for eligibility. Several of these used the concept of education 4.0 in extension of mentioning Industry 4.0, but without further definition, discussion, or application of the concept in the study. These studies were excluded. Several studies include education 4.0 in a rather broad introduction to societal and technological tendencies, followed by a small case study of experiments with technology in teaching. Such studies were also excluded. A geographical limitation to Europe and North America had to be abandoned due to insufficient information in the databases. In the end, we identified 11 publications of relevance, three of which were review articles (Benavides et al., 2020; Benavides et al., 2023; Fernandez et al., 2023).

Despite the increasing spread of the concept of "Education 4.0" seen in recent years, only a few studies have been published where Education 4.0 seem to have shaped development activities, research projects, or institutional development programs. As mentioned above, in the 48 studies retrieved and assessed, the concept was used very loosely and without any defining effect. In some publications, Education 4.0 is used mainly to mean teaching and learning, where digital technology is integrated into (e.g. Ersoy, 2021) or as a way of describing what one may call a constructivist understanding of teaching and learning such as problem based and other forms of active learning (e.g. Iniesto et al., 2021; Koul & Nayar, 2020). Some studies use Education 4.0 as a reference to an updated view on education, teaching or learning, and then proceeds to present a small-scale experiment with technology in teaching and learning (e.g. Sarango-Lapo et al., 2021; Miranda et al., 2021). As described by several sources, Education 4.0 can be viewed as a response to the technological, social, and economic transformations that have accompanied the rise of Industry 4.0 (Rienties, 2023; Miranda et al., 2021; Salmon, 2019), meaning that as industries increasingly integrate advanced technologies such as AI, big data, and the Internet of Things, institutions of higher education (HE) are similarly compelled to rethink their structures, methods, and objectives. Thus, Education 4.0 aims to equip learners with the skills needed in an evolving digital economy, promoting critical thinking, adaptability, and digital literacy (Oliveira & Souza, 2022; Alenezi, 2021).

Despite a growing interest in Education 4.0 illustrated in the literature, we find that the practical implementation of its principles remains under-explored, and the development of institutional strategies that align with Education 4.0 is still in its early stages (Mukul & Büyükozkan, 2024; Christiansen et al., 2018; Hussin, 2018). Central to this challenge is the need for institutions to undergo significant organisational transformation, not only in their pedagogical approaches but also in their internal operations and strategies (Bohari et al., 2024, Benavides et al., 2020). In this paper, we present a study which explores the intricate process of digital transformation within a HE institution, thus addressing the organisational aspects of developing and implementing innovative ways of teaching and learning.

4. Research Design and Methods

The overall research interest in this study is “How may Higher Education Institutions further digital transformation of education (Education 4.0)” and the empirical study has a particular focus on a targeted organisational change program as a mechanism for creating change, enhancing capacity building, and developing new educational designs with digital technologies. For a period of two years, researchers followed the program activities. The agreed approach to the study can be described as *formative dialogue* research or what Van de Ven (2007) calls *engaged scholarship*. The study was characterized by a dialogical approach in which the research findings may or may not shape the activities through formative dialogues. In formative dialogue research, activities are studied in real time without direct involvement of the researchers in the activities. During

the two years, we interviewed key participants, a total of 21 in-depth interviews over 12 months and collected documents for analysis. Observation of teaching activities was planned in relation to some of the ideas developed in the project, however, in this paper, only interviews and document analysis are used. Through interviews with stakeholders across three organisational tiers (the strategic, the tactical, and the operational levels), our study explores the extent to which, and by which means, the targeted program enhanced institutional capacity, contributing to the broader goal of integrating Education 4.0.

The institutional program had two appointed program leaders who were responsible for the design, implementation and progress of the activities. They were key persons in our study, and were formally interviewed at three separate occasions, as well as our dialogue partners in more informal ways. They were also gate keepers for us and among other things they helped set up interviews with others in the organisation. In the following section, we present our analysis of interviews with both the program leaders and members of the steering committee (five people in managerial positions). Inspired by Braun & Clarke (2006), we have carried out thematic analysis of the material, resulting in identification of eight themes across the interviews.

5. Analysis

The eight themes are: Vision and purpose, a catalyst for change; Digital technology: driver, not destination; Bottom-up innovation and ownership; Organisational development and cultural change; Leadership, structure, and strategic framing; Governance, incentives, and organisational alignment; Experimentation, learning, and impact; and Evolution and tensions.

In the following, we illustrate each analytical theme and subsequently discuss the findings. Due to limited space, we do not fully unfold each theme, rather we choose to demonstrate the complexity of viewing educational development in an organisational perspective. The Education 4.0 program aims to reshape educational practices through digital technology, pedagogical innovation, and organisational change. Interviews with both the steering committee and the program leaders provide a rich insight into the program's ambitions, design principles, challenges, and evolving identity. While their perspectives differ slightly in scope and emphasis, a common vision of cross-institutional innovation and future readiness emerges through the analysis.

5.1 Vision and Purpose: A Catalyst for Change

For both the steering committee and program leaders, Education 4.0 represents a significant opportunity to modernise and strengthen the institution's educational formats, teaching practices, and institutional culture. However, their visions are expressed through slightly different lenses. The steering committee members highlight the program's potential for deep and wide-ranging change, from the visible classroom level to broader shifts in educational design, technology integration, and academic culture. One member described the initiative as aiming to "push the development of the teaching culture," while also acknowledging its limitations:

> "The program is also a way of improving the educational quality (...) but if you're talking about the total recalibration of something - I see that as being relatively far-fetched in a program path like this." (Head of Studies)

The program leaders, on the other hand, frame the initiative as a long-standing strategic curiosity driven by the 2018 whitepaper on Education 4.0 (Christiansen et al., 2018). They emphasize that the program is not a fixed solution to a specific problem, but a platform for experimentation, driven by the idea that digital transformation is inevitable.

> "We must also reach those who shout and scream. Point forward and say: "Something is coming, and we cannot say no to it. We can prepare ourselves as best we can for it". With a future that cannot be described, should we build windmills or shelters? Our opinion is that we must try to prepare for the future that is coming. And as far as possible also try to influence it." (Program leader)

5.2 Digital Technology: Driver, not Destination

Both groups agree that digital technology is a central component, but not the goal of the program. Steering committee members see the program as a natural extension of previous models (e.g., Education 3.0), with the potential to enhance learning formats and pedagogical approaches. As one explained:

> "We will have to see if we can offer education and skills development, perhaps using technologies, in a different way. I believe we will be teaching in new ways." (Head of Studies)

The program leaders stress that technology should not be added for its own sake. Instead, it must serve pedagogical aims and create real value for students.

> "How is it that it (technology) gives students something that has an 'impact' in relation to a reality, a society, and a work life that is changing. A gadget, a device, or an app. It's about framing it in a slightly broader context, so that you also think about which learning activities it is linked to, and in what ways you can draw it into a broader understanding that students should also have some meta-learning that fits into work life". (Program leader)

The program leaders also noted that many teachers were primarily motivated by the opportunity to engage in teaching development, whether it involved technology or not. For that reason, the program leaders sometimes had to remind participants to include a technological element in their project proposals. During the program period, it became clear that the dynamics of technological and pedagogical knowledge is also very much at play when development is framed by Education 4.0.

5.3 Bottom-up Innovation and Ownership

A strong bottom-up approach is a defining feature of the program, especially in the view of the program leaders. They advocate for co-creation, ensuring that those working closest to students, namely the teachers, have real influence.

> "Yes, well it has been a means of trying to achieve the goal of the whole basic idea of co-creation. And we want to go out and believe that it is out there, and this should not be misunderstood negatively, but out there in the outermost link, where the teachers are, and where they stand together with the students every single day. Day in and day out experiencing what is going on. That is where the value is created. And it is also out there that any frustrations, problems, or wishes would arise, and we believe that they will be more validly formulated. And perhaps also in relation to an output - it's easier to create value in the end if there is a bottom-up mindset about where the ideas come from." (Program leader)

While the steering committee supports this participatory model, there is also recognition that organisational transformation requires multi-level engagement. Members act with a dual mandate: representing their home departments and contributing to cross-organizational goals. This sometimes generates tension between local strategies and institutional innovation. Program leaders also emphasize breaking down silos and replacing fragmented, one-off pilot projects with sustained, cross-disciplinary initiatives. They regard the program's cross-institutional structure, including the steering committee's diverse makeup, as essential for legitimacy and reach.

5.4 Organisational Development and Cultural Change

For both leadership groups, the program is about more than educational content: it is about changing how the organisation works. The program leaders envision it as a driver of cultural transformation, seeking to establish a stronger role for innovation and experimentation across the institution.

> "Habits, situated practice, and people's way of thinking are also some of the things we want to influence with this. So, there is something about the governance structure that is different, and which ensures cross-functional management support and anchoring. There is something about the fact that program management lies with us. We can move across the organisation somewhat as free agents. But we also have an obligation to do so. It is stated in our departmental charter. So, there is something about the management mechanism around it that is different from what we have seen before." (Program leader)

The steering committee also expects lasting impact, though they express it more cautiously. One member said:

> "I have no expectation that we will have something that just runs smoothly after this. But I do have an expectation that some of the initiatives that are being tested, that several of them... I believe that most of them (initiatives) will become something that becomes part of the operation." (Dean)

Both groups acknowledge that competence development, particularly in online teaching and modular course delivery, is an important side effect, even if it's not the program's explicit goal. This also relates the above-mentioned dynamics between pedagogy and technology, which often relates to teacher competencies, but also to the competencies of the consultants who give guidance to the participants in the program. The majority of the consultants were from the IT-department, which meant they were technologically knowledgeable, but somewhat distanced from the teaching practices and curriculum of the study programs.

5.5 Leadership, Structure, and Strategic Framing

The steering committee largely views Education 4.0 as a framework for exploring new ways of teaching and organising education. Some emphasize technology, others pedagogy, but they all point to the importance of future-proofing the programs offered in the institution. The program leaders frame their leadership through a strategically placed, cross-sectional unit (named "Digital Learning"), which is designed to operate across departments. They argue that innovation needs this kind of structural flexibility to flourish. One structural innovation they highlight, is the role of the so-called track-leader, which replaces traditional project leadership with a more coaching-oriented model (see figure 1 and section 2 for further explanation).

> "It is no coincidence that we have chosen the structure that is based on organizational theory when it comes to the program. We also considered everything up to portfolio management. When we are program leaders, we need some project managers. They shouldn't be called project managers because that sends the wrong message, so we changed it to track leaders. And it went from a more documenting role to a more coaching role. But the idea is the same. Always make sure that we are responsible for the track managers in terms of helping them. And they are responsible for their idea creators. So, the responsibility falls upwards, but the tasks fall downwards." (Program leader)

Although resource-intensive, this function is seen as a long-term investment in organizational competence and innovation capacity.

5.6 Governance, Incentives, and Organisational Alignment

Both the program leaders and the steering committee are mindful of incentive structures. Program leaders emphasize co-funding and cross-functionality as levers to ensure participation and institutional anchoring. The steering committee underscores the need to balance experimentation with operational relevance. Some expressed concern about resource demands, particularly on teachers and IT staff, and the need for low entry thresholds to encourage broad participation. A shared concern is that Education 4.0 competes with other institutional priorities. One steering committee member observed:

> "Education 4.0 as a program competes with so many other agendas in our institution. So, the risk of being downgraded is always there. So, there is also a resource battle over what you should invest development hours in on the programs." (Head of studies)

5.7 Experimentation, Learning, and Impact

The program was intentionally designed to encourage experimentation without rigid goals. For the program leaders, this is essential to stimulating creativity and agency:

> "It's about spotting and experimenting with attractive new opportunities… and developing new ways of thinking." (Program leader)

Rather than determining outcomes in advance, they prefer to let ideas evolve and consolidate learning across projects. While program targets (like the intended number of ideas and participants) were established, they were never intended to restrict creativity or local ownership. The ultimate hope is to influence not only practices but mindsets, instilling a lasting capacity for innovation within the institution. One program leader reflected:

> "I actually think that the programme has achieved what I wanted. Cultural change is of course a big word (...). But for me it has been to spread knowledge of 4.0, and some insight into what it will come to mean. (...) Then there is an understanding that the future is more digital, asynchronous and data-based, and that is the cultural change that I was interested in from the start. That, and then having some people out there who see the potential in it (...). I think we

> have achieved that too. It has been written into our foundation, in the new strategic guidelines for our institution. Education 4.0 is also mentioned there." (Program leader)

5.8 Evolution and Tensions

Over time, both program leaders and the steering committee have acknowledged shifts in the program's focus. Notably, the original bottom-up emphasis has given way, at least partly, to strategic top-down impulses, such as introducing AI as a new theme. This reflects a growing tolerance for hybrid leadership, where ideas may emerge both from the grassroots and management. While this challenges the original co-creation model, program leaders recognize its necessity in certain contexts.

> "We'd rather see leaders cultivating environments where people can raise their hands and say: 'I'd like to try this.'" (Program leader)

6. Conclusion

In this paper, we have investigated how a targeted organisational change program can enhance capacity building to support the implementation of Education 4.0 in higher education. Through analysis of a series of in-depth interviews, we have found that the program has addressed all organisational levels with different impact. Structural and strategic changes introduced by the Education 4.0 program led to strategic management focus on several issues which may not necessarily be easily combined: Breaking down silo mentality, strengthening inter-departmental collaboration, and long-term capacity building. At the operational level, participants in the program were caught in a dilemma between the free experimentation in the co-creation process and the restrictions of study regulations and institutional structures, which seem to hinder innovation. The program focuses on integrating technology into the program, not just as a tool but as a key driver for transforming teaching, learning, and educational formats. However, we find both tensions, ambitions, and successes related to incorporating digital technology into teaching and educational designs. We also find that the use of design principles may hinder rather than further direction in the experiments.

In summary, we find that the program takes a technology-driven approach despite intentions of the opposite; that management of the institution see great potential for change in the program; and that participants in the program's experimental activities can get caught between innovation and everyday practices and educational culture.

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Ethics Declaration

No ethical clearance was required for this study. In connection with the interviews, we have obtained informed consent from the participants for the interviews and for publication of our results of the study.

AI Declaration

We have used Napkin.ai to generate figure 1.

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Learning and Education in Organizational Theories: From Rationality to Metaphors

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Abstract: The current world of work is changing and its current form also requires a change in the competence framework that an adult individual needs for their work performance. We are moving away from clearly defined qualification education as the only possible indicator of the ability to succeed in the labor market. For some time now, a clear indicator of this has been the shift of educational goals to abilities and competences, such as the ability to work in a team, flexibility or willingness to communicate. In the post-industrial organizational environment, individuality, which until recently was the addressee and actor of education and training, is being suspended. However, the expansion of the number of necessary competencies also requires that part of the competence framework be completely unique in something, so that we can succeed in a work environment overwhelmed by a large number of competent people. The space for andragogic action in the area of formal organizations is so enormous. This chapter is devoted to the still current theories of organizations, their principles of learning and education, with an emphasis on the reference to the current social context of the world of work. Organization is understood here not as a static application of organizational principles, but as a process. Theorists such as Niklas Luhmann , Bruno Latour , Karl Weick and James March have made significant contributions to the process view of organization. The chapter provides a basic analysis of these theoretical approaches in the context of learning and education in companies. The interpretation is based on three basic dimensions of organization theory. (1) The basic dimension is the principle of the organization of the world and its organization. (2) A general explanation of social relations and mutual relations between individuals, groups and entities. (3) What are the possibilities of predicting future developments and possible expectations of people, groups and organizations. These conclusions are related in the chapter to the main principles of andragogic work, learning and education in organizational environments.

Keywords: Organizational Theory; Organizational Learning; Education in Organizations; Socio-technical Systems; Organizational Processes; Enrollment; Material Mediation.

1. Introduction

In recent decades, corporate learning has transformed from a mechanical transfer of knowledge to a complex process of shaping meaning, identity, and capabilities within changing organizational contexts. This text develops a process-oriented approach to learning in organizations, drawing on the theoretical frameworks of prominent representatives of organizational theory – Bruno Latour , Niklas Luhmann , James March and Karl Weick – and above all the analytical scheme of process organizational analysis, as systematically developed by Tor Hernes in his work Understanding Organization as Process (2007). The aim is to show how these approaches can be used for a deeper understanding, design and implementation of educational strategies in companies and institutions.

2. Theoretical Background of Selected Theorists in the Context of Organizational Learning

2.1 Bruno Latour and Organization as a Process

Bruno Latour , best known for his work in the sociology of science, transcends the traditional dichotomy between the technical and the social world. His key claim is that the world is not composed of fixed entities, but of interconnected actors—human and nonhuman—who come together in more permanent groupings through networks. Latour criticizes classical sociology for neglecting the role of material objects and technologies in maintaining social structures. Like Whitehead , Latour sees relations and processes as primary, not subjects or objects in themselves. Latour's Actor -network theory (ANT) shows how social and technical elements are inextricably intertwined. Actors are not stable entities, but products of relationships that are constantly renewed. Technologies do not arise only as a result of human activity – they themselves also shape human actions. Latour refers to these elements as “actants”, emphasizing their role in shaping permanent socio-technical configurations. In his concept, organizations are not fixed structures, but temporary stabilizations of processes that take place between people, things, texts and technologies. A key mechanism in Latour's thinking is the process of translation – the way in which various elements of a network are translated into new contexts and their meaning is stabilized through material records (e.g. graphs, devices, or documents). Such translations enable organizations to persist over time because they remove dependence on individuals. Here, Latour builds

on Weber's idea of rationalization and shows how human activity gradually becomes technically mediated and less personal.

In practice, Latour's theory can be applied, for example, to the analysis of corporate mergers: they are not just rational decisions resulting from the market, but a complex network of decisions, technologies and discourses that shape each other. Organizing is seen here as a form of experimentation, where results are never guaranteed, but are based on constant testing, improvisation and adaptation. Latour also rejects the classic levels of analysis – micro vs. macro – and instead proposes to monitor connections and interactions regardless of predetermined scales. According to him, even large institutions are formed by local interactions, the stability of which depends on the strength of associations, often mediated by artifacts. Stabilization is then not the result of some external force, but arises from reproduced relationships that can be materialized, for example, in technologies or standardized procedures.

Another important concept is enrollment , the incorporation of actors into a network. This occurs when their interests align with those of others and can thus be “enrolled” into more permanent structures. This process is not one-sided – even non-human elements such as machines can “recruit” people and shape their actions. Latour’s work offers an alternative to traditional sociological thinking – instead of abstract structures and universal theories, he emphasizes concrete connections, translations and material mediations. According to him, organizations are constantly evolving networks, where stability is the result of efforts to connect and transfer meanings. His approach brings a new way of thinking about organizations as a continuous process of “becoming” and at the same time a challenge to methodological modesty – no theory can capture the whole tangle of reality.

2.2 Niklas Luhmann – Autopoiesis , Recursion and Organization as a Communication System

Nicklas Luhmann (1927–1998) is one of the most important social theorists of the 20th century. In his theory of autopoietic systems, he combines inspiration from biology (autopoiesis Maturana and Varela), philosophy (especially Husserl and Spencer Brown) and systems thinking. Unlike Parsons , from whom he learned, but from whom he significantly distinguished himself, Luhmann understands social systems as operationally closed communication units that reproduce themselves on the basis of their own internal rules. He does not deal with the behavior of individuals, but exclusively with communication - that is how systems exist. The fundamental concepts of his theory are autopoiesis (self-creation), recursion (self-referential reproduction) and distinction (delimitation of system boundaries). Social systems are not determined by the external environment, but create their own meanings through internal operations - especially communication. This communication is not only the bearer of meaning, but also the main mechanism of the existence and change of the system.

2.2.1 Autopoiesis and Closedness of the System

Luhmann borrows the term autopoiesis from biology, where it refers to the ability of a system to create and renew itself. In the social realm, this means that social systems – such as organizations – are not “open” in the sense that they directly absorb influences from the outside. Instead, they are cognitively open, meaning that they perceive their environment through their own meaning structures. Any input from the outside must first be interpreted by the system according to its internal logic, otherwise it has no effect.

For example, an organization does not respond directly to the “reality of the market”, but to how it defines this reality in its decision-making and communication structures. This creates structural selection – the system accepts only those stimuli that correspond to its internal logic and current codes of meaning.

2.2.2 Communication as the Basic Unit of the System

Luhmann's fundamental contribution is the change of the analytical unit from the individual to the act of communication. In his concept, communication is composed of three moments: information, utterance and understanding. It is not important who speaks, but whether the utterance enters the communication chain of the system. Individuals are not part of the system - they are its environment. In this way, Luhmann disrupts the classical concept of social action as individual intentional action.

2.2.3 Structure and Process: Stability and Change

Social systems are both stable and changeable. Stability is provided by a structure that maintains continuity between the past, present, and future. Structure in Luhmann’s view is not a set of roles or functions, but rather patterns of communication, such as repeated meetings, decision-making procedures, or values embedded in

corporate texts. This stability allows systems to “return to themselves” and evolve in the form of feedback (recursion). Change is made possible through events that the system links into a trajectory. Events are unique and irreversible (such as decisions), but if the system is able to integrate them meaningfully, they contribute to its development. The key is that change is only possible if it is interpretable—if it “fits” into existing codes. Otherwise, the system ignores the event.

2.2.4 Expectations as Anticipatory Structures

In addition to communication, the category of expectations is also an important element. It allows the system to anticipate the future, choose from options and orient its actions. Expectations are structures of meaning – they allow us to decide what is important, what can be assumed, what can be considered a failure or a success. However, with high accuracy of expectations, there is a risk of disappointment and closure towards the unexpected. Luhmann draws attention to a paradox: the more accurate the expectations, the less adaptable the system.

2.2.5 Identity, Complexity and Texts

In his concept of identity, Luhmann follows his theory of communication: an organization is what it says about itself. Identity is the product of the texts that an organization creates about itself – annual reports, codes, strategies. These texts do not reflect the “true essence”, but stabilize certain meanings and thus enable decision-making. Identity is thus recursive – it arises as a result of its own messages and serves as the basis for further decisions. The system cannot express all its complexity, so it creates simplified self-images .

2.2.6 Critique of the Absence of the Subject

One of the most common objections to Luhmann is his rejection of the role of the individual subject. Individuals enter the system as an environment, but they are not part of it. This can be reductive, especially in organizational studies that examine the role of managers, leadership, or human decision-making. Luhmann's theory is more of an analytical tool than a description of everyday life. At the same time, however, it opens up space for analyzing organizations as dynamic systems of meaning reproduction, not as a collection of acting individuals.

2.3 James March and the Logic of Organizational Processes: From Organizations as Structures to Organizations as Decision Streams

James March is considered one of the founders of modern organization theory. His early collaboration with Herbert Simon led to the seminal publication Organizations (1958), which attempted the first systematic study of organizational behavior. Later, with Richard Cyert , he published A Behavioural Theory of the Firm (1963), which represented an early version of the process approach in the economic theory of organizations. A characteristic feature of March's approach is that it does not start from preconceived ideas about what organizations "are" but focuses on what organized action enables and sustains in an often volatile and ambiguous world. Organizations are not rigidly bounded entities, but rather dynamic, open-ended systems of decision-making that cannot be easily reduced to a set of norms or predictable structures.

March, organizations are not fixed and logical structures, but patterns of formalized decision-making processes that can acquire varying degrees of stability. While an organization—for example, the Red Cross—may appear consistent from the outside, its internal decision-making processes may be chaotic and incoherent. Such an organization may appear coherent only because of the way it is viewed from the outside—for example, by the media, funding agencies, or the public. In reality, the set of decisions and actions may be very inconsistent. This inconsistency is not only present, but is also key to the survival of organizations in an ambiguous world. March understands organizations as “loosely coupled systems” (loosely coupled systems) coupled systems), which means that the individual components of an organization (decisions, people, problems, technology) do not have to be tightly coupled. In his famous "garbage can" decision-making model (can model), which he developed with Cohen and Olsen , decisions are the result of the random connection of four elements: problems, solutions, participants and decision-making opportunities. The organization is therefore not a predetermined framework, but the result of a process in which the individual elements meet. March compares this dynamic to the sharing of fire: only some decisions (for example, a “dry log”) are able to ignite other, less flammable parts (for example, “wet branches”), thus creating a self-sustaining process. According to March , symbolism is an important part of organizational life . Decision-making in modern society often serves more to create an impression of rationality and control than to actually produce functional results. The fact that people believe in rational decision-making

has value in itself - it strengthens trust in structures and enables collective action. March recalls the story of a military unit that survived a snowstorm thanks to a map – although it was a map of the Pyrenees, not the Alps. The power of the symbol (the map as a guarantee of orientation) therefore played a more important role than factual accuracy. Many organizational decisions also operate in this spirit – they are rituals that maintain the appearance of order.

This is also related to March's criticism of the rationalist concept of learning in organizations. In his concept, the organization is not a rational unit that learns on the basis of fixed truths, but a system that creates its own certainties in conditions of uncertainty. Learning is a means of connecting the past, present and future - through experience and collective memory, expectations and goals are formed. Failure is often simplistically associated with the failure to meet expectations, while success is the reward for fulfilling them. This emotional interpretation of past events has a fundamental influence on future decision-making.

Another key element of March's theory is routines. Organizations as systems are neither completely controlled nor completely random - their stability is the result of provisional connections that are constantly reshaped. Overall, March's approach shifts our idea of how organizations work. He shows that organizations are not fixed entities with a clear structure and hierarchy, but rather fluid networks of processes in which decisions, symbols, routines, and learning interact. His emphasis on ambiguity, symbolism, and the spatiotemporal dynamics of decision-making makes a fundamental contribution not only to organizational theory but also to the understanding of institutional and collective action in modern society.

2.4 Karl Weick and Organizing as a Process: The Verbal World of Meaningfulness in Organizations

Karl Weick is one of the most influential authors in the field of organizational theory, particularly due to his emphasis on processes rather than static entities. Instead of studying organizations as objectively given structures, he focuses on organizing – that is, the dynamic, ongoing activities through which people create social order. In his concept, an organization is not something that can be directly grasped or located; rather, it is a network of interconnected events that exists through the meaningful interconnection of the actions of actors in time and space.

Weick builds on the pragmatist tradition and approaches the paradigms of social constructivism. The key concept in his theory is sensemaking – the process by which people actively create meaning for the situations they find themselves in. In this sense, he differs from the more traditional concept of interpretation, which may suggest that meaning is something that is already present in reality and waiting to be recognized. For Weick , however, reality is actively shaped – through language acts, interactions and reflections. In their actions, actors draw imaginary boundaries, create categories and label situations, thereby giving rise to environments that did not exist before.

Weick , not only norms or institutions have a fundamental influence on the organization , but also how individuals coordinate with each other in a given context. This coordination takes place through interactions, linguistic exchanges and immediate decisions – for example, in crisis situations, where it is shown how organizational processes emerge from the verbal world. Weick classifies the intersubjective (personal, contextual) and generically subjective (structural, routinization) dimensions as two key levels of organizing. Organizational life oscillates between these two poles – between spontaneous sharing of meaning and institutionalized forms such as budgets, roles or strategies.

Weick, organizing as a process consists of three phases: enactment (the initiated activity that creates the environment), selection (the selection of interpretations and models), and retention (the storage of successful schemes and their reproduction). Here, he replaces the traditional biological model of variation-selection-retention with his own version that emphasizes the active role of man more. Meaning therefore does not emerge from objective reality, but from the way in which actors react to a given situation through action, how they “anchor” it using language and shared labels. This phase of “labeling” becomes a key moment of stabilization – the verbal act constitutes a reality to which one can further relate. In this context, Weick draws attention to the importance of the linguistic tension between verbs and nouns. The verbal form is an expression of movement, flow, relationships – that is, of what is fleeting, changeable, and contextual. On the contrary, nouns denote what is stable, nameable, that which can be standardized and transferred across situations. According to him, organizing takes place precisely in the space between these two levels: between the live interaction of people (the verbal side) and the structures that allow the generalization and institutionalization of experience (the nominal side). Stability in an organization does not arise from predetermined structures, but from the repetition of processes that have proven successful in a given context – even though they were

originally the result of improvisation or intuition. In his empirical studies (e.g. on aircraft landings on aircraft carriers or on the interventions of firefighting teams), Weick shows how in extreme situations we rely on nonverbal signals, shared intuitions and immediate collective decision-making. From these cases, he derives concepts such as heedfulness (attention to others in the team) or collective mind – a concept that shows how team consciousness transcends individual actors. He points out that while everyone may feel in danger, the collective context (e.g. one person keeps the tools, others decide the situation is safe) can lead to a dangerous interpretation of reality.

When Weick considers the role of structures in organizing, he acknowledges that stability and routines (i.e., “nouns”) have a function. Stability is not neglected—it is rather understood as the result of previous processes of meaning-making. For example, the introduction of a new technological device can disrupt existing scripts (scenarios of common behavior) and create tension between the old intersubjective plane and the new generic structure. This moment is crucial for understanding how institutions change—through the tension, dissonance, and subsequent recalibration between the verbal and nominal worlds.

The significance of Weick's work lies in its connection of immediate experience (e.g. intuition) with organizational structures. He points out that the process of organizing is a continuous "moving balance" between the emergent and the stabilized, between what is happening now and what was previously recognized as functional. This view is in line with Whitehead's process philosophy , which understands reality as a stream of events, not as a set of fixed entities. Both authors agree that "organization" is not a static object, but a constantly renewing dynamic between the past, the present, and the possibilities of the future.

3. Organizing as Connecting: Connect, not Just Contextualize

While traditional approaches to education assume that learning takes place “within” the organization as a context, the process approach emphasizes learning as an organizing act – that is, as the creation of new connections between people, tools, discourses, and knowledge. Hernes (2007) builds on Whitehead’s philosophy of “becoming” and argues that organizations are not fixed entities, but fluid configurations of relationships that need to be constantly renewed through connections.

Latour's concept of networks of actors (Latour , 2005) allows us to understand education as a process in which heterogeneous elements – people, technologies, rules, values – are connected into temporary but functional relationships. Luhmann (1995) adds that each connection is the result of the communicative operations of the system, not the mechanical connection of objects. Thus, the organization is not created " from above ", but through repeated interactions that give individual actors the opportunity to become part of a meaningful whole.

3.1 Decision-making, Meaning and Uncertainty: Education as Meaningful Action

James March (1994) viewed organizations as places of decision-making flows where we learn through trial and error. Learning here is associated with the search for a “logic of appropriateness” and expectations. Hernes (2007) extends this framework with a process logic of decision-making, in which not only the decision itself is important, but also its repetition, reinterpretation and connection with other decisions. Karel Weick (1995) adds the concept of sensemaking – the process in which people create meaning in an environment of ambiguity. Hernes (2007) understands meaning as the result of activity over time – that is, as part of how the organization becomes itself in the process. In an educational context, this means that it is not just about transferring knowledge, but about creating a context in which individuals can understand their role, goals and value in the organization.

3.2 Stability and Change: Reiteration and Novelty in the Educational Process

Hernes’s (2007) key concepts is reiteration – repetition as a form of temporary stabilization in an unstable world. Corporate learning is reiterative in the sense that it stabilizes knowledge, norms, and behavior through their regular re-introduction into practice. However, this stability is only apparent – each repetition takes place in a new context and opens up new possibilities. As Hernes says , “nothing organized starts completely from scratch, but neither is it ever repeated in the same way” (Hernes , 2007, p. 133).

3.3 The Organizational Plot: Education as a Storyline

In Hernes's conception of the organization, each structure has its own “plot” (plot) – a theme around which individual activities cluster. This plot is not given in advance, but is constantly created and reproduced through

activities and interactions. Education in organizations does not arise “from the outside”, but as part of this plot – it thematizes meaning, shared orientation and goals. According to Hernes, it is the plot that makes it possible to distinguish one organization from another, not only structurally, but also in terms of meaning (Hernes , 2007, pp. 134–136).

3.4 Potentiality and Actuality: Education Between Possibilities and Reality

The process approach, inspired by Whitehead and elaborated by Hernes , operates with the dichotomy of potential and actual reality. Education is a mechanism for transforming potential into actual skill, knowledge, or ability. All education actualizes certain possibilities and at the same time generates new ones – not as a linear plan, but as an emergent process of “ verbs ” and “nouns” (Weick , 1995; Hernes , 2007, p. 137).

4. Current Examples of Research in the Field of Process-oriented Education

4.1 Effectiveness of Process-based Management in Public Higher Education

A study conducted at a Brazilian public university analyzed factors influencing the effectiveness of process-based management. The results showed that understanding and commitment, user value, process standardization, continuous improvement, and identification of non-value-added activities significantly influence process effectiveness. This study provides quantitative evidence on how process-oriented management can improve governance and decision-making in educational institutions.

4.2 Using Process Data Mining for Curriculum Analysis

A systematic review of studies on the use of process data mining (process mining) in curriculum analysis shows that this method allows identifying students' educational trajectories, revealing deviations in their behavior, analyzing bottlenecks, and preventing early dropout. This technique provides valuable information for making decisions about curriculum adjustments and improving the quality of education.

4.3 Professional Learning Communities and Their Impact on Teaching

Research focused on professional learning communities (PLCs) shows that collaboration between teachers supports deeper and continuous student learning. Organizing teaching through these teams allows for flexible grouping of students and collective responsibility of teachers for their education, which leads to more effective planning, implementation and evaluation of teaching.

5. Conclusion

Incorporating current research into a process-oriented approach to corporate learning confirms its relevance and practical applicability. Empirical studies show that process management and collaboration within training teams lead to more effective decision-making, better learning outcomes, and higher organizational adaptability (Dirani et al., 2019; Poell et al., 2021). The use of modern analytical tools such as process data mining (process mining), further strengthens the ability of organizations to respond to dynamic changes and continuously improve their learning processes (Calegari & Delgado , 2024).

The process-oriented approach is based on the assumption that organizations are not static structures, but constantly evolving configurations of actors, practices, rules and technologies. In this context, education has a key role: not as a one-time transfer of knowledge, but as a continuous, distributed and interactive process of creating meaning and capabilities (Weick , 1995). The process perspective emphasizes the importance of time, the sequence of events and the narrative framework in which learning activities take place. This means that effective education must be situated, reflective and capable of adaptation in real time.

Recent research also shows that successful educational interventions are closely linked to organizational goals and are co-created by participants. For example, studies focused on professional learning communities (Professional Learning Communities (PLCs) demonstrate that collective responsibility for learning and sharing experiences among colleagues leads to increased learning effectiveness and transferability of knowledge to practice (Shand & Batts , 2023). It is this ability to connect individual and collective learning that is a fundamental element of process effectiveness.

From a technological perspective, the digitalization of education plays a significant role, enabling the tracking and analysis of learning trajectories. Methods as a process Data mining allows us to visualize how participants navigate through learning programs, where bottlenecks or deviations occur in the processes, and how processes can be optimized (Calegari & Delgado , 2024). This approach opens up new possibilities for the design of personalized and data-driven learning.

Moreover, contemporary organizations are faced with the necessity of frequent and profound transformations. Research shows that the ability of an organization to learn and adapt – the so-called organizational agility – is conditioned not only by technological innovations, but also by the ability to reflect on its own processes and structures (Dirani et al., 2019). The process approach thus allows us to understand education not only as a tool for developing competencies, but also as a key organizing mechanism that allows us to question existing schemes and create new possibilities.

It follows from the above that a process-oriented approach to corporate learning not only better responds to the challenges of the current turbulent environment, but also provides a framework for deeper integration of learning into the everyday functioning of organizations. Thus, learning becomes not a supporting but a constitutive part of organizing.

Ethics Declaration

The submitted text of the paper is not the result of research, but of scientific research. It is a theoretical text, therefore it was not necessary to ask the ethics committee for approval.

Declaration on Artificial Intelligence

In my contribution, I used the AI tool for the formal editing of APA citations. The code of ethics is not relevant for the content of the text itself.

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Exploring E-Learning and Inclusion: A Bibliometric Analysis of Research Trends

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Abstract: In the context of the recent global transition to digital education, inclusion in e-learning has emerged as a topic of growing significance. This study conducts a bibliometric analysis of 731 publications retrieved from the Web of Science database, aiming to uncover prevailing research trends, thematic frameworks, and collaborative networks that have emerged around the intersection of e-learning and inclusion. The keyword analysis, conducted using VOSviewer software, revealed that 'e-learning' occupies a central position in the literature, exhibiting strong associations with related themes such as online learning, blended learning, higher education, and gamification. Notably, the concept of 'inclusion' demonstrated significant connections with terms such as accessibility, digital divide, diversity, and artificial intelligence, indicating a multidimensional approach to inclusion within technology-enhanced learning environments. These findings underscore that inclusion in such contexts is not a singular notion but a complex, multifaceted construct. Its strong associations with the aforementioned themes suggest that truly inclusive e-learning environments must address a broad spectrum of social, technological, and pedagogical dimensions. Moreover, temporal visualization illustrated a marked increase in scholarly attention to topics like COVID-19, mental health, and social inclusion in the post-2020 period, highlighting the pandemic's influence on educational research trends. Publication and citation analyses revealed a significant rise in scientific output and impact beginning in 2018, with a peak observed in 2022. Country-level collaboration maps identified the United States, Spain, Germany, and China as central contributors, while institutional analyses highlighted universities such as the University of British Columbia and the University of Melbourne as leading entities in the field. These findings underscore the necessity of designing e-learning environments that are not only technologically sophisticated but also socially inclusive. In the current landscape of digital education, increasing attention is being directed toward themes such as e-inclusion, web accessibility, and equity in education. This study contributes to the understanding of inclusive practices in e-learning and provides valuable insights for researchers, educators, and policymakers.

Keywords: E-learning, Inclusion, Digital Education, Accessibility, Social Inclusion in Online Learning, Bibliometric Analysis

1. Introduction

The global shift toward digital education has generated growing interest in how inclusive pedagogical practices can be sustained and enhanced in virtual learning environments. This interest has intensified particularly since the educational disruptions caused by the COVID-19 pandemic in 2020. As digital learning platforms have become central to educational delivery worldwide, concerns surrounding access, equity, and diversity have gained prominence. Within this evolving landscape, inclusion in e-learning has emerged as a critical topic, prompting interdisciplinary attention from education, technology, and social policy scholars alike. This study investigates the intersection of e-learning and inclusion through a bibliometric analysis of scholarly literature indexed in the Web of Science database. Employing quantitative mapping and visualization techniques, the study identifies prevailing research trends, central themes, and patterns of collaboration among countries and institutions. The findings aim to uncover the intellectual structure of this growing research domain and offer insights for future educational research and policy development.

2. Theoretical Background

The integration of inclusion within e-learning environments is rooted in broader discourses surrounding equity in education and the role of technology in reducing—or exacerbating—barriers to learning. Inclusion in this context refers not merely to physical access to digital platforms but also to the creation of educational experiences that are accessible, responsive, and supportive of learners from diverse backgrounds and with varied needs. Research in this domain has built upon foundational principles of universal design for learning (UDL), which advocates for flexible learning environments that accommodate individual learning differences (Meyer et al., 2014). At the same time, literature on the digital divide has emphasized the socio-economic and infrastructural disparities that prevent equitable participation in online learning (van Dijk, 2020). Concepts such

as web accessibility, assistive technologies, and digital literacy have increasingly been foregrounded in discussions on how to make e-learning more inclusive.

Recent studies have also focused on how artificial intelligence, gamification, and data-driven personalization can contribute to more inclusive educational experiences—provided they are designed with ethical considerations and learner agency in mind (Holmes et al., 2019). However, inclusion remains a multifaceted construct, encompassing issues of cultural sensitivity, language, mental health, and learner autonomy, all of which must be considered when designing digital education systems. This conceptual framework guides the current study's bibliometric investigation, aiming to identify how these diverse strands of research are reflected in the scholarly literature on e-learning and inclusion. By tracing thematic developments and collaborative patterns, the study seeks to illuminate how the academic community has engaged with these complex issues over time.

3. Methodology

Bibliometric techniques serve as a valuable complement to traditional literature reviews, particularly in the analysis of large bodies of research, by offering an objective, transparent, and replicable methodological structure (Öztürk et al., 2024). This approach enables a multidimensional mapping of the field's development through indicators such as publication performance, patterns of collaboration, and thematic clustering (Galvagno, 2017; Lim & Kumar, 2024). This study adopts a bibliometric approach to examine the evolution and structure of academic research at the intersection of e-learning and inclusion. Bibliometric analysis offers a systematic method to quantify scholarly output, map intellectual structures, and uncover emerging patterns in scientific publications (Donthu et al., 2021). In this research, the methodology integrates both performance analysis and science mapping techniques to provide a comprehensive overview of the field.

3.1 Data Source and Selection Criteria

The data for this bibliometric analysis were retrieved from the Web of Science (WoS) Core Collection, a database frequently preferred in scholarly research due to its high indexing standards and extensive citation network. The search was conducted on April 15, 2024, using the keywords "e-learning," "inclusion," "accessibility," "equity," and "digital education." Only peer-reviewed journal articles and conference proceedings published in English were included, while editorials, book reviews, and non-refereed content were excluded. Publications from the period 1992 to 2023 were fully included in the analysis. Although publication numbers were relatively low between 1992 and 1999, these records were retained to ensure comprehensive coverage. Records from 2024 and 2025 were excluded, as they were either not fully indexed or listed as early access at the time of data extraction. This exclusion was made to maintain the validity of year-based comparisons.

Following data cleaning and filtering processes, a total of 731 publications were included in the final analysis. The data were exported in plain text format, including full records and citation information. Figure 1 displays the annual distribution of publications and total citation counts between 1992 and 2023. The presence of data points for 2024 and 2025 in the figure is due solely to system-level tagging discrepancies and was not considered in the analysis.

3.2 Analytical Tools and Techniques

The data were analysed using VOSviewer (version 1.6.19), a specialized software tool for constructing and visualizing bibliometric networks. The analysis focused on three key dimensions:

- Keyword Co-occurrence Analysis: to identify dominant themes and conceptual linkages between key terms.
- Temporal Analysis: to explore the evolution of topics over time.
- Co-authorship and Institutional Collaboration Networks: to identify key countries, institutions, and their levels of collaboration.

Keywords were normalized by merging semantically similar terms (e.g., "e-learning" and "elearning"), and a minimum occurrence threshold was applied to filter out noise. The overlay visualization feature of VOSviewer was utilized to trace the chronological development of themes. This methodological framework enabled the identification of both quantitative publication trends and qualitative shifts in thematic focus, offering a rich, multi-dimensional understanding of how research on inclusive e-learning has evolved over the past two decades.

4. Results

This section presents the results of the bibliometric analysis in four main areas: publication trends, keyword co-occurrence patterns, thematic evolution, and collaboration networks across countries and institutions.

4.1 Publication and Citation Trends

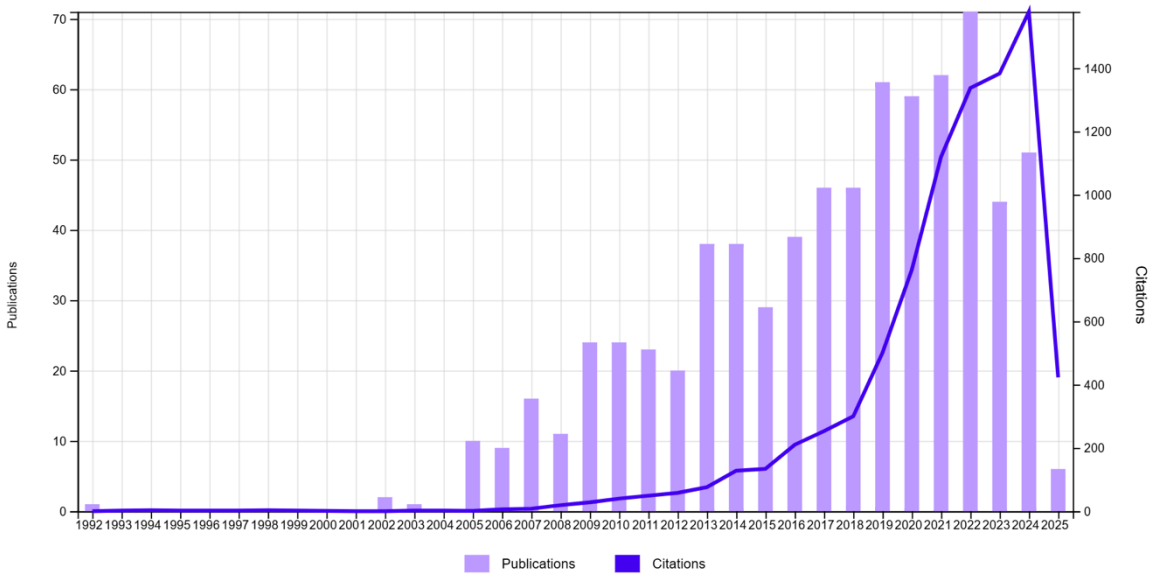


Figure 1: Publication and citation trends

The volume of publications on e-learning and inclusion has grown steadily since 2000, with a particularly notable increase observed after 2018. The number of annual publications peaked in 2022, reflecting intensified research efforts in response to global educational disruptions caused by the COVID-19 pandemic. Citation counts followed a similar trajectory, suggesting both increased interest and impact in this research domain.

4.2 Keyword Co-Occurrence Analysis

Figure 2 presents the keyword co-occurrence network generated from the titles and abstracts of 731 publications. Five clusters are highlighted using modularity-based colour coding. The term “e-learning” was retained in the network as it appears in all publications and plays a central role by linking the clusters and establishing structural coherence across the dataset.

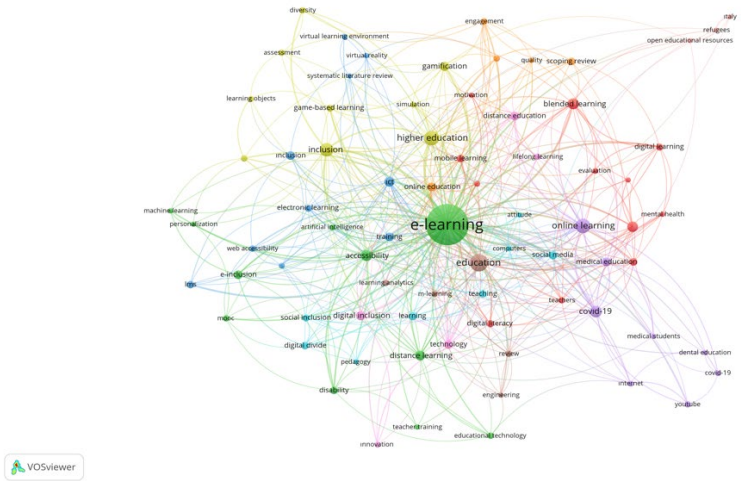


Figure 2: Keyword co-occurrence network map

4.2.1 Cluster 1 (Red): Pedagogical Design and Online Learning

This central cluster includes terms such as e-learning, online learning, learning environment, instructional design, and student engagement. These keywords highlight ongoing research on how digital learning platforms are structured and how learners interact with them. The prominence of blended learning and gamification within this cluster also signals a growing interest in hybrid approaches and motivation-enhancing strategies.

4.2.2 Cluster 2 (Green): Higher Education and Assessment

Keywords such as higher education, assessment, learning outcomes, course design, and MOOCs are grouped here. This suggests a body of research focused on the implications of inclusive e-learning in tertiary education settings. Topics like student performance, academic success, and formative feedback further indicate that inclusion is increasingly framed around equitable achievement metrics.

4.2.3 Cluster 3 (Blue): Inclusion, Equity, and Accessibility

This cluster centres around terms such as inclusion, accessibility, digital divide, diversity, and equity. It reflects a growing scholarly focus on the structural and systemic barriers that impact learners' ability to fully participate in digital education. The frequent co-occurrence of policy, barriers, and support systems points to the relevance of institutional and governmental roles in shaping access.

4.2.4 Cluster 4 (Yellow): Technology and Innovation

Featuring keywords like artificial intelligence, adaptive learning, educational technology, and mobile learning, this cluster emphasizes the technological advancements driving personalized and inclusive learning experiences. It also suggests a parallel discourse on how innovation can either reduce or reinforce exclusion depending on design intentions.

4.2.5 Cluster 5 (Purple): Mental Health and Social Inclusion

Emerging more prominently in recent years, this cluster includes terms such as mental health, well-being, social inclusion, and emotional support. These keywords signal a shift toward a more holistic understanding of inclusion—one that integrates affective, psychological, and community-based dimensions of learning.

Taken together, the co-occurrence map illustrates how the concept of inclusive e-learning is not confined to access alone but is distributed across diverse pedagogical, technological, institutional, and emotional domains. The dense interlinkages among clusters also reveal that these themes are not isolated silos but intersecting facets of a broader discourse on equitable digital education. This map visualizes the co-occurrence of terms in the dataset, highlighting five major thematic clusters that define current research directions.

4.3 Thematic Evolution Over Time

Figure 3 presents an overlay visualization illustrating the temporal evolution of keyword usage based on the average publication year of the associated documents. In this network, node colours represent temporal trends—ranging from shades of blue for earlier studies (e.g., pre-2015, which predominantly addressed infrastructure and basic accessibility) to yellow for more recent research (up to 2023). The visualization captures a shift in research focus over time, with themes such as social inclusion and mental health gaining prominence particularly after 2020. While colour plays a central role in conveying these temporal dynamics, node size and spatial positioning further support interpretation.

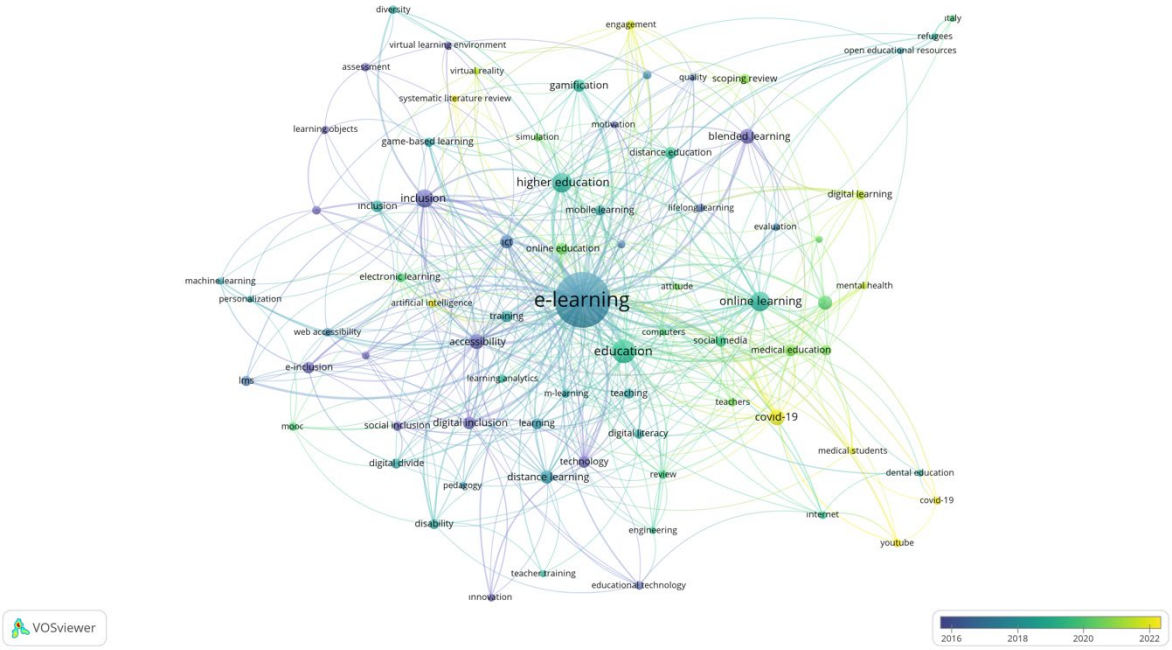


Figure 3: Overlay visualization of keyword development over time

Earlier research (2005–2015) predominantly emphasized the technological infrastructure and access dimension of e-learning. Terms such as ICT, web-based learning, learning management systems, and accessibility were dominant during this period. These topics reflect an early-stage preoccupation with building the foundations of digital learning environments and ensuring basic technical participation. Between 2016 and 2019, the field began to incorporate themes related to learner diversity, instructional design, and higher education policy. Keywords like inclusive education, MOOCs, course design, and formative assessment gained visibility. This shift marks a growing pedagogical interest in how digital education could support diverse learners and institutional adaptation.

From 2020 onwards, there is a clear thematic expansion into socio-emotional, health-related, and ethical issues, aligning with the onset of the COVID-19 pandemic. The emergence of terms such as mental health, digital well-being, social inclusion, equity, and remote learning suggests that inclusion is no longer viewed solely through a structural or technological lens, but also through the lens of emotional resilience, digital fatigue, and student support systems. This evolution highlights a broadening of the concept of inclusion, encompassing not just physical or technological access but also psychological safety, equitable engagement, and social justice. The overlay visualization thus serves as evidence of a maturing academic discourse that is increasingly concerned with the human-centred dimensions of e-learning. This figure illustrates the chronological layering of research themes, showing the shift from infrastructure-based inclusion toward holistic and learner-centred concerns in recent years.

4.4 Country-Level Collaboration Networks

Figure 4 illustrates the international collaboration network in the field of e-learning and inclusion. Countries are represented as nodes, where node size reflects the total number of publications and the thickness of connecting lines indicates the strength of co-authorship ties. Country names appear as indexed in the Web of Science database (e.g., “Türkiye” instead of “Turkey”). Some smaller countries are not labelled due to node overlap, which resulted in their automatic suppression by VOSviewer. This visualization highlights the global distribution of research activity and provides insight into patterns of international scholarly collaboration.

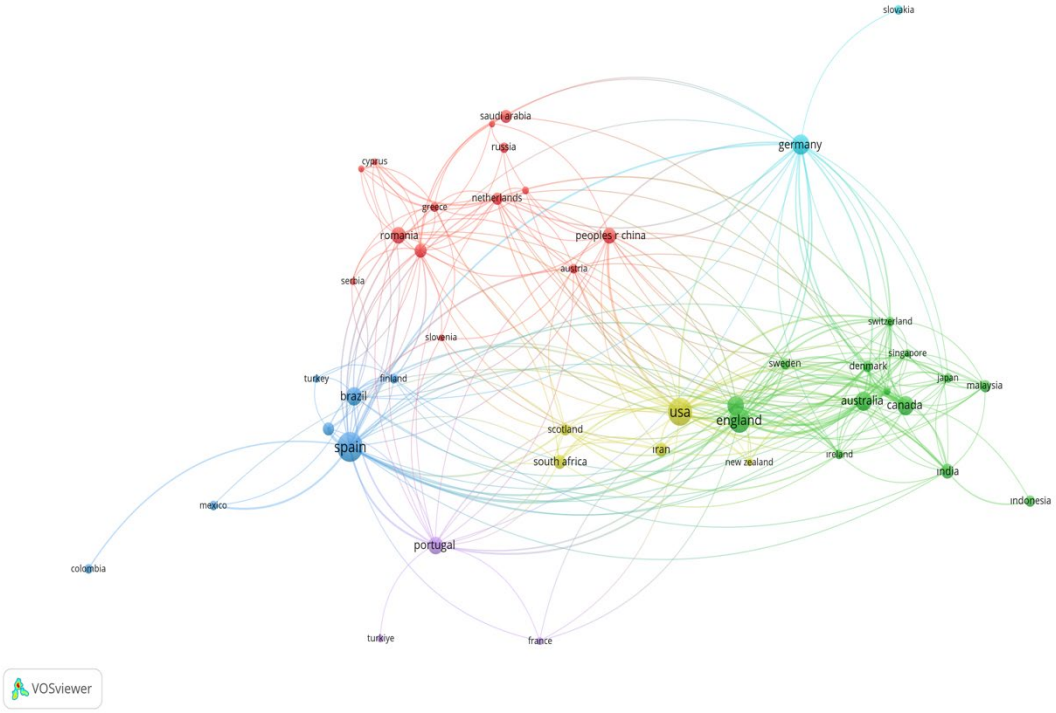


Figure 4: Country Collaboration Map

The United States appears as the most prominent hub, maintaining extensive bilateral connections with numerous countries, including the United Kingdom, Canada, and Germany. Its centrality in the network reflects both its research capacity and influence in setting global educational technology agendas. Spain, Germany, and China also stand out as highly collaborative and productive countries. Spain, in particular, demonstrates strong ties across Europe and Latin America, suggesting that linguistic and regional affiliations may facilitate international cooperation. Germany and China show significant academic engagement, especially in producing policy-oriented and technology-driven studies.

Beyond these central actors, the visualization reveals a second layer of emerging contributors, notably Türkiye, India, and Brazil. These countries, while producing comparatively fewer publications, are increasingly visible in international collaborations. Their growing presence indicates a gradual diversification of the research ecosystem and highlights the rising importance of inclusive digital education in developing and transitional economies. However, the map also suggests persistent geographical imbalances. Several regions—particularly Sub-Saharan Africa, Southeast Asia, and parts of the Middle East—remain underrepresented in terms of both research output and collaborative integration. This points to a need for more inclusive global research partnerships that can bridge knowledge gaps and support capacity building across underserved regions. This map visualizes co-authorship and citation-based connections among countries, highlighting central actors, emerging contributors, and underrepresented regions in the global discourse on e-learning and inclusion.

4.5 Institutional Collaboration Patterns

Figure 5 illustrates the co-authorship network among the most productive universities in the field. Due to the limited number of clusters and relatively weak inter-institutional collaboration, the network appears sparse. Node size represents the number of publications per institution, while the thickness of connecting lines reflects the strength of co-authorship links. The horizontal spacing in the visualization results from VOSviewer's layout algorithm, which separates distant clusters to optimize clarity.

At this institutional level, prominent universities such as the University of British Columbia, the University of Melbourne, and the University of Copenhagen emerge as central research hubs. The network highlights clusters of institutions connected through joint publications and shared thematic orientations, suggesting that research in this domain remains concentrated around a limited number of leading academic centres.

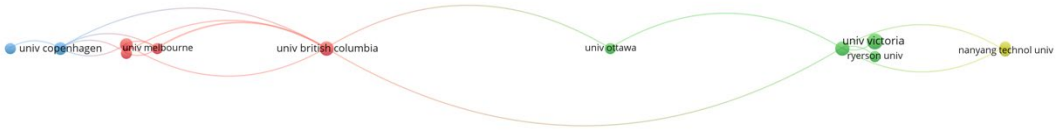


Figure 5: Institutional Collaboration Network Map

5. Discussion

The findings of this bibliometric study suggest that the rapid transformations observed in the post-2020 period—such as the widespread adoption of digital learning, the evolution of social inclusion policies, and increased attention to accessibility—may not yet be fully captured in the empirical literature. Consequently, the dataset analysed in this study is more reflective of conceptual and policy-oriented publications than of practice-based empirical research. Given that bibliometric analyses primarily uncover the structural and trend-based dimensions of a field rather than its content depth, such temporal lags are contextually expected (Donthu et al., 2021). Furthermore, this study is limited to English-language publications indexed in the Web of Science Core Collection. This constraint may result in the underrepresentation of research published in local languages, particularly from regions such as Asia and Africa. Nevertheless, this restriction was a deliberate methodological choice, intended to ensure data consistency, citation traceability, and standardized terminology (Zupic & Čater, 2015). Despite these limitations, the study provides a robust overview of the thematic contours of the field and serves as a foundational framework for guiding future empirical and qualitative inquiries.

The analysis reveals a rapidly growing body of literature at the intersection of e-learning and inclusion, mirroring broader transformations in digital education. The marked increase in publication and citation activity since 2018 aligns with global disruptions such as the COVID-19 pandemic, which intensified the imperative to secure equitable access to education. This surge underscores a paradigmatic shift in which inclusion has moved from the periphery to the forefront of educational research and policy discourse in the digital age. Moreover, the keyword analysis shows that while e-learning remains the dominant anchor concept, its connections to terms such as accessibility, diversity, equity, and digital divide indicate an evolving recognition of the complex layers that constitute inclusive learning environments. Earlier studies often treated access as a binary condition—either a learner has internet access or not—whereas more recent research explores psychological, cultural, linguistic, and cognitive dimensions of participation. This thematic broadening aligns with global calls for education systems that are not only inclusive by design but also responsive to learners' lived realities (UNESCO, 2020).

The temporal analysis further suggests that recent scholarship is increasingly concerned with socio-emotional aspects of learning, such as mental health and digital well-being. These themes, largely absent from early e-learning literature, point to a deepening understanding of the learner experience in digital contexts. It is not sufficient to provide technological infrastructure; inclusive e-learning also demands pedagogical models that foster community, empathy, and individualized support. Collaboration networks across countries and institutions reinforce the global relevance of this field. High levels of engagement from countries such as the United States, Spain, and Germany indicate mature research infrastructures, while emerging contributions from regions like Latin America and Southeast Asia reflect growing international interest in inclusive education. However, the observed clustering of institutional partnerships also suggests potential barriers to broader knowledge diffusion, particularly among underrepresented regions.

Despite the richness of the existing literature, the analysis highlights several underexplored areas. For example, the role of artificial intelligence and adaptive learning technologies in promoting or hindering inclusion remains insufficiently examined. Likewise, while accessibility features are frequently discussed, few studies interrogate how learners themselves perceive and interact with these tools in diverse cultural settings.

In sum, the findings underscore a shift toward more nuanced, interdisciplinary perspectives on inclusion in e-learning. They call for future research that bridges technical, pedagogical, and social concerns—especially in designing systems that prioritize equity, learner agency, and ethical digital practices.

Beyond mapping thematic and collaborative trends, this study contributes to the academic debate by highlighting a conceptual transition in the literature—from a predominantly access-based understanding of inclusion toward a more holistic, affect-oriented framework. While prior research often equated inclusion with technological accessibility or infrastructure, our analysis reveals an emerging discourse that positions emotional well-being, social connectedness, and learner agency as integral to inclusive digital education. This shift remains under-theorized in current frameworks and suggests a need to reconceptualize inclusion as a multidimensional construct that bridges technological, pedagogical, and socio-emotional domains. By uncovering this trajectory, the study invites future research to engage critically with the normative assumptions embedded in digital inclusion policies and to develop theoretical models that reflect the lived realities of diverse learners in online environments.

6. Conclusion and Recommendations

This study provides a comprehensive bibliometric analysis of research at the intersection of e-learning and inclusion, drawing on 731 peer-reviewed publications indexed in the Web of Science database. Through performance and science mapping techniques, the study has identified prevailing themes, influential contributors, and emerging directions in this rapidly evolving field. Findings indicate that inclusive e-learning has become a central concern in digital education scholarship, particularly in response to global challenges such as the COVID-19 pandemic. The literature has progressively shifted from a narrow focus on technological access to a broader exploration of equity, diversity, and learner-centred design. This evolution underscores the growing recognition that inclusive education must encompass not only infrastructure but also culturally responsive content, emotional well-being, and adaptive pedagogical approaches. Keyword co-occurrence and temporal analysis revealed increasing attention to mental health, accessibility, and social inclusion—topics that reflect contemporary educational concerns in digitally mediated contexts. The visualization of global collaboration patterns highlights both established centres of research and emerging contributors, while also pointing to regional disparities that merit further attention.

Based on the findings, several recommendations emerge to support the advancement of inclusive e-learning environments. First, fostering interdisciplinary collaborations among educators, technologists, and policymakers is essential for the development of inclusive learning systems that are responsive not only to cognitive but also to social, emotional, and cultural dimensions of learner diversity. In addition, expanding research efforts to explore learner experiences with digital inclusion tools—particularly in underrepresented regions and among marginalized populations—will help generate more equitable solutions and address existing gaps in the literature. Furthermore, ensuring transparency and upholding ethical considerations in the deployment of emerging technologies such as artificial intelligence and learning analytics is critical to prevent the reinforcement of existing inequalities and to promote equitable access and participation. A key priority should also be investment in institutional capacity building, especially in the Global South, to enhance the participation of these institutions in international research networks and enable their contributions to the global discourse on inclusive education. Through a structured examination of current trends, this study contributes to the ongoing dialogue on digital equity and inclusive pedagogy, serving as a valuable reference for researchers, educators, and practitioners committed to designing e-learning systems that are not only technologically sophisticated but also socially just.

Ethics Declaration

This study is based exclusively on a bibliometric analysis of secondary data derived from published scholarly articles indexed in the Web of Science database. While it does not involve human participants or experimental interventions, it does include publicly available bibliographic metadata (e.g., author names and affiliations), which may be considered personal data under certain data protection frameworks. As such, all data were used in compliance with ethical guidelines for research involving secondary use of public data, and no ethical approval was required.

AI Declaration

No generative AI tools were used to create, analyse, or synthesize data in this study. However, language-enhancement features of AI-based writing assistants (e.g., grammar and clarity suggestions) were selectively employed during the manuscript editing process. The authors maintained full control over the content and

interpretation of the findings. Any automated suggestions were reviewed and verified for accuracy and alignment with the scholarly intent of the work.

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Lessons Learned from Creating Course Content using Generative AI

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Abstract: The release of generative AI tools such as OpenAI's ChatGPT has sparked interest in their implications for education. While early discourse emphasized concerns about plagiarism and academic integrity, recent studies have begun to explore the potential of these tools to support teaching and learning. This paper presents a case study on the use of ChatGPT in the redesign of a first-year systems development project course for informatics students. The course required the integration of various course materials, making it a suitable context for evaluating generative AI's role in course material development. The aim of the study is to present lessons learned from using ChatGPT in the development of course content. Drawing on our practical experience as course designers and instructors, we outline lessons learned from using ChatGPT in the creation of key course elements, including case descriptions, SQL scripts, and requirements specifications. We found that ChatGPT was effective for generating coherent initial drafts of content, but its outputs often required refinement to ensure pedagogical alignment. Challenges included the generation of misleading or irrelevant non-functional requirements and logically flawed code, despite syntactic correctness. Our findings highlight the importance of prompt engineering, critical review, and maintaining a human-in-the-loop approach. We conclude that while ChatGPT can significantly reduce development time for some tasks, it should be used as a complementary tool. This study contributes practical insights to the growing field of AI-assisted education.

Keywords: Content Creation, Generative AI, Large Language Models, ChatGPT, Course Development

1. Introduction

Since the release of OpenAI's large language model (LLM) ChatGPT in November 2022, the technology has shown the potential to be a disruptive force in education (Mills et al., 2023), as well as to revolutionize and transform many aspects of higher education (Ansari et al., 2023; Lee, 2024; Koraishi, 2023). Early reports, especially in mainstream media, portrayed ChatGPT primarily as a tool for plagiarism and cheating. Since then, the discourse in both media and academic research has become more nuanced. Educators and researchers have begun to explore how generative AI can be used to enhance student learning and to streamline teaching and administrative tasks. For example, studies have investigated how LLMs can be used to generate feedback on student assignments (Ali et al., 2024; Dai et al., 2023; Escalante et al., 2023), serve as personalized tutors (Ansari et al., 2023; Currie, 2023), or provide automated administrative support (Rasul et al., 2023; Kshetri et al., 2023). While AI holds great potential to benefit education, there are also notable risks and challenges. These include issues such as bias and stereotyping in generated texts, as well as the generation of false or misleading information (Dempere et al., 2023).

While there are many types of generative AI, this study focuses on ChatGPT, an interactive AI system that uses a natural language processing model to simulate human-like conversations in text (Ansari et al., 2023). An essential aspect of using ChatGPT for generating text is prompt engineering.

"Prompt engineering is the process of designing, refining, and optimizing input prompts to effectively communicate the user's intent to a language model like ChatGPT. This practice is essential for obtaining accurate, relevant, and coherent responses from the model" (Ekin, 2023, p. 3).

By providing the LLM with rules, guidelines, and context for the "conversation," users can clarify what information is important and what the desired output should be (White et al., 2023). For example, in addition to specifying the actual question, users can include contextual details such as tone, intended audience, and constraints on the response. However, even carefully designed prompts do not guarantee accurate responses. The hallucination effect - when generated texts appear realistic but do not correspond to reality (Alkaissi & McFarlane, 2023) - is a significant concern, as users may not be able to distinguish between accurate information and fabrications. Therefore, maintaining a human-in-the-loop approach is essential (Guo & Wang, 2023), and ChatGPT should be viewed as an assistant rather than a replacement.

Designing educational resources is a time intensive and complex task, particularly when courses include multiple components. There is limited empirical research on the practical benefits, limitations, and challenges involved. This creates a need to better understand how tools such as ChatGPT can support teachers in course design, especially in a way that align with pedagogical goals, how to avoid misinformation, and to mitigate the risk of

overreliance on AI-generated content. The aim of this case study is to present lessons learned from using ChatGPT in the development of course content. The case concerns a first-year systems development project course at Örebro University in Sweden. In the spring of 2024, the course project was redesigned using ChatGPT. In this paper, we explain the redesign process and present the lessons learned from using ChatGPT in course development.

2. Literature Review

Early experiments using generative AI to produce various types of course content have been cautiously optimistic. For example, Mikeladze (2023) used ChatGPT in the design of English language teaching materials with positive results. The material could be contextualized for specific learners, and its customization led to increased effectiveness and learner motivation. Another benefit was the time and resources saved for teachers. Similarly, Rouabhia (2024) used ChatGPT to create content for a multimedia databases course. The findings from the study suggest that generative AI can significantly enhance content creation, offer scalable and customizable solutions, and save time for teachers. In an experimental research project, Meron and Araci (2023) used ChatGPT to develop course assignments and design a postgraduate course, also with positive results: "ChatGPT was a competent partner with regard to saving time, structuring textual content and documentation, and as a brainstorming tool" (p. 1). The generated content was clearly structured and well-formatted. All three studies highlight that using ChatGPT for course material development leads to positive educational outcomes, enables content customization, and significantly reduces the time and effort required by teachers.

A common theme in the successful use of generative AI for course content development is prompt engineering. The quality of generated content depends on the prompts provided (Rouabhia, 2024) and "requires considerable effort and calculated prompting by professional, design-educated, and experienced human course developers" (Meron & Araci, 2023, p. 19). While it is easy to ask simple questions of ChatGPT, designing prompts that tailor the generated outputs to your specific needs is more complex. The hallucination effect - where ChatGPT appears to "make up information seemingly out of thin air" (Koraishi, 2023, p. 69) – also means that we cannot blindly trust its outputs. That ChatGPT may generate misleading or false information is a concern (ibid), and it is something that must be taken seriously. There is also the issue of bias in generated material (Davis & Lee, 2023; Koraishi, 2023), where AI may introduce, for example, cultural biases or stereotypes related to gender or ethnicity. This highlights the need for continuous human oversight (Kasneci et al., 2023) of the generated content.

In summary, recent studies on the use of generative AI in course content development report positive outcomes, highlighting benefits such as time savings, improved content structure, and enhanced customization for specific learning contexts. However, these successes depend heavily on the quality of prompt engineering, which requires expertise and iterative refinement. Despite its strengths, generative AI tools like ChatGPT can produce misleading or biased outputs, making continuous human oversight essential.

3. Method

In this study we explore the use of generative AI, specifically ChatGPT, in the development of course materials for a university-level systems development course. This study is based on a case study methodology, through which we investigate a contemporary phenomenon in a real-life context involving a relevant real-world problem (Yin, 2018). The contemporary phenomenon is the use of ChatGPT in education, and the real-world problem is the development of course content. The course used as a case, designed for first-year informatics students, requires the integration of various course materials, making it an ideal context for evaluating the role of generative AI in course content development. Both authors of this paper are teachers on the course and are responsible for creating the materials. Our method involved multiple cycles, during which we created, evaluated, and refined course materials with ChatGPT, guided by both pedagogical goals and practical constraints.

The overall development process consisted of five stages: (1) ER-model design, (2) database script generation, (3) generating example data, (4) case description generation, and (5) requirements specification. Each stage, except for the ER-model design, involved human-AI interaction, where we iteratively refined both the input prompts and the resulting output to align with the course objectives and student needs. Throughout the development process, we documented each interaction with ChatGPT, including the specific prompts used, the generated outputs, and our evaluation of the output. This documentation enabled us to track what had worked (or not) in previous prompt designs. It provided a basis for post-hoc analysis, including the discussion of recurring issues such as hallucination, syntactic vs. logical validity, and prompt design. The documentation also allowed us

to trace the origins of design decisions and to reflect on the implications of using generative AI in educational contexts.

3.1 Course Description

The course used as the case for this study is a systems development project course at Örebro University in Sweden. It is the final course of the first semester in the Informatics, Basic Course program (30 credits) and aims to help students apply previously acquired knowledge to develop an information system. The course has two parts: in the first week, students model an organization using entity-relationship (ER) modeling; in the final five weeks, they develop the system using Java in groups of four.

In spring 2023, we replaced the existing case with a new one focused on developing a system for an NGO involved in sustainability projects. While existing recorded materials (lectures, tutorials) were largely reusable, all case-specific documents had to be created from scratch:

- An ER-model of the organization - This is used both to develop the database and as a reference model against which students compare their own models as part of the assessment in the first part of the course.
- A database script, including example data - At the start of the development phase, all student groups receive the same database script to ensure a common starting point.
- A case description - A detailed description of the NGO, used in both the analysis and development phases of the course. In the analysis phase, students use it to model the organization; in the development phase, it provides contextual background for the system they are building.
- Requirement specifications - These include the functional and non-functional requirements students must implement. A sample functional requirement is: “As a project supervisor, I need to be able to change the date of the projects I am assigned.” A sample non-functional requirement is: “The system should not crash if the user enters incorrect data in a field.”

When developing the new material, we decided to experiment with using ChatGPT. However, we needed a base from which to generate prompts for ChatGPT, so we manually created the ER-model of the NGO as a starting point. Once the ER-model was finalized, the remaining documents were generated using ChatGPT.

4. Course Design Using ChatGPT

In this section we will explain how the new materials for the course were generated. Figure 1 show the process for the development of the course material.

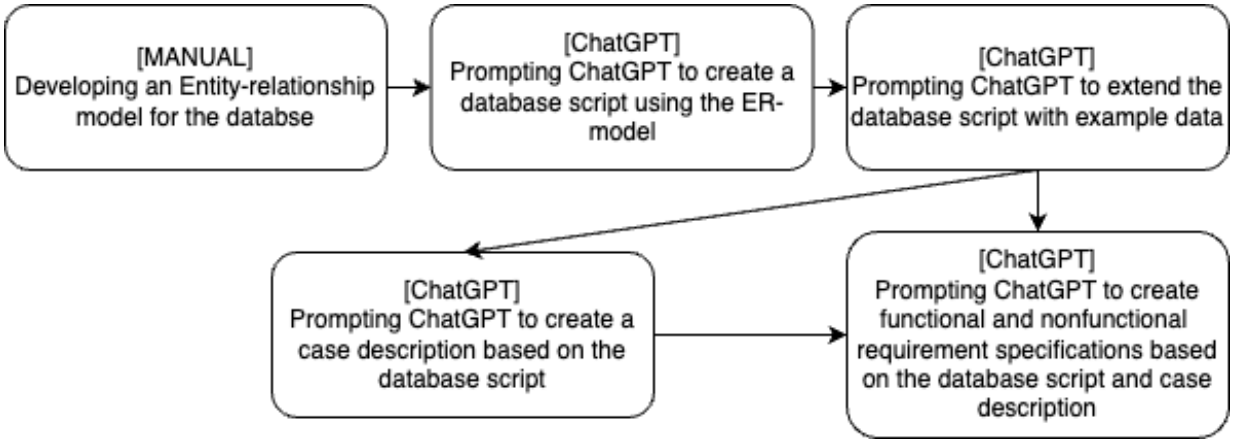


Figure 1: The course material development process

4.1 Creating the ER-Model

The first step in developing the project case was to establish a starting point that could later be used with ChatGPT. We needed something to “feed” into ChatGPT in our prompts. In this case, we opted to begin by creating an ER-model for the database. This decision was based on two main reasons, 1) We had a general idea of the case’s focus (an NGO working with the Sustainable Development Goals), but few specific details. Starting with the ER model allowed us to model the organization and discuss which entities, relationships, and other

components should be part of the system. 2) An important aspect of the course is that students work with different components of a relational database. Creating the model manually ensured that these components (e.g., different types of relationships) would be included.

Although we did not attempt it, we believe another starting point could have worked - for example, manually creating the case description and using ChatGPT to generate the database structure and requirement specifications.

4.2 Creating the Database Script

Once the initial ER-model was completed, it was uploaded, and we prompted ChatGPT to generate an SQL script containing DDL code for MySQL based on the provided image. We copied the generated code into an IDE and executed it to create the database. This allowed us to review the code for potential errors (there were none) and to understand how the completed database would appear. It also helped us evaluate whether the model required revisions, such as adding or removing elements that did not align with the course objectives.

The initial ER-model did not specify attributes for the entities and the generated DDL code included only key attributes for each entity in the model. Therefore, we revisited our ER-model, added attributes for each entity, and re-uploaded the image to the same session before prompting ChatGPT to regenerate the DDL script. This ensured that the attributes were in Swedish and included the details we required for the case. ChatGPT then generated a new SQL script, which we copied into the IDE, checked for errors or inconsistencies (there were none), and used to recreate the database.

4.3 Creating Example Data

Using the final SQL script generated by ChatGPT, we then prompted ChatGPT to create SQL code for inserting multiple rows with example data into each table. Since the case relates to the UN's sustainability goals, we asked ChatGPT to generate insert statements for the UN goals, which we then copied and pasted into an IDE, checked for errors, and executed. We followed the same process for all tables, prompting ChatGPT for relevant insert statements. Additionally, we asked ChatGPT to suggest suitable projects for an NGO working with UN sustainability goals and appropriate responsibilities for departments focusing on specific UN goals. Based on these suggestions, we created insert scripts for each table. Occasionally, we encountered issues where the amount of generated data exceeded ChatGPT's capabilities, requiring us to reduce the dataset's size. Once all inserts were generated and inserted into the MySQL database, the final step was to create an SQL dump of the entire database. We then uploaded it to ChatGPT and prompted it to:

1. Identify any errors or inconsistencies.
2. Suggest possible improvements.

Based on this, we finalized the script and added some code, including a stored procedure that would allow students to re-run the script in its entirety to revert the database to its original state whenever needed. However, the code generated by ChatGPT did not fully adhere to the ER-model. This was not discovered until the course was underway, and students using the case experienced issues when implementing the information system. The ER-model included disjoint specializations, which occur when each real-world entity can belong to only one subclass at most. When ChatGPT created the code for inserting multiple rows, it did not account for the disjoint relationships. Due to the large amount of example data generated by ChatGPT, this issue went unnoticed. Disjoint relationships are not enforced by SQL but rather handled in the Java code. Therefore, although the SQL code generated was syntactically correct, it was logically incorrect because it disregarded parts of the ER-model.

4.4 Creating a Case Description

In the next step, we used the database script to prompt ChatGPT for a case description. The description is used by the students in modeling the NGO; hence, it needed to include all aspects of the database and be detailed enough to guide the students in their own modeling work. The case description is also used in the realization part of the course to provide the students with a description of the NGO and the context for the information system they are developing. In this step, we tried several different prompts. We started with a very simple prompt:

Create a case description based on the SQL script [insert SQL script]

Unsurprisingly, the results were unsatisfactory. The results focused too much on explaining the database rather than describing the NGO. In the next iteration, we extended the prompt to include that the case description should explain the NGO rather than the database:

Create a case description of the NGO that will use this database [insert SQL script]; all aspects of the database need to be included in the description.

The result of this prompt was better but still flawed in the sense that it did not include enough detail. As mentioned, the case description was to be used by the students not only to understand the NGO but also to be able to model the NGO using ER-modeling. We again extended the prompt:

Create a case description of the NGO that will use the database included below; all aspects of the database need to be included in the description. The case description will be used by systems development students to create an ER-model of the NGO. [insert SQL script]

This prompt resulted in a case description that focused on explaining the NGO and had enough detail to enable the students to model the NGO based on it. However, the case description had two issues that needed to be fixed. The first was that it included the names of the tables in the database (the students were supposed to find the tables from the description themselves, so we did not want those included). That was easily fixed by just adding *"Do not include the names of the tables in the description"* to the prompt. The second problem was that the description did not give enough "clues" for the different types of relationships we wanted the students to model. We were also unsuccessful in updating the prompt so that the description managed to include a detailed enough explanation of all the relationships, and instead, we decided to manually update the case description with the missing details.

4.5 Creating a List of Requirements

After the case description was completed, we used ChatGPT to create a list of requirements for the students to implement. The requirements should include both functional and non-functional elements. This list essentially defines what is being assessed - that is, students are expected to implement all requirements. We started with the following prompt:

Create a list of requirements for an information system based on the SQL script below. The list should include both functional and non-functional requirements. [insert SQL script]

The results of this prompt were unsatisfactory. The requirements were either too technical or very unclear. Next, we used the same prompt but replaced the SQL script with the case description. The results were more in line with what we wanted, but many of the requirements were still unclear. Additionally, the prompt generated requirements that would be impossible to implement using the current database. In the next iteration, we asked ChatGPT to consider both the SQL script and the case description. We also clarified the purpose of the list of requirements within the prompt:

Create a list of requirements for an information system based on the case description and SQL script below. The list should include both functional and non-functional requirements. The list of requirements will be used by beginner programmers in a 6-week university course. [insert case description] [insert SQL script]

Due to limitations in how much texts that can be added in prompts, we had to divide the texts based on functionalities. The result of this prompt was much more in line with what we wanted. The functional requirements were detailed, feasible, and (for the most part) appropriately challenging for beginner programmers. For example:

Functional Requirements:

1. User Management
    - The system must allow the creation, updating, and deletion of user accounts (administrators, project managers, and staff).
    - The system must support role-based access control to ensure that users have appropriate permissions based on their roles.

However, most of the non-functional requirements were not satisfactory. This is likely because the case description and SQL script provided few clues as to what non-functional requirements would be necessary for the information system. Instead, ChatGPT included generic non-functional requirements commonly found in information systems. Examples of proposed non-functional requirements included:

- Data Encryption: All sensitive data (such as passwords) should be encrypted both in transit and at rest.
- System Uptime: The system should be operational and accessible at least 99.5% of the time, excluding planned maintenance.

The data encryption requirement would be too complex for our students, and the system uptime requirement is not relevant. We tried tweaking the prompt by adding more context (e.g., the students' level of programming experience and the type of system - a desktop system coded in Java), but we received similar results. Ultimately, we chose to manually add the non-functional requirements to the list.

5. Discussion

Similar to previous studies on the use of ChatGPT to generate course content, we are cautiously optimistic about its usefulness. We were mainly successful in generating course material, except for the non-functional requirements and relationships in the case description, which we ultimately created manually. While ChatGPT proved effective in generating coherent descriptions and initial drafts, its outputs required careful refinement to align with the course objectives. Based on our experience using ChatGPT for content development, we draw five important lessons:

1. The design of prompts is critical to the results, and it is an iterative process:

Consistent with other studies (e.g., Rouabhia, 2024; Meron and Araci, 2023), we found that prompt design is crucial to obtaining relevant results and that it is a complex process requiring iteration. In our case, only after specifying the audience (students and their level) and explicitly stating what not to include did the generated texts begin to align with our needs. We also found that the more background information included in the prompts, the better the results. For example, when generating requirements, we added the SQL script for technical requirements and the case description to provide context.

2. The hallucination effect results in misleading or false information:

The most apparent example of the hallucination effect in our case was in generating non-functional requirements. We encountered challenges in producing detailed and contextually appropriate requirements and had to manually adjust them to ensure their relevance to the course. The generated non-functional requirements were not based on the case and were not applicable to the course content. While the case description and SQL-script provided some clues as to what the non-functional requirements could be, it lacked sufficient detail. As a result, ChatGPT added generic requirements not relevant to the course - i.e., it generated misleading information (Koraishi, 2023). Our solution was to manually edit the non-functional requirements, but another option would have been to add more contextual information about the system so that ChatGPT did not need to "hallucinate."

3. Syntactic correctness is not the same as logical validity:

Generated code that is syntactically correct may still contain contextual and logical flaws that do not fully align with the underlying data model or system requirements. In such instances, the issue is not hallucination—the code is technically correct and functional, and it partially meets the stated requirements. However, ChatGPT's inability to fully account for contextual and logical constraints can cause problems when the course material is implemented. This highlights the importance of critically reviewing and validating AI-generated outputs, especially in educational contexts where implicit assumptions - such as disjoint specializations in an ER-model - may not be correctly implemented without explicit guidance.

4. Choose the correct starting point for your prompts:

In our case, we aimed to create several documents that were interconnected. We had two logical starting points: either begin with a model of the organization (an ER-model) or the case description. While starting with the case description might have worked, the advantage of manually creating the ER model was ensuring the inclusion of necessary concepts. If we had started with the case description, it is likely that several concepts would have been missing in the ChatGPT-generated ER-model - unless we included more detail than we needed. A flawed or overly simplistic ER-model would have introduced errors into all subsequent documents generated from it.

5. Using ChatGPT for content generation can save time:

We agree with previous research that ChatGPT can save teachers time in content development (e.g., Meron and Araci, 2023). Using the ER-model as input to generate the SQL script and example data was significantly faster

than doing it manually. However, both the script and the data contained errors that were only discovered during course implementation, despite our efforts to review them beforehand. However, these errors were minor and easily corrected. ChatGPT is effective at generating content with a clear structure and well-defined rules. However, generating context-dependent content, such as non-functional requirements, was more problematic. We ultimately had to create these manually, and the time spent trying to prompt ChatGPT to generate them was, in retrospect, a loss.

This study contributes to the growing body of research on AI-assisted education by offering practical insights into the benefits and limitations of generative AI in course design. We conclude that while ChatGPT can be a valuable tool for content generation, its role should be complementary rather than substitutive, requiring educators to critically engage with and refine AI-generated outputs. A human-in-the-loop approach (Guo and Wang, 2023) is essential to ensure that the content is appropriate, accurate, and aligned with the course objectives. The contributions are based on our roles as both educators and researchers. Both authors were responsible for the design, development, and implementation of the course materials discussed in this paper. This included designing prompts for ChatGPT, evaluating and refining AI-generated outputs, and manually revising components that did not meet pedagogical, of practical, requirements. Our findings are thus based on direct, hands-on experience using ChatGPT in a real-world educational setting. By documenting and analyzing this process, we contribute a practice-based perspective that complements existing theoretical and experimental research on AI-assisted education.

Ethical Declaration

Ethical clearance was not required for the research.

AI Declaration

ChatGPT has only been used for spelling and grammar correction of the texts. No text in the paper, nor any analysis, has been generated by AI.

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Investigating Robot-Assisted Second Language Teaching Under Social Interactive Education: A Systematic Review

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Abstract: Artificial Intelligence (AI) supported educational robots hold great promise for second language teaching. Robots using advanced AI capabilities such as emotion recognition and real-time feedback can create dynamic and interactive environments that improve engagement and educational outcomes. Additionally, they have the ground-breaking potential to enable personalised teaching adapted to the unique needs of different learners. This paper aims to systematically explore the recent developments of educational robots in second language learning and teaching through conducting a systematic literature review to investigate the research gaps and propose a novel framework for AI-supported personalised teaching with educational robots. This study utilised Scopus to search for recent publications (2017-2024), applying specific criteria such as keywords, publication dates, and subject areas to ensure the relevance of the results. These criteria have been carefully designed to identify high-quality research that is consistent with the scope of the study. Based on these search criteria, 25 studies were identified using the PRISMA method, which systematically screened and selected studies for inclusion criteria. The results highlight that the novelty and social interaction capabilities of educational robot design, coupled with the support of AI technology, provide language learners with engaging new learning opportunities. These robots, by incorporating advanced AI features, can simulate real-life social interactions, making language practice more immersive and motivating for learners. These opportunities enhance the interactivity of teaching sessions by instantly recognising students' questions and providing pertinent feedback. Therefore, this study suggests the benefits that AI and robotics offer for second language teaching, particularly in offering greater potential for personalised learning and interactive teaching. However, despite these advantages, this remains a key implementation challenge in integrating educational robotics with traditional teaching. The willingness of teachers to embrace educational robotics, the need to coordinate with current lessons, and the high cost of robotics are all still barriers that must be addressed. These limitations highlight the importance of further research and development to adapt different teaching environments, grounded on the initial design of the work. Future work includes a planned validation study in a second language school in Wales, scheduled for autumn 2025.

Keywords: Second Language Education; Educational Robotics; AI; Student-Robot Interaction.

1. Introduction

1.1 Background of Second Language Social Interactive Education

In the research of traditional second language teaching methods, researchers have proposed many educational theories and methods. Among them, Vygotsky (1986) proposed the theory of social constructionism, which emphasises the importance of language in society as a tool for regulating social relations. Based on the social constructionism theory, the second language social construction was derived, which suggests that the construction of linguistic knowledge is produced through socialised interaction and negotiation. Researchers proved that the social construction theory had a positive impact on students' learning of a second language learning in the classroom (Harun *et al.*, 2019; Newman and Latifi, 2021; Xiao and Zhao, 2022; Knoll and Becker, 2023). In a comfortable practice language environment, students can enhance learning through interaction and improvement (Wagner *et al.*, 2022). However, students' personal factors can affect participation in social interactive learning and influence learning outcomes (Alarnah *et al.*, 2021). It was found that the limitations of teachers' competence could not provide appropriate scaffolding for teaching because the gaps of the students were unknown (Hamidi and Bagherzadeh, 2018).

1.2 Educational Robotics in Second Language Acquisition

Following the limitations mentioned in 1.1, to date, there have been various scientific approaches to help with second language learning (Liu *et al.*, 2002; Zeng and Takatsuka, 2009). Among others, Robot-Assisted Second Language Acquisition (RASLA) receives attention for its social engagement and educational advantages (Gordon *et al.*, 2016). In second language education, improving the learning experience (Arar *et al.*, 2021) or as a social practice tool (Cheng *et al.*, 2022). However, there are limitations to a uniform method of educational robotics

teaching to students with diverse learning abilities (Kanero *et al.*, 2018). Therefore, the direction of this study is to provide the customised robotics teaching methods according to students' preferences.

There are multiple research studies to enhance interaction in RASLA through AI. Earlier studies have demonstrated the significant impact of learning companions in personalised second language learning (Gordon *et al.*, 2016). Chew and Chua (2020) found that educational robots could leverage computer vision techniques to discern students' emotions. AI also had a positive effect on the RASLA speaking part (Lin, Yeh and Chen, 2022). This paper systematically reviews the literature on educational robot-assisted second language education over the past nine years and proposes a conceptual framework of Personalised Learning Tutor (PLT). Investigating the impact of AI-supported educational robots on second language education under social construction theory.

1.3 Problem Definitions and Research Motivation

Although educational robotics has shown a positive impact in second language teaching, there are still limitations in robotics design based on the previous works in multi-facets for real-life value engineering. Therefore, designing an intelligent teaching framework for educational robotics that adapts to students' learning abilities remains a research priority.

This review presented in this paper examines the current research on the impact of robot-assisted language teaching in language education and proposes a design framework to provide personalised second language education integration. The following research questions are initially defined:

Q1. How can robots enhance second language learning?

Q2. How to design educational robotics for second language educational scaffolding?

Q3. What methods of student interaction with educational robots are effective?

Q4. How can AI assist robots in second-language education?

1.4 Research Methodology and Inclusion Criteria

Based on the research questions provided in 1.3, this study used the Scopus indexed database (2004), launched by Elsevier, to search and preview analysis of the latest literature. The keywords were identified as: '**Second language**', '**Language**', '**Educational robot**', '**Classroom**', '**Teaching**', and **'AI'**. The articles were set to meet the following criteria to be selected for the review: (1) Published in English; (2) 'Robotics in language education' was within the topic; (3) Clear and rigorous research findings were provided; (4) Published between 2017-2024. This paper follows the PRISMA Preferred Reporting Items: Identification, Screening, Eligibility, and Inclusion. The purpose of PRISMA is to help the authors critically evaluate the analysis (Sarkis-Onofre *et al.*, 2021), and the progress results in Figure 1.

A total of 1,347 literature was found on Scopus, 664 literatures before 2017 were excluded, then 625 non-educational literatures were excluded according to the research direction, then 33 literatures that were unrelated to language teaching and those that could not be viewed were excluded, and finally, a total of 25 literatures were included in this literature review.

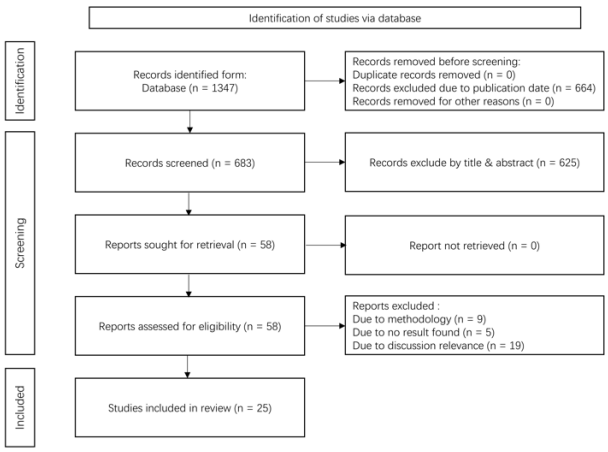


Figure 1: PRISMA diagram of data collection

2. Literature Review

2.1 Educational Robotics Supporting the Classroom

Researchers introduced educational robots in the classroom to encourage students' understanding of a second language through their interest in robots. For examples of some earlier works in this specialist area are the programmable humanoid educational robots at Monash University for Chinese Language learning, by not taking teachers' job (Chew & Chua, 2020); and LEGO Mindstorms robotics kits used by Segovia (2018) to teach six- to nine-year-olds how to complete the robotics curriculum and help students communicate in a second language. The potential of incorporating robotics and language learning was demonstrated by this research. Ververi (2020) drew on this idea to inform further research into the promotion of language learning because of students' interest in robots and the introduction of robots into the curriculum. The study reinforced the earlier findings that robots were effective at teaching and understanding. Recent studies have shown that adding the Dash robotics competition theme for young students (Lee and Chiu, 2024), with the primary purpose of allowing students to learn through hands-on manipulation and exploration. The result of measuring students' motivation through the English learning motivation scale showed an increase in motivation in English and a decrease in anxiety levels.

In contrast to traditional teaching methods, Konijn (2022) confirmed that in primary education, the use of a single robot was more effective than a combination of robots and tablets, leading to heightened student engagement and attention. Tolksdorf (2022) examined the educational effects of students switching between various educational robots during the same course, and this research found that students could quickly adapt to new robots. Feng and Wang (2023) used the e-reading mode of the educational robots with audio e-books and character-play-based reading, and the results showed that interesting interaction is the main factor affecting the reading effect. In addition to the help of the educational robots, the motivation to read, the amount of reading, and the ability to learn independently have been significantly improved. Liang and Hwang (2023) proposed a robot-based digital narrative telling method (DST) to enhance multimodal narrative competence and engagement in English language learners. Compared to students using the traditional animated DST method, the DST significantly improved students' speaking skills and outperformed the traditional method in terms of interaction. In addition, in terms of communication comprehension and engagement, the robot DST method also showed better results than the traditional method in terms of communication comprehension and engagement.

2.2 Robotics Education Scaffolding

To help students learn second languages, Jones and Castellano (2018) investigated the effectiveness of using the NAO robot as an autonomous educational tutor in self-regulated learning for primary school students. The results showed that students can quickly learn how to use the educational robots to study a second language through scaffolding. Demir-Lira (2020) used scaffolding guidance on another display to study the NAO robot as a tutor to teach vocabulary words to children. The robot's verbal cues helped these learners to learn more effectively. Additionally, the integration of educational robots and the Internet of things could create interactive teaching textbooks that visually and audibly pique students' interest in learning vocabulary, which in turn leads to a positive emotional state in students and a significant improvement in learning outcomes (Lin *et al.*, 2022).

2.3 Student-Robot Social Interaction

Educational robots with social interactive skills have earned interest in making learning more engaging. Vogt (2017) found that the body movements of the NAO humanoid robot can stimulate students' interest in learning. Moreover, Kory Westlund *et al*. (2017) explored the impact of a robot's performance, such as tone and emotion, on student learning. This study found that emotionally supportive interactions help students learn. Gavrilova (2019) uses the OP2 robot to teach English vocabulary to preschool students by simulating a story environment through robots. Arar *et al.* (2021) used the EMYS robot head to study the effectiveness of language learning supported by facial expressions and found that the social interaction of the robot's facial expression capabilities was helpful for students' learning. Similarly, Estévez *et al*. (2021) demonstrated that social robotics could improve students' English vocabulary comprehension. In addition, Aguilera *et al.*, (2024) designed a voice-controlled robotic system for early education and tested it on children aged four to six years old, giving voice commands through verbal ability, thus demonstrating the many possibilities of early education robots. However, not all social interactions are accepted, Yin *et al.*, (2024) used the educational robot AlphaMini to do educational

testing with 6–7-year-old students using word cards interacted with the robot, but the robot's social behaviours, such as gesture movements, did not have an impact on learning. The voice interactions were the most effective in increasing learning gains.

2.4 Intelligent Educational Robot Perception and Feedback.

AI supports robotics through vision (cameras), and interactive conversations (deep learning, mics and speaker of a robot), are a better design at understanding students' learning positions and showing the potential for personalised teaching. Tuna and Tuna (2019) use of NAO robots that are capable of multilingual interaction with the help of artificial intelligence and can provide real-time feedback can provide a positive impact on learners and uncover the possibilities of humanoid robots in second language teaching. Chew and Chua (2020) also used the NAO robot to explore the possibilities of a robotic Chinese language teacher, noting that AI-supported emotion detection features can be effective in providing feedback to enable students to have a positive attitude toward learning. Similarly, Hakim (2022) explored the effects of AI-supported robots providing proper feedback in language teaching and observed substantial increases in student engagement and motivation. Hsu *et al.* (2023) found that AI photo identification systems significantly improved scholar self-regulation and reduced learning anxiety. Fung *et al.* (2024) developed an educational robot system on vocabulary, phrases and sentence expansion aspects, tested on 6–10-year-old students from the same primary school and reviewed by the teacher. This study also demonstrates that the feedback provided by AI support enhances learners' interest in learning. The above authors argue for a similar approach, which is the positive engagement of the learning innovation and personalised support.

Recent studies have demonstrated how AI, particularly Natural Language Processing (NLP), is being integrated into educational robotics to enhance second language teaching. Obadia *et al.* (2024) developed a low-cost robot with NLP capabilities that can naturally answer students' questions, thus assisting student-robot interaction. Similarly, Baksh *et al.* (2024) introduced a customisable low-cost social robot to provide multimodal interaction to increase student engagement. This study has shown that NLP can support robotics to play a tutor in learning companions. Furthermore, Hu, Fu and Yeh (2024) explored the effectiveness of AI-supported educational robotics which used NLP and machine learning, by analysing students' feedback and learning data, the robot can adapt teaching methods to students' needs, thus achieving a similar level of teaching as a human teacher. These studies highlight how AI-supported educational robotics enables natural interactions and personalised education with students' data. However, future research is still needed to assess the effectiveness of robotics in different learner situations and contexts.

3. Discussion and Initial Design

In total, 25 papers were selected for this review to answer the four questions about educational robot in language teaching in 1.3. they are categorised as below. Table 1 categorises the results of this literature review. The literature review highlights the advantages and potential of educational robots in second language teaching. A key finding is that integrating educational robots into the learning process can effectively inspire students to engage in language acquisition. Their unique features stimulate curiosity, encouraging interest in second language learning (Segovia, 2018; Ververi, 2020; Lee and Chiu, 2024). There are also studies that point to the ability of robots to have more appeal compared to virtual devices such as tablets (Konijn 2022). A such this advantage is because the interactivity of educational robots, such as gestures, movements and facial expressions, and other social actions positively impact second language teaching (Vogt *et al.*, 2017; Gavrilova *et al.*, 2019; Yin *et al*., 2024). With the social interactivity of educational robots, student interaction in the classroom has also improved (Arar *et al*., 2021). At the same time, in the student and robotics interaction, the robot can assist in simulating the language situation, thus enhancing the students' learning experience and learning effect (Liang and Hwang, 2023).

Table 1: Literature Review Categories

Literature Categories	Count	References
A. Educational robots second language class scaffolding	3	Jones and Castellano (2018). Demir-Lira, *et al.* (2020). Lin, *et al.* (2022)
B. Practising the second language in robotics teaching tasks	3	Segovia and Souza (2018); Ververi, *et al.* (2020) Lee and Chiu (2024)
C. Comparison of educational robots with other teaching tools	4	Konijn, *et al.* (2022). Tolksdorf, *et al.* (2022). Feng and wang (2023). Liang and Hwang (2023)
D. Robot's social interaction enhances second language teaching	7	Vogt, *et al.* (2017). Kory Westlund, *et al.* (2017). Gavrilova, *et al.* (2019); Estévez, *et al.* (2021) Arar, *et al.* (2021); Aguilera *et al.* (2024); Yin *et al.* (2024)
E. Machine Learning in AI in Language Education Robotics	8	Tuna (2019). Chew and Chua (2020). Hakim, *et al.* (2022). Hsu, *et al.* (2023). Fung, *et al.* (2024). Jobaida *et al.* (2024); Hu, Fu and Yeh (2024); Baksh, *et. al.* (2024)

Educational robots can also support language education with various teaching methods. Using English in courses on robotics, such as storytelling or science competitions, students could learn English vocabulary and actively try to communicate to complete robotics tasks (Segovia, 2018; Ververi 2020; Liang and Hwang, 2023). There are positive results from robot-guided language instructions, students can easily study a second language with educational robotics guidance (Jones and Castellano, 2018; Demir-Lira *et al.,* 2020; Lin *et al.*, 2022). However, the ability of robots to be suitable for more areas and more teaching scenarios is still a challenge, and research on low-cost robots is a research option to speak of the popularisation of educational robots (Baksh *et al*., 2024; Jubaira *et al*., 2024).

The most important things about educational robots are the social interaction and feedback. Researchers have conducted a lot of research on AI-powered education to support personalised feedback and learning (Tuna, 2019; Hakim, 2022). In these studies, AI methods are used for speech recognition, emotion recognition, image recognition, and voice dialogues. Emotion recognition uses machine learning models to analyse vocal tones, facial expressions and contextual cues, enabling the system to understand and adapt to the user's emotional state, and the voice dialogue system integrates advanced AI algorithms to facilitate seamless communication between users and robots, providing more engaging and intuitive interactions, these applications showcase the transformative power of AI in delivering tailored and impactful educational experiences (Chew *et al*., 2020; Hakim *et al*., 2022; Hsu *et al*., 2023; Hu, Fu and Yeh, 2024).

Large Language Model (LLM) is integrated into chat robots offers excellent potential for language education (Jeon, Lee and Choe, 2023; Pack and Maloney, 2023). These AI-supported robotics can be customised to suit the needs, learning styles, and progress of each student. By analysing the learner's actions and learning progress, these robots can personalise their teaching to provide more appropriate explanations, exercises, and feedback. Robots can also spark curiosity, respond to questions, and engage in dialogue. However, the application of educational robots in second language education is still very challenging. How to adapt educational robots to different teaching contents and whether the robots can cope with unexpected situations are also elements to be considered (Vogt, 2017). In general, the combination of LLM and educational robots has the potential to personalise language teaching.

This study introduces the Personalised Learning Tutor (PLT) framework in Figure 2, educational robots can interact with students socially (dialogues and actions) (Vogt,2017), as well as to generate personalised lessons based on students' learning needs (Chew, 2020; Arar, 2021; Wu, 2023), and the ability to realise Contextual learning through visual interaction (Lin *et al.*, 2022l Cheng *et al*. 2024). The PLT framework can provide

personalised learning content and interactions for students, and the physical presence and realistic interactions of the robots can reflect the student-robot companion for second language learning, in addition to the promise that teachers can use multiple robots to meet the challenges of personalised teaching in a multi-person classroom.

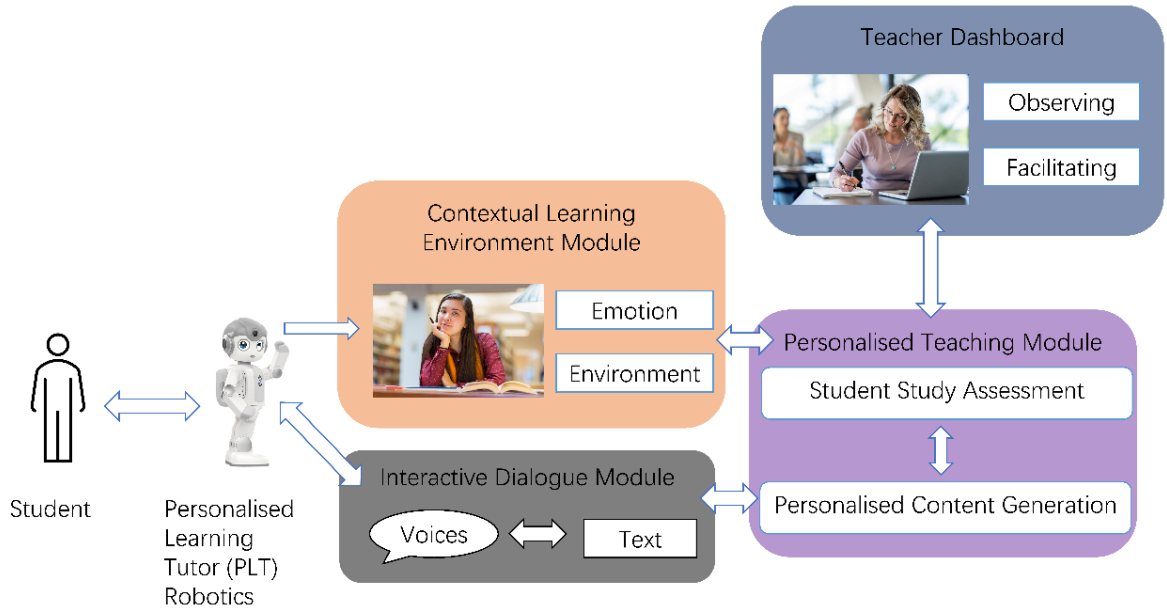


Figure 2: PLT Framework

4. Conclusion and Limitations

This research discusses the use of educational robots in second language teaching and reveals that they have an important role to play in enhancing the learning experience, improving learning efficiency, and developing students' language skills. Robots can stimulate students' interest in language learning through their socially interactive, novel teaching modes, and improve learning outcomes through personalised feedback and interaction. In addition, AI support can further enhance the pedagogical capabilities of educational robots, with sentiment analysis, free language interaction, and dynamic feedback providing more appropriate learning support for students. Low-cost educational robots also offer the possibility of universal access. However, robots should provide educational support rather than completely replace teachers' job, even though educational robots have evolved from teaching tools to participants in teaching, and robots can provide comprehensive teaching, but further research is needed in the future to clarify the role and tasks of robots in teaching. As a result, research on educational robots should not only be technologically upgraded but also integrated with conventional pedagogy for effective teaching implementation.

Therefore, in future research, how to make the robot accurately provide the teaching content needed by students is the key to personalised teaching. Secondly, further research can be done in the interaction of the robot so that the robot can do the interaction with the objects in the real environment through the camera. In addition, the different abilities of students in different countries and regions need to be considered, and the applicability of the PLT framework needs to be verified.

Although studies have found that educational robots have good results in second language education, there are still some limitations in current research on AI educational robots. Firstly, many studies focused mainly on short-term experiments in a controlled environment, limiting the generaliasbility of robots in real classrooms, and the effectiveness of educational robotics in long-term learning engagement has not been fully explored. Secondly, while robotics can offer the potential to personalised education, its suitability for different learning styles, and ages remains unclear. Educational robots depend on limited data inputs, which may not reflect the real classroom complexity. Finally, there is a lack of evaluation of ethical issues, especially the learner data security and potential bias in artificial intelligence algorithms are critical to developing student-robot interaction,

therefore, ethical design standards that comply with the General Data Protection Regulation (GDPR) need to be discussed in future research.

Ethics Declaration

This paper is a literature review and did not involve any participants, and the study was not subject to ethical review.

AI Declaration

The use of AI for articles was limited to vocabulary and grammar checking and corrections.

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Evaluating WEBPOSE: A Posture Feedback System for Oral Presentations

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Abstract: Effective oral communication is a crucial skill in academic and professional contexts. However, practising and refining these skills is challenging without structured guidance and feedback. This paper presents a user evaluation of WEBPOSE, a web-based Oral Presentation Automated Feedback (OPAF) system that provides immediate feedback on posture to improve non-verbal communication skills. In this study, WEBPOSE was tested with sixteen researchers specialising in educational technology. Using a mixed-methods approach, which included a Technology Acceptance Model (TAM) questionnaire, open-ended questions, and observational data, we investigated the perceived user experience, usability, and usefulness of the system. The results indicate that WEBPOSE was generally perceived as user-friendly and beneficial for fostering self-awareness around body language and presentation timing. Moreover, user feedback also highlighted non-functional and functional points of improvement for WEBPOSE, such as improving the visualisations of the system status, and the display of the immediate feedback. This paper concludes with design implications for improving user guidance, feedback mechanisms, and the integration of structured rehearsal stages. These insights aim to inform the future development of scalable, user-centred OPAF systems that can effectively support the development of presentation skills.

Keywords: Oral Presentation Automated Feedback System, public speaking, Technology Acceptance Model, automated feedback, WEBPOSE, Educational Technologies, user acceptance.

1. Introduction

Effective communication is a cornerstone of success in both personal and professional life. Among its many facets, public speaking stands out as a particularly vital skill in the 21st century, playing a crucial role in situations such as job interviews (Patil and Katre, 2024), negotiations (Svendsen, 2022), and collaborative work (Chan, 2011). However, mastering public speaking is no easy task. It requires deliberate practice to master communication aspects such as body language, tone modulation, and speech clarity (Kerby and Romine, 2009).

Several methods are available to support the development of these skills. Practicing in front of a mirror is a simple but limited strategy due to its lack of feedback (Levasseur, Dean and Pfaff, 2004). Video recordings offer more value by allowing for self-reflection and targeted improvements (Zimmerman and Schunk, 1989); however, watching the recorded videos is time-consuming, and novice presenters have trouble identifying points for improvement (Korthagen et al., 2001). Additionally, one-on-one coaching with feedback from instructors remains highly effective due to its personalized guidance (Heinicke et al., 2022).

Recent technological advances have led to the development of Oral Presentation Automated Feedback Systems (OPAFs) (Ochoa, 2022). These software tools utilise sensors such as cameras and microphones to automatically evaluate presentation performance and support the development of communication skills (Kurihara et al., 2007). While promising, OPAFs have not yet achieved widespread adoption (Ochoa and Zhao, 2024). Many remain at the prototype stage and are typically evaluated only in laboratory settings due to the use of specialized hardware like depth cameras, which are not accessible to the general public. In a prior study (Hummel et al., 2025), we found that 13 out of 14 systems were tested exclusively under such conditions, leaving open questions about their real-world applicability.

To address this gap, we developed WEBPOSE (Web-based Evaluation of Body Posture for Oral Skill Enhancement), a system that focuses on improving non-verbal communication through immediate posture

feedback. The system was informed by the expertise of public speaking instructors and grounded in relevant literature.

In this study, we conducted user tests to evaluate WEBPOSE based on perceived user experience, ease of use, and usefulness, with the aim of having a formative evaluation that will allow us to understand the current maturity status of WEBPOSE and how to improve it in future iterations.

To guide this evaluation, we address the following research questions:

RQ-MAIN: What is the perceived general user acceptance of WEBPOSE?

RQ1: What is the perceived usability of WEBPOSE?

RQ2: What is the perceived usefulness of WEBPOSE?

RQ3: How can we improve WEBPOSE based on the test results?

2. WEBPOSE: A Web-based OPAF System

WEBPOSE is a web-based application designed to support the development of non-verbal communication skills for presentations. The purpose of making it a web-based application is that it can run on regular PCs, laptops, tablets, and smartphones without the use of any specialized hardware and thus minimizing its accessibility barriers.

Experts' input inspired WEBPOSE by following a human-centered design approach to provide immediate feedback on improper postures, such as crossed arms (as shown in Figure 1). The goal of WEBPOSE is to enhance non-verbal communication skills and become a more effective presenter. WEBPOSE offers the ability to run either globally (hosted on a server) or locally (on a client machine). WEBPOSE was designed to minimize accessibility barriers by utilizing standard sensors over specialised equipment, which are now built-in even in low-budget devices like budget notebooks or Smartphones, combined with a simple User Interface (see Figure 1).

2.1 Pedagogical Approach and Technical Implementation

WEBPOSE was developed based on insights from a preliminary study involving interviews with 13 university teachers specializing in presentation skills (Blinded for review. What is most important when giving a presentation? Authenticity! - Insights on how presentation teachers imagine a software to help with presentation preparation and presentation skills training).

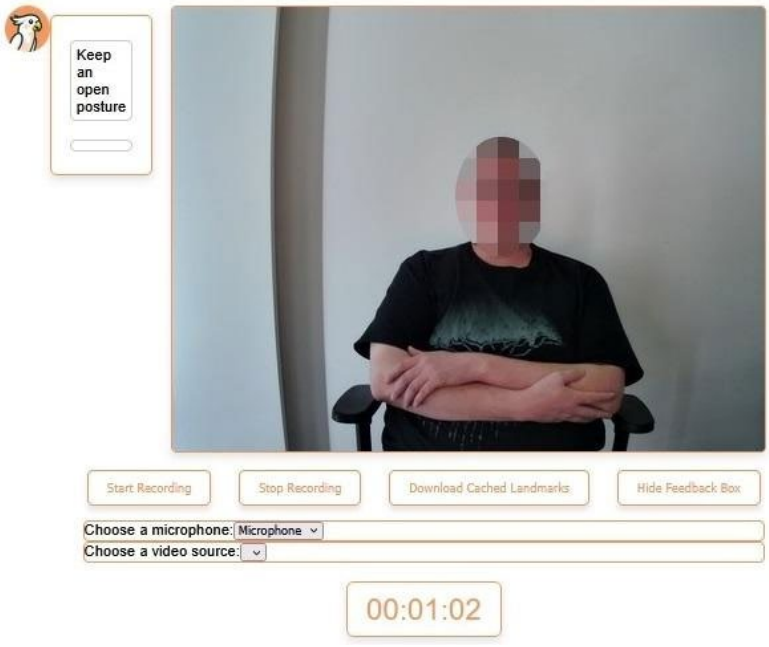


Figure 1: WEBPOSE in action, providing immediate feedback on posture patterns, e.g., when crossing arms.

Our interviews with university teachers revealed that improving non-verbal communication skills is crucial for enhancing overall presentation performance [Blinded for review. What is most important when giving a presentation? Authenticity! - Insights on how presentation teachers imagine a software to help with presentation preparation and presentation skills training].

As mentioned by Brooks and Platz (1968), rehearsing presentations is a widely recognized method for enhancing public speaking performance. It involves repeatedly practicing a talk in a realistic setting to become more familiar with the content, structure, timing, and delivery. Through rehearsal, speakers can refine their verbal communication, improve clarity and confidence, reduce filler words, and become more aware of their body language and vocal tone. Practicing also allows presenters to identify weak points, adapt their message to the audience, and reduce performance anxiety. WEBPOSE supports this process by enabling users to record their pitch using a webcam and microphone while receiving feedback about their posture (see Figure 1). By reviewing these recordings, users can self-assess and observe how their delivery comes across, gaining insights into aspects such as eye contact, pacing, and gesture use. This reflective loop encourages iterative improvement and builds stronger presentation habits over time. The goal is to help users become more confident, engaging, and effective communicators by offering a practical and feedback-driven way to rehearse and improve their presentation skills.

In addition to non-verbal skills, it is important to manage time effectively. For many types of presentations, such as thesis defences or conference talks, it is essential to convey your message within the specified time frame. Significantly exceeding the allotted time is usually penalised in these contexts and should therefore be avoided. To support this, our software features a stopwatch to provide users with real-time feedback on elapsed time (see Figure 1 - 1 minute and 2 seconds have already passed). This stopwatch is triggered when the user presses the “Start Recording” button, which also signals the start of the presentation. The goal is to help presenters optimise their presentations to fit within the given time limits.

2.2 Technical Features of WEBPOSE

To provide immediate feedback on specific body postures, WEBPOSE utilizes a webcam to capture the presenter and extract visual data, which is then fed into a pre-trained machine learning model (specifically, the pose estimation model from the Google MediaPipe framework is used by WEBPOSE). Google decided to call this model “BlazePose”, which is capable of detecting a human pose in a video stream and outputting the x, y, z coordinates of 33 joints related to the human body (Bazarevsky et al., 2020). These coordinates can then be used to identify certain patterns.

Designed with flexibility in mind, WEBPOSE supports both server-based and fully client-side operation, accommodating different educational contexts and privacy requirements. For institutions or instructors who prefer centralised access and management, the system can be hosted on a server, following a model similar to that of well-established platforms such as Moodle. Alternatively, for scenarios where data privacy, offline use or unreliable internet connectivity are important considerations, WEBPOSE can run entirely on the client side. In this configuration, all necessary files (HTML, CSS and JavaScript) are executed locally on the user's device, eliminating the need for an internet connection and ensuring that no personal data leaves the user's computer. We used this client-side mode during our study. The interface is intentionally minimalistic and features four core functions (see Figure 1): starting and stopping a video record + starting and resetting a stopwatch (both events are triggered simultaneously), downloading cached pose data (X, Y and Z coordinates in JSON format) and toggling the live feedback display on and off.

The underlying data pipeline of the software (see Figure 2), comprising sensing, analysis, and feedback, was designed to be straightforward to ensure intuitive operation and avoid overwhelming users. It provides feedback on posture-related patterns that according to literature (Blinded for review. What is most important when giving a presentation? Authenticity! - Insights on how presentation teachers imagine a software to help with presentation preparation and presentation skills training) (Schneider et al., 2017), negatively influence the performance of a presentation, such as crossing arms, crossing legs, looking away from the camera, covering face, hands inside pockets, and hands behind the back. To implement these postures, WEBPOSE uses hard-coded thresholds and heuristic conditions based on joint positions provided by the BlazePose pose estimation model. For example, to detect crossed arms, the system compares the relative x- and y-coordinates of wrists, shoulders, and hips to determine whether the arms are positioned across the torso. If the conditions are met, the system immediately displays visual feedback prompting the user to adjust their posture.

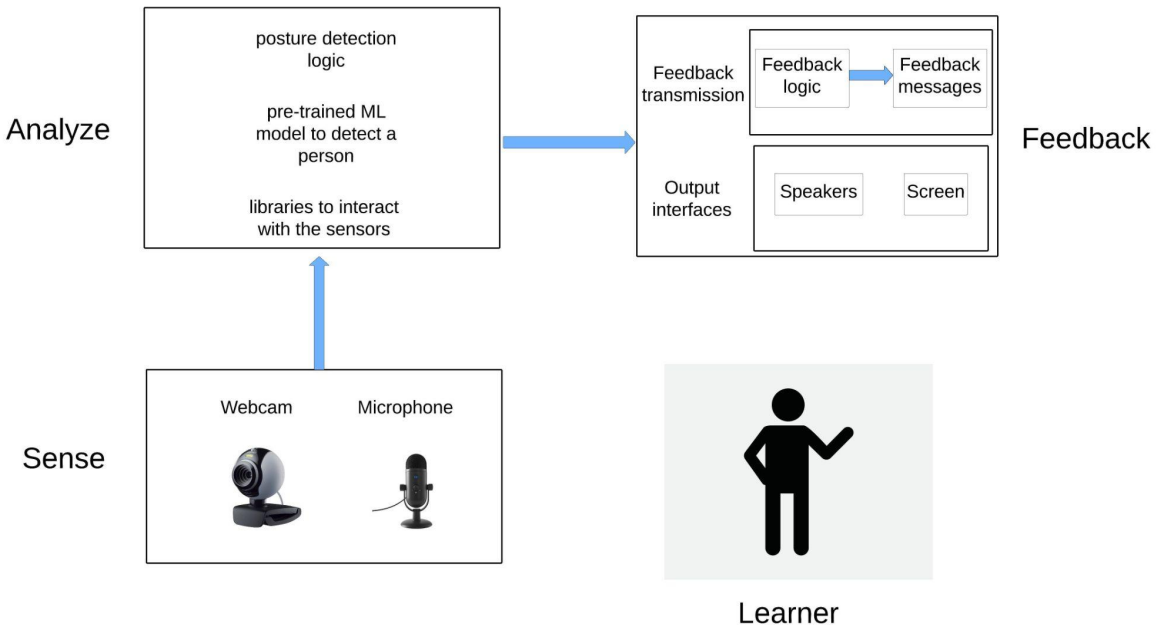


Figure 2: Internal data processing of WEBPOSE from Sensors to Feedback

3. Method

The purpose of this study is to evaluate how users use and perceive WEBPOSE.

3.1 Participants

The study involved 16 participants who worked as researchers in educational technologies or similar fields. The participants ranged in age from 26 to 54 years, with self-reported gender distribution of 3 male and 13 female. All participants signed an informed consent to participate in the study.

3.2 Procedure

The study took place within the context of a 90-minute workshop on presentation competencies at a summer school for researchers in educational technologies. The procedure started with a general introduction (15 minutes) about the concept of the project in which the study was situated, and the study procedure. After the introduction participants filled in a pre-test questionnaire (see section 3.3). Participants were then asked to prepare a 3 to 5-minute-long elevator pitch following some guided instructions. Once they finished the preparation of their pitch, participants had the chance to practice their pitch using WEBPOSE. After practicing the pitch, participants had the opportunity to review their practice sessions and answer self-reflection questions. Finally, participants answered a post-test questionnaire (see section 3.3).

3.3 Apparatus and Materials

Set-up: The study took place in the main hall of the event venue. Each of the four corners of the room was equipped with a table, a laptop running WEBPOSE, and a wireless microphone paired to the corresponding Laptop.

To collect data, we used a pre-test questionnaire, a post-test questionnaire, logged data, and notes taken by the experimenter. The pre-test questionnaire included demographic questions such as age and gender. The post-test questionnaire included a TAM survey and six open-ended questions concerning the usability and user experience of WEBPOSE (see Table 1).

4. Results

To assess the participants' acceptance of WBPOSE, we asked them to answer the Technology Acceptance Model (TAM) questionnaire. Based on these answers we used descriptive statistics to extract the Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) of WEBPOSE.

The mean score for Perceived Usefulness was 4.99 (SD = 1.25), and the mean score for Perceived Ease of Use was 5.03 (SD = 1.14), both on a 7-point Likert scale. Internal consistency was evaluated using Cronbach's Alpha. The PU scale demonstrated excellent reliability with an alpha of 0.959, and the PEOU scale also showed strong internal consistency with an alpha of 0.906.

Figure 4 illustrates the distribution of Perceived Usefulness ratings, which ranged from 2 to 7 and tended to cluster in the upper half of the scale. This indicates that participants generally perceived WEBPOSE as beneficial, though responses varied. Figure 5 shows the distribution of Perceived Ease of Use ratings, also ranging from 2 to 7, with a similar tendency towards higher values. This suggests that participants considered the system easy to navigate and user-friendly.

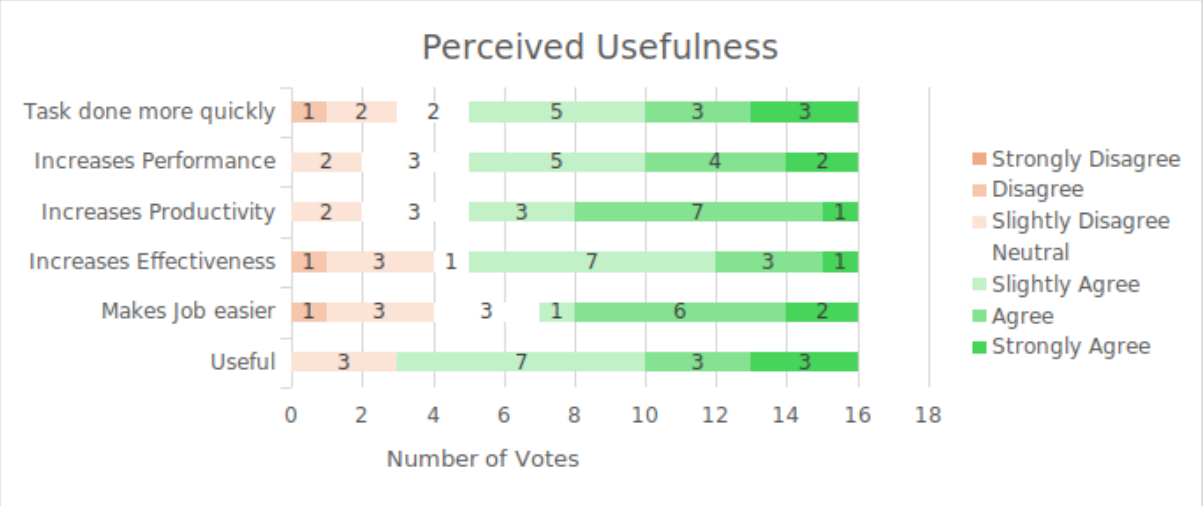


Figure 4: Distribution of Perceived Usefulness (TAM) ratings of all 16 participants on a 7-point Likert scale.

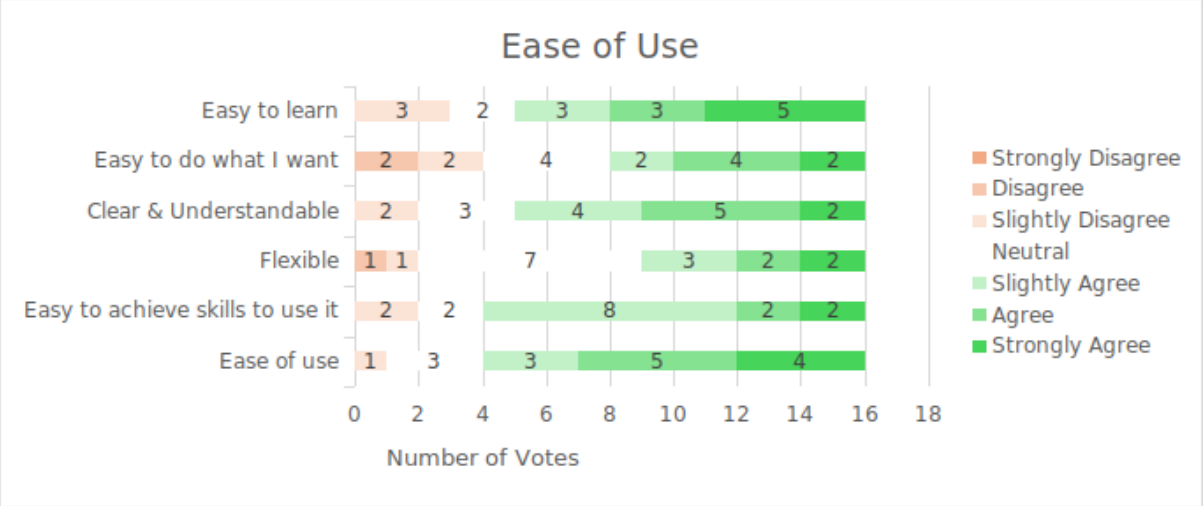


Figure 5: Distribution of Perceived Ease of Use (TAM) ratings of all 16 participants on a 7-point Likert scale.

To examine how participants used WEBPOSE, we looked at the log data obtained from their interactions with the software. On average, participants took 140 seconds (SD = 66 seconds, median = 136 seconds) to complete their pitch. This corresponds to an average overrun of 20 seconds beyond the intended 2-minute timeframe. The shortest pitch lasted 45 seconds, while the longest extended to 283 seconds.

We asked the following open ended questions on the post-test questionnaire to gain qualitative insights about WEBPOSE:

- Q1: What are three things you would improve about WEBPOSE?
- Q2: What are the three things you liked most about WEBPOSE?
- Q3: What do you think about the system's immediate feedback? How would you make it more beneficial in terms of content and visualization?

- Q4: What do you think about the self-reflection tasks? How would you make it more beneficial in terms of content and visualization
- Q5: What, if anything, did you learn from using this software?
- Q6: Any extra comments you would like to add?

By examining the answers to the first two open-ended questions concerning future improvements and what participants liked about WEBPOSE, we identified three categories of answers: guidance, usability, and look & feel.

Guidance: WEBPOSE seems to be a system whose navigation is easy and self-explanatory. One participant commented that the buttons required more explanation. Another one commented that WEBPOSE would benefit from a general explanation of its purpose and the tasks that the user should follow. The remainder of the participants shared positive impressions about the navigation and guidance of WEBPOSE.

Usability: Participants generally mentioned that WEBPOSE was easy to use. Four participants explicitly mentioned to like the low barrier that the software can be used immediately with no additional hardware/sensors. One usability complaint that we got was related to the fact that participants needed to start the recording, then step back a few meters to start rehearsing the pitch, and then approach the laptop again to finish the recording. Three users pointed out the need for a more visible indication to know when the recording started.

Look and feel: Four participants mentioned that they liked the colors and our parrot avatar presented by WEBPOSE. Moreover, they appreciated the simple design and the fact that everything ran flawlessly.

Feedback (Q3): Regarding the software's feedback aspect, two participants explicitly mentioned that they liked the aspect of getting real-time feedback on their posture. Two other participants explicitly mentioned their positive experience with the timer feature. Five participants stated that if they got feedback, they did not notice it. Suggestions on how to improve the feedback included: increasing the size of the feedback messages (3 participants) and adding an animation to the feedback messages (4 participants).

Concerning the self-reflection tasks (Q4): Four participants appreciated the ability to re-watch the recorded videos and evaluate themselves using the provided self-reflection questions. Three participants mentioned that they find our chosen self-reflection questions beneficial. In terms of improvements to the self-reflection of the system, three participants mentioned that they would want to combine the self-reflection questions with other feedback aspects, such as expert feedback and automated software feedback. Two participants mentioned they prefer a Likert scale option instead of open self-reflection questions.

In terms of perceived learning (Q5), participants reported that using the software helped them become more aware of their body language, such as closed posture, nervous appearance, insufficient eye contact, or gestures. Three participants noted the value of seeing their recordings to identify areas for improvement and acknowledged the importance of rehearsing their pitches.

As additional comments (Q6), four participants encouraged the team to continue developing WEBPOSE further.

When examining the notes taken during the study, we identified that three participants vocally expressed discomfort and a lack of confidence in presenting to a laptop. Three participants expressed their dislike of watching their recording. Finally, six participants required help from the experimenter in order to fulfil their tasks.

5. Discussion

This section discusses the key findings in relation to the research questions, incorporating participant feedback, observed challenges, and contextual limitations.

Our Main RQ deals with the general user acceptance of WEBPOSE, and to answer it, we broke it down into the general usability (RQ1) and the perceived usefulness (RQ2) of WEBPOSE. Based on the collected quantitative data (TAM), WEBPOSE is relatively easy to use. Our qualitative results showed that in terms of usability, the navigation and general visual design are aspects that positively influence the user experience of WEBPOSE. Moreover, the low entry barrier, meaning that WEBPOSE can be used without the need for specific hardware, is a positive feature affecting how the general public can experience the use of WEBPOSE.

Concerning the perceived usefulness of WEBPOSE, the collected quantitative data (TAM) show that WEBPOSE is generally perceived as a useful tool. Particularly, due to its real-time feedback and self-reflection features, which can support the improvement of non-verbal communication habits when giving a pitch or presentation. So overall, we can state that the user experience of WEBPOSE is acceptable (Main RQ).

The study also showed us how WEBPOSE can be improved (RQ3). In terms of usability, the recording process can be improved, first, by highlighting when WEBPOSE is recording and assessing the rehearsal. Second, by adding a different interaction mechanism that allows users to start and stop recordings once they are at the correct distance to perform their rehearsals. Examples of these mechanisms can be countdown timers or the use of predefined voice commands, and/or gestures. In terms of usefulness, the biggest point of improvement relies on a careful implementation of the immediate feedback, so that it becomes highlighted enough to be perceived without becoming overly distracting, as pointed out by (Schneider et al., 2015)

While the findings offer valuable insight into the user experience of WEBPOSE, several limitations should be noted. Notably, most of the participants were fellow researchers from the field of educational technology. Their familiarity with educational technology prototypes may have influenced their responses, as reflected in some encouraging or congratulatory remarks, which may have stemmed from a sense of collegial support. Their background may also have impacted their ability to engage with the system critically, compared to lay users or students.

Another limitation was the constrained timeframe of the workshop. Participants were only able to go through one rehearsal cycle, which restricted the ability to measure iterative improvements. Although many users expressed interest in rehearsing multiple times, time constraints prevented a second round. Nonetheless, based on our results we argue that rehearsing a speech with the use of WEBPOSE is perceived to be valuable.

To sum up, this study presented a first formative evaluation of WEBPOSE, displaying its potential as an easily accessible OPAF that can support the development of public speaking skills, which are vital 21st-century skills and a cornerstone of success in both personal and professional life.

6. Conclusion

This paper presented a formative evaluation of WEBPOSE, a web-based system designed to provide posture-related feedback during oral presentation rehearsals. Based on a study conducted with sixteen researchers in educational technology, the findings demonstrate that WEBPOSE is generally well-received, offering a user-friendly and accessible way to support the development of non-verbal communication skills.

As one of the first OPAF systems tested in a real-world setting without specialized hardware, WEBPOSE contributes to closing the gap between lab-based prototypes and practical, scalable tools. Its low setup requirements, ease of use, and integration of self-reflection capabilities make it a promising candidate for broader application in educational and professional training contexts.

At the same time, the evaluation revealed several opportunities for improvement. Enhancing the visibility and clarity of feedback, refining the recording interaction, and offering clearer user guidance emerged as key areas to address in future versions. Furthermore, combining real-time feedback with expert-driven insights or structured reflection stages may further increase its educational impact.

Future research should explore the longitudinal use of WEBPOSE across multiple rehearsal cycles and with more diverse user groups, including novice presenters and students. Investigating the impact of such systems on actual learning gains and presentation performance over time remains an important next step.

In summary, this study highlights the potential of accessible, web-based feedback systems such as WEBPOSE in supporting the development of oral presentation skills, which are becoming increasingly important in modern education and professional life.

Ethics Declaration

This study was conducted in accordance with the ethical standards of research involving human participants. All participants were informed about the purpose and procedure of the study and provided written informed consent prior to participation.

AI Declaration

Portions of this paper were prepared with the assistance of the AI language model ChatGPT (OpenAI, GPT-5). The tool was used to improve the clarity and conciseness of the language, to refine sentence structure, and to suggest alternative phrasings. All AI-generated suggestions were critically reviewed and edited by the authors, and the final content reflects the authors' own analysis and conclusions.

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[under review] What is most important when giving a presentation? Authenticity! - Insights on how presentation teachers imagine a software to help with presentation preparation and presentation skills training

A Case Study on Transition From Teacher-Centered Learning to Online, Asynchronous Learning

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Abstract: The transition from teacher-centered to online, asynchronous learning represents a significant shift in educational paradigms. Traditional teacher-centered approaches, characterized by direct instruction and passive student roles are being increasingly replaced by asynchronous online models that prioritize learner flexibility and engagement. This shift allows students to access content at their own pace and encourages self-directed learning. While the flexibility of asynchronous formats can empower students and accommodate diverse learning styles, the lack of real-time interaction may lead to challenges in motivation, time management, and reduced opportunities for immediate feedback. Adapting to online, asynchronous learning can be challenging and can have varying levels of ease and difficulty. There is a lack of information in this regard when it comes to the learners' perspective. This study attempts to provide insights on the shift from traditional learning to modern online, asynchronous learning by analysing the results of a group of students which followed an elementary mathematics module as per the requirements of a degree programme in information technology offered by the University of Moratuwa, Sri Lanka. The cohort of students came from varying backgrounds and streams of study. However, all students in the group had obtained at least a credit pass for mathematics at the GCE Ordinary Level examination (secondary school) and passed the GCE Advanced Level (high school) examination. The preliminary results indicated a significant positive correlation ($r=0.287$, $p<0.001$) between the marks obtained for mathematics at secondary school and marks obtained at the university. The findings of this study provide insights on the learners' experience on transition from teacher-centered learning to online asynchronous learning. Furthermore, the study proposes best practices to be adopted to ensure a smooth transition.

Keywords: Distance Education, Online Asynchronous Learning, Self-directed Learning, Teacher-centered Learning, Educational Paradigm Shift

1. Introduction and Background

The transition from teacher-centered instruction to online, asynchronous learning marks a significant shift in pedagogical practice, with implications for learner engagement, autonomy, and instructional design. Traditional models emphasize instructor-led delivery and passive student roles, whereas asynchronous formats promote self-directed learning and flexible access to content. Despite these advantages, challenges such as reduced real-time interaction, motivation, and time management persist. This paper presents a case study from the University of Moratuwa, Sri Lanka, examining how a cohort of undergraduate students adapted to asynchronous learning in an elementary mathematics module.

The transition to asynchronous learning is underpinned by key instructional theories that advocate for learner autonomy and digital engagement. Constructivism promotes active, self-directed learning, where learners build up knowledge through experiences and reflection (Alam, 2023). Such an approach corresponds effectively with asynchronous learning frameworks, which emphasize self-directed learning. This emphasis is especially important in mathematics education, where conceptual understanding develops progressively. Complementing this, connectivism highlights the role of digital technologies and social networks in facilitating learning beyond the physical classroom (Alam, 2023). These theories collectively justify asynchronous learning as a deliberate, contextually appropriate design rather than a makeshift alternative to real-time instruction. Observational evidence further reinforces this shift. Comparative studies of teacher-centered and student-centered instructional models indicate that student-centered approaches are grounded in constructivism and connectivism as learning theories. These approaches are linked with increased engagement, enhanced conceptual understanding, and superior academic performance (Alam, 2023). These findings support the relevance and effectiveness of learner-centered asynchronous learning environments in higher education.

The effectiveness of asynchronous learning has been widely compared across disciplines, especially in mathematics, where conceptual continuity is critical. (Libasin, et al., 2021) conducted a study comparing academic performance between synchronous and asynchronous online learning modes during the COVID-19

pandemic. Their findings revealed a statistically significant difference, with students in synchronous settings outperforming their asynchronous peers (mean scores of 79.31 and 74.86 respectively; $p = 0.004$), highlighting the potential performance gap attributed to mode of delivery. Asynchronous learning allows students to study at their own pace and engage deeply with content. At the same time, it demands strong self-regulation and can increase feelings of isolation (Libasin, et al., 2021). These insights are particularly relevant in the context of mathematics education, where (Libasin, et al., 2021) suggest that the suitability of a learning mode may vary by subject. Their study underscores the need to evaluate how asynchronous environments affect learner outcomes, especially in theoretically intensive subjects.

(Awacorach, et al., 2021) highlight that transitioning from teacher-centered to student-centered models such as Problem-Based Learning (PBL) can significantly enhance students' research capabilities and employability. Through engagement with real-world community problems, students developed critical thinking and practical skills, suggesting that learner-centered approaches have value beyond academic performance. This aligns with asynchronous learning environments, where students often work independently on problem-solving tasks. The study further highlights that reallocating responsibility from instructors to students fosters learner autonomy; however, elements of traditional hierarchical structures continue to persist in some learning environments (Awacorach, et al., 2021). These findings resonate with the challenges faced in asynchronous models, where students may struggle if accustomed to directive instruction. Finally, the success of student-centered transitions like PBL depend heavily on institutional and instructor readiness. Researchers identified barriers such as low digital literacy among faculty and infrastructural constraints. These findings imply that asynchronous learning environments need parallel investment in educator support and technological infrastructure (Awacorach, et al., 2021).

Research on student preferences across academic disciplines indicates a clear inclination toward teaching methods that combine both teacher-centered and student-centered elements. Students consistently favored approaches such as lectures with opportunities for interaction, demonstrations followed by hands-on practice, and free-flowing classroom discussions (Murphy, et al., 2021). These findings support the notion that even in asynchronous learning environments, student engagement can be sustained by embedding interactive components like collaborative tasks or application-based exercises. In contrast, students viewed teacher-centered approaches such as impromptu quizzes, unsupported lectures, and passive media as least effective. These methods limited interactivity and reduced learner participation (Murphy, et al., 2021). This highlights the importance of rethinking traditional delivery when adapting to asynchronous modes to avoid replicating passive learning structures online. While teaching preferences may vary slightly by academic major, there is strong evidence that students across fields value methods that promote active participation, real-world relevance, and autonomy in learning (Murphy, et al., 2021). The evidence points to a critical need for structured yet adaptable instructional approaches in asynchronous mathematics modules to ensure both flexibility and sustained student engagement.

Studies comparing online and face-to-face learning environments indicate that instructional format significantly affects student performance, particularly among traditional undergraduates. One study found that traditional students were less likely to pass online courses than face-to-face courses. In contrast, non-traditional students achieved better outcomes in the online format (Spencer & Temple, 2021). This suggests that asynchronous learning may pose challenges for younger students who are still developing self-regulation skills. Despite reporting that online tools facilitated prompt feedback, enhanced problem-solving, and met their learning needs, students expressed a clear preference for face-to-face instruction (Spencer & Temple, 2021). This preference was largely attributed to discomfort in online peer and instructor interactions, highlighting a limitation of asynchronous environments. Furthermore, course structure and the effective use of instructional technology by instructors were found to be crucial factors in student success. Organized course design, regular communication, and meaningful engagement strategies significantly contributed to positive student outcomes in online settings (Spencer & Temple, 2021). The results emphasize the necessity of well-designed asynchronous instructional frameworks, especially in content areas like mathematics that demand sequential and cumulative understanding of concepts.

Recent innovations in online mathematics education highlight the importance of maintaining instructor presence and real-time interactivity to support student engagement. One study introduced a method where the instructor and content are displayed simultaneously on screen, enabling the use of eye contact, body language, and digital handwriting during live-streamed lectures (Jin, 2023). Students reported significantly higher satisfaction and engagement with this approach compared to conventional screen-sharing, suggesting that social cues and instructor visibility play a crucial role in maintaining focus during mathematical instruction (Jin,

2023). The use of real-time handwritten content improved comprehension by aligning spoken explanations with written visuals. This benefit is supported by the temporal contiguity principle in multimedia learning (Jin, 2023). These findings highlight the value of adding visual embodiment and simulated instructor presence to asynchronous learning designs. This is particularly important in mathematics courses, where high cognitive load and abstract reasoning require strong guidance.

2. Problem Statement

There is lack of knowledge on the students' transition from traditional teacher-centered learning to modern teaching and learning methods which focus on student-centered, synchronous/asynchronous online activities. It is unclear what factors may be helpful for the students to adapt seamlessly.

3. Methodology

This study employed a quantitative, observational research design to investigate the relationship between students' prior mathematics performance and their achievement in first-year university-level mathematics. The research also explored how educational background specifically A/L subject stream and geographic origin relate to academic performance in an asynchronous learning environment.

3.1 Data Collection

The dataset used in this study consisted of academic records from first-year Bachelor of Information Technology (BIT) students enrolled in the first semester mathematics module at the University of Moratuwa. Data were collected through the institutional student registration database, which included G.C.E. Ordinary Level (O/L) Mathematics results, A/L subject stream, and regional data.

Key variables included:

- O/L Mathematics grades
- A/L stream
- ITE1813 Mathematics scores
- District (inferred from A/L region)

Only students with complete and valid records were included. Those with missing or invalid A/L stream information, or those absent from the exam, were excluded.

3.2 Data Preparation and Transformation

To enable analysis, several transformations were applied to the dataset:

- O/L Mathematics grades were encoded numerically on a 1–3 scale, where A = 1, B = 2, and C = 3. Since university entry requires a minimum of a 'C' in O/L Mathematics, any lower grades were excluded from the analysis.
- A/L stream was encoded using values from 0 to 12, with higher values assigned to streams involving greater mathematical intensity (e.g., Physical Science and Combined Maths), and lower values to less mathematically intensive streams (e.g., Arts).
- Mathematics performance in the first semester module was calculated from students' grades, which were numerically estimated using the average value within each grade range.
- District information was inferred from the A/L examination region, as explicitly recorded in the registration database.
- Students with missing or ambiguous A/L stream data were excluded to preserve the integrity of group-wise comparisons.

These transformations allowed for effective application of statistical and visual analysis techniques, while ensuring that comparisons were grounded in consistent and meaningful representations of students' academic backgrounds.

3.3 Statistical Analysis

3.3.1 Normality Testing

The Shapiro-Wilk test was applied to both the O/L Mathematics grades and first semester scores to assess whether they followed a normal distribution. As both variables significantly violated normality assumptions ($p < 0.05$), non-parametric methods were prioritised in subsequent analysis.

3.3.2 Correlation Analysis

Both Pearson's correlation coefficient and Spearman's rank correlation coefficient were used to measure the association between prior performance in mathematics (O/L grades) and ITE1813 scores. These methods provided complementary insights into the linear and monotonic aspects of the relationship.

3.3.3 Group-wise Analysis by A/L Stream

The average Semester 1 mathematics score was computed for each A/L stream to explore how subject specialisation influenced mathematical performance in an asynchronous setting. Additionally, the number of students achieving an 'A' in O/L Mathematics was analysed per stream to assess foundational readiness.

3.3.4 Geospatial Visualisation

A map-based visualisation was developed using Tableau, representing average mathematics scores and O/L Mathematics grades by district. The map used marker size to indicate average ITE1813 scores, and colour gradient to reflect O/L grade averages, allowing clear geographic comparisons of academic performance.

3.4 Tools and Software

The following tools were used:

- Python (pandas, scipy, matplotlib, seaborn) – for data manipulation and statistical analysis
- Tableau – for map-based visualisation
- Microsoft Excel and Word – for data handling and documentation

3.5 Ethical Considerations

All student data were anonymised, and no personally identifiable information was used. Data access and processing complied with institutional ethical standards and relevant data protection regulations.

4. Analysis and Discussion

This section presents a comprehensive analysis of the relationship between students' prior mathematics performance at the G.C.E. Ordinary Level (O/L) and their outcomes in the first-year university mathematics module (ITE1813). The analysis also explores the impact of the asynchronous learning model adopted for this module, investigating correlations, distribution patterns, and performance trends across various demographic and academic segments.

4.1 Correlation Analysis

The statistical analysis was performed using Python. Figure 1 illustrates the code used to compute both the Pearson and Spearman correlation coefficients between students' G.C.E. Ordinary Level (O/L) Mathematics grades and their performance in the first-year mathematics module.

```
In [1]: import pandas as pd
        import matplotlib.pyplot as plt
        import seaborn as sns
        from scipy.stats import pearsonr, spearmanr, shapiro

In [2]: link_grades = '/kaggle/input/olvs1813/OLvsITE1813.csv'
        grades = pd.read_csv(link_grades, index_col='reg')

In [ ]: print(grades.head())

In [3]: # Pearson
        pearson_r, pearson_p = pearsonr(grades['ol'], grades['ite1813'])
        print(f" Pearson Correlation (r): {pearson_r:.3f}")
        print(f" Pearson p-value: {pearson_p:.3e}")

        # Spearman
        spearman_r, spearman_p = spearmanr(grades['ol'], grades['ite1813'])
        print(f"\n Spearman Correlation (r): {spearman_r:.3f}")
        print(f" Spearman p-value: {spearman_p:.3e}")

Pearson Correlation (r): 0.287
Pearson p-value: 2.460e-11

Spearman Correlation (r): 0.279
Spearman p-value: 9.167e-11
```

Figure 1: Correlation Analysis

The Pearson correlation coefficient between students' grades in G.C.E. Ordinary Level (O/L) Mathematics and their performance in the first-year mathematics module was found to be r = 0.287, with a p-value of 0.000 Similarly, the Spearman rank correlation coefficient was ρ = 0.279, with a p-value of 0.000. These results indicate a weak but statistically significant positive correlation between students' prior performance in mathematics and their achievement in the Semester 1 Mathematics module.

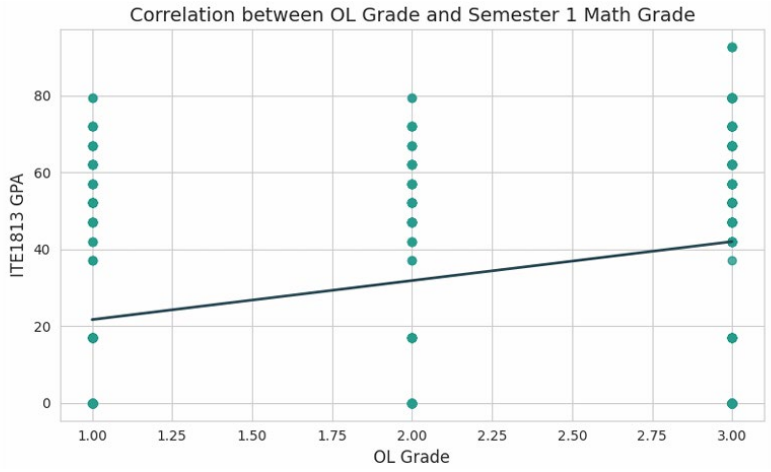


Figure 2: Correlation between O/L Grade and Semester 1 mathematics grade

The closeness of the Pearson and Spearman coefficients implies an approximately linear and monotonic relationship. However, the relatively low magnitude of these coefficients suggests that O/L mathematics performance accounts for only a small portion of the variance in university mathematics outcomes.

4.2 Normality Testing

To determine the suitability of applying parametric statistical methods, a Shapiro-Wilk normality test was conducted on students' O/L Mathematics grades and their Semester 1 Mathematics scores. In both cases p=0.000 was observed, indicating strong rejection of the null hypothesis of normality. Consequently, non-parametric statistical approaches are deemed more appropriate for this dataset.

4.3 Geographical Performance Analysis

A map-based visualisation (shown on Figure 3) was created to illustrate average university Semester 1 Mathematics scores by district. Marker size represented the average Semester 1 Mathematics score, while

colour denoted the average O/L Mathematics grade for each district. High-performing districts such as Galle (47.21), Ratnapura (42.13), Matara (41.58), and Kandy (41.80) demonstrated strong prior academic foundations. In contrast, districts like Badulla (23.18), Anuradhapura (24.26), and Puttalam (24.43) had lower average scores. Interestingly, regions such as Trincomalee (29.92) and Batticaloa (29.98) exhibited moderate university-level performance despite weaker O/L results, implying the influence of additional contributing factors.

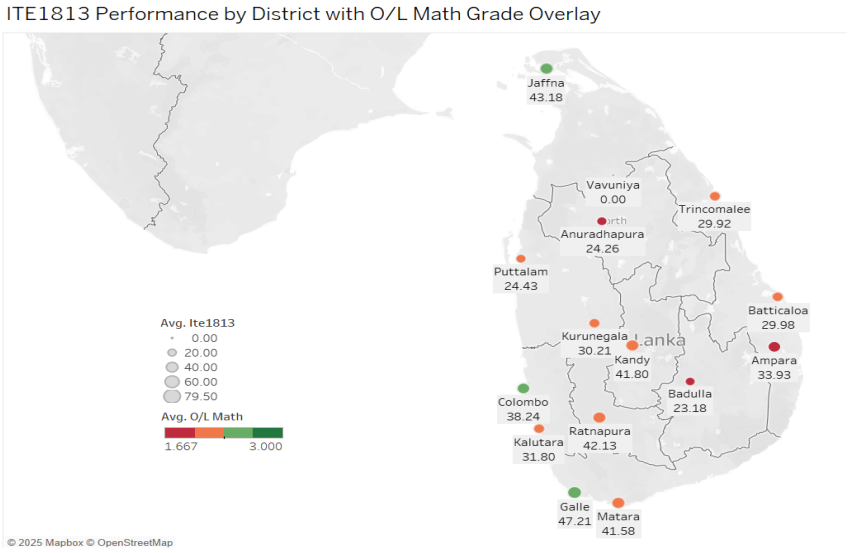


Figure 3: Semester 1 Performance by District with O/L Mathematics Overlay

4.4 Impact of A/L Stream on Semester 1 Mathematics Performance

An analysis of average Semester 1 mathematics scores by A/L stream as displayed on Figure 4 reveals the impact of prior subject specialisation. Students from Combined Maths (54.50) and Maths (53.46) streams exhibited the highest performance, underscoring the advantages of strong mathematical foundations. Conversely, students from the Arts (26.37) and Engineering Technology (25.89) streams scored the lowest, likely due to limited prior exposure to abstract mathematical concepts. Notably, students from No Stream (46.20) and Other (44.23) categories performed relatively well, suggesting that attributes such as digital readiness, motivation, and adaptability may significantly influence success in asynchronous learning environments.

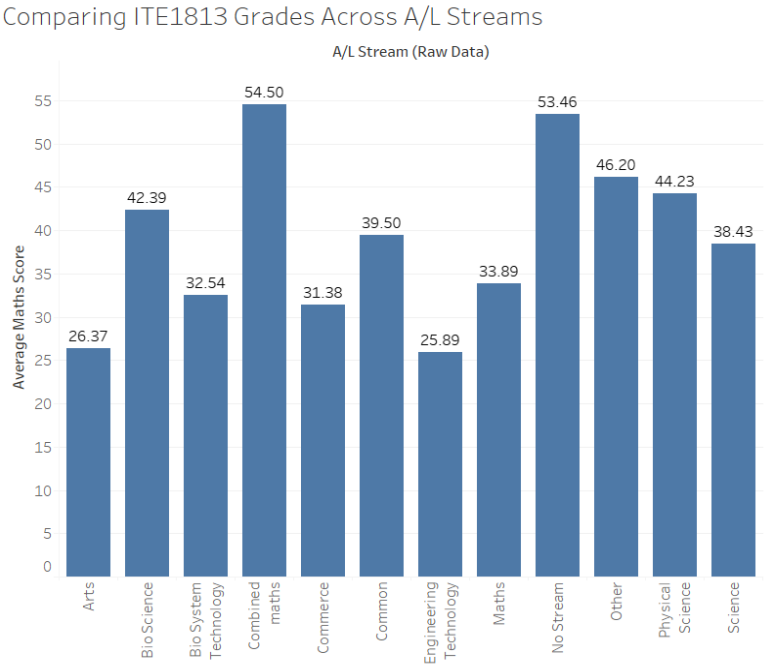


Figure 4: Comparing Semester 1 Mathematics Grades Across A/L Streams

4.5 Distribution of 'A' Grades in O/L Mathematics by Stream in A/L

A breakdown of students who earned an 'A' in O/L Mathematics and their subsequent A/L streams as indicated on Figure 5 reveals dominance by Physical Science (88) and Bio Science (51) students. Commerce (39) and Engineering Technology (26) also had notable contributions, while Arts (23), Maths (15), and other streams showed lower numbers. As these students move into asynchronous university-level mathematics, the disparities suggest a need for targeted interventions to support learners from less mathematically intensive backgrounds.

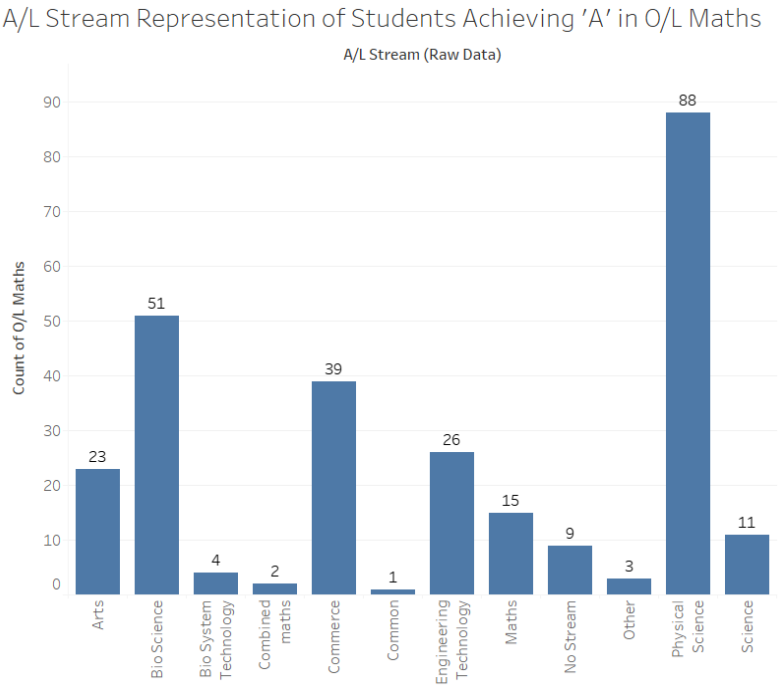


Figure 5: A/L Stream Representation of Students Achieving 'A' in O/L Maths

4.6 Failure Analysis by O/L Mathematics Grade

The pie chart analysis shown on Figure 6 indicates that 57.14% of students who failed the first-year mathematics module had received a C in O/L Mathematics. Surprisingly, 23.21% had achieved an A, and 19.64% had a B. These findings challenge the assumption that high academic achievement in the past guarantees success in asynchronous learning suggesting that success in such environments also relies heavily on skills like self-directed learning, time management, and the ability to understand abstract mathematical concepts.

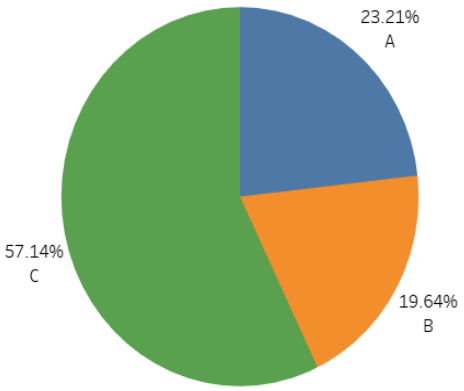


Figure 6: Failure analysis by O/L Mathematics Grade

4.7 O/L Performance of High Achievers in Semester 1 Mathematics Module

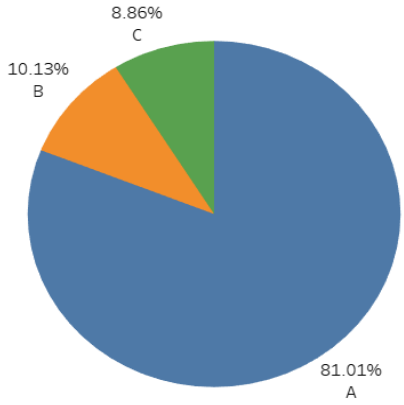


Figure 7: Performance of High Achievers in Semester 1 Mathematics Module

Among students who earned higher grades (A+, A, A-) in the Semester 1 mathematics module, 81.01% had previously secured an A in O/L Mathematics. Meanwhile, only 10.13% had a B and 8.86% had a C. This reinforces the idea that a strong foundation in synchronous O/L learning provides a significant advantage in adapting to the demands of asynchronous university education.

4.8 Failure Distribution by A/L Stream

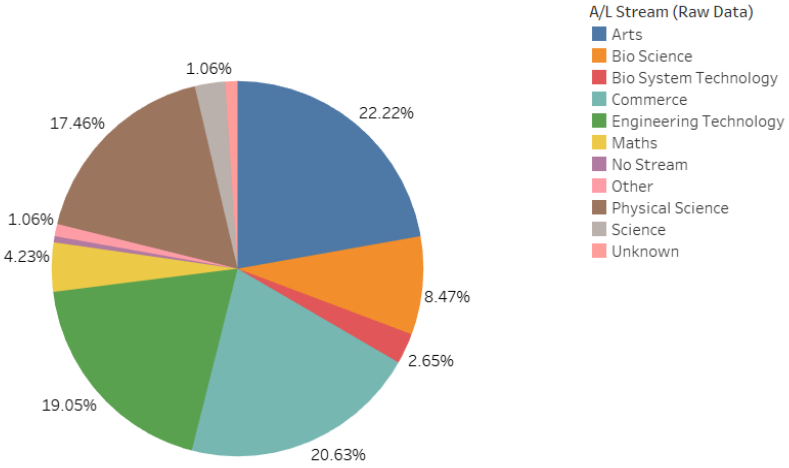


Figure 8: Failure distribution by A/L stream

The chart shown in Figure 8 presents the A/L stream background of students who failed the first-year university mathematics module. The largest proportions come from Arts (22.22%), Commerce (20.63%), and Engineering Technology (19.05%), followed by Physical Science (17.46%). These figures indicate that failure is not isolated to any single stream but is notably higher among those from non-mathematics intensive backgrounds.

Interestingly, even students from mathematically rigorous streams such as Physical Science and Maths (4.23%) are represented, suggesting that prior exposure alone is not sufficient to guarantee success in an asynchronous learning environment.

The presence of students from Arts, Commerce, and Technology among those who failed highlights the potential challenges faced by students who may lack deep mathematical grounding or are less accustomed to independent learning structures. These findings reinforce the need for adaptive support strategies that go beyond prior academic stream and focus on strengthening self-regulated learning skills.

5. Conclusion

This study examined the transition from teacher-centred to asynchronous online learning by analysing the performance of first-year IT students in university mathematics module. The analysis incorporated prior academic indicators, including secondary school mathematics grades, subject stream chosen in high school, and district-level background. These findings, while contextually grounded in Sri Lanka, may hold broader relevance for regions undergoing similar transitions from teacher-centred to asynchronous learning models.

The results revealed a statistically significant but weak correlation between prior mathematics performance and university-level outcomes, indicating that foundational knowledge alone is not a strong predictor of success in asynchronous settings. Students from mathematically intensive A/L streams and higher-performing districts generally achieved stronger results; however, variation was evident, with some students from less intensive backgrounds also performing well.

The occurrence of low performance among students with great prior qualifications, as well as success among those with weaker academic backgrounds, emphasises the need of self-directed learning, adaptability, and digital readiness. These findings underscore the need for enhanced academic support structures that account not only for prior attainment, but also for the skills required to navigate independent, technology-mediated learning environments effectively.

6. Limitations

This study is subject to several limitations that should be considered when interpreting the findings.

The analysis relied exclusively on quantitative data extracted from institutional academic records. As such, it did not account for qualitative variables such as motivation, digital competency, or study habits which are factors that could play a substantial role in asynchronous learning. This limitation is particularly important when considering diverse regions, where socio-economic background, digital access, and cultural attitudes toward independent learning may strongly influence outcomes.

The dataset was limited to a single group of students enrolled in the Bachelor of Information Technology programme at the University of Moratuwa. As a result, the generalisability of the findings to other academic disciplines, institutions, or learning contexts may be constrained. As such, the findings may not fully represent students from other Sri Lankan universities, or learners in different countries where infrastructure, institutional support, and student preparedness vary widely.

Finally, the focus on a single first-year mathematics module provides only a snapshot of academic performance. A longitudinal study incorporating multiple modules and semesters would offer a more comprehensive understanding of the dynamics involved in adapting to asynchronous learning environments. Moreover, regional differences in curriculum design and delivery methods may further limit the transferability of these results to other contexts.

7. Future Work

Building on the findings of this study, several directions for future research are proposed.

Firstly, incorporating qualitative methods such as student surveys or interviews would provide richer insights into learner experiences, particularly regarding self-regulated learning, motivation, and digital literacy in asynchronous environments.

Secondly, extending the scope to include students from multiple disciplines or institutions would enhance the generalisability of results and allow for comparisons across different educational contexts and technological infrastructures.

Future studies may also adopt a longitudinal approach, tracking the performance of students across multiple modules and academic years. This would help assess how adaptation to asynchronous learning evolves over time and whether initial academic background continues to influence long-term success.

Finally, including learning analytics such as engagement measures from learning management systems may provide a more comprehensive picture of student behaviour and its relationship to academic success in asynchronous situations.

Ethics Declaration

Ethical clearance was not required for this research.

AI Declaration

AI-based tools were used solely for formatting assistance and language refinement. All intellectual content, analysis, and conclusions presented in this paper are the original work of the authors.

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Cross-Disciplinary Educator Training Approaches for Education for Sustainable Development in a Post-digital Perspective

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Abstract: The call for Education for Sustainable Development (ESD) connects with the agenda for addressing the anthropogenic challenges, aiming at a transition towards a sustainable future for planet Earth, humanity, and all living beings. As part of this agenda, educators play a vital role in developing and implementing ESD in their teaching. In recent years, there has been a focus on developing digital teaching and learning resources to support educators in their work on developing and delivering ESD. In a post-digital era with digital technology intricately woven into education and teaching, educators must excel in both designing and orchestrating teaching to effectively support ESD learning experiences. This implies that educators must acquire both pedagogical, technological, and sustainability knowledge to make informed pedagogical decisions on designing for ESD. Thus, pointing to a need for focused educator training and adequate learning materials to empower educators. This study investigates an international cross-disciplinary project, focusing on developing, integrating, and scaling ESD in Higher Education Institutions (HEI) and Vocational Education and Training (VET) educations, by developing and delivering educator training, supported by a digital ESD Academy (i.e., an online learning platform (OLP)). An ethnographic study of a series of educator training was carried out, focusing on; (1) "What are the educators taught about the key sustainability competencies and ESD. (2) "How are the educators taught to teach for such competencies". Field notes, pictures, and documents, such as programs, slides, and hand-outs, were collected to address the research questions. This paper discusses how educator training handles the interplay of the components; knowledge, skills, affective dispositions, and actions toward sustainable development when designing for ESD. Findings from this study show a disposition for the knowledge dimension when teaching the key sustainability competencies in educator training and further reveal challenges in addressing the pedagogical choices for teaching these and delivering action-oriented teaching. When designing an OLP to support educators in developing and delivering ESD, this study points to a need for an awareness of the complexity of teaching key sustainability competencies and calls for reflections on both knowledge of pedagogy, technology, and the key sustainability competencies.

Keywords: Education for Sustainable Development, Post-digital Learning, Learning Design, Educator Training, Higher Education, Vocational Education.

1. Introduction

Education for Sustainable Development (ESD) has become a means to address the anthropogenic challenges and support the transition towards a sustainable future for planet Earth, humanity, and all living things (Leicht, Heiss and Byun, 2018). Research has pointed to teaching for key sustainability competencies as important in this transition. Likewise, several pedagogical approaches applied for teaching these competencies have been identified, although with limited research into the connection between the two (Lozano et al., 2017; Lozano and Barreiro-Gen, 2022). As educators are expected to play an important role in developing and implementing teaching for ESD, knowledge is needed on how to build the capacities of educators delivering ESD. The current ethnographic study investigates a series of ESD educator training in Higher Education Institutions (HEI) and Vocational Education and Training (VET), carried out as part of TEACH4SD, a cross-disciplinary international project. Part of the project is designing and developing an online learning platform (OLP) to support the educators in designing and delivering ESD. As Fawns (2019, 2022) highlights, there is always a digital aspect of any educational activity in HEI, as well as digital education also always being material, social, and embodied. Hence, in a post-digital era, where digital technology is entangled in complex ways in formal and informal teaching, educators need to be good at both designing and orchestrating teaching (Fawns, 2019), including when delivering ESD. To inform the development of the OLP, a study was carried out pursuing two objectives, namely, (1) "What are the educators taught about the key sustainability competencies and (2) "How are the educators taught to teach such competencies" in educator training. This article presents and discusses the findings of the study to inspire and inform future development of an OLP and to support educators in designing and delivering ESD.

2. Designing for an ESD OLP

As ESD is complex and educator training can be interpreted broadly, it is important to develop knowledge on how to design an ESD OLP to support educators in designing for and teaching ESD. In previous studies, the B-ESD framework and workshop (Jensen and Pilgaard, 2022) have been applied to support the design of a blended ESD training course and the design and development of an ESD OLP. The B-ESD framework (Figure 1) is inspired by the field of research of Learning design (LD) and is developed based on an understanding of LD as a methodology (Conole, 2013, 2014), facilitating educators in the process of making informed decisions in designing for learning, using digital technologies. The framework's structure intends to facilitate design reflections and decision making by addressing; WHY, which relates to identifying overall objectives for the design, WHO are the leaners, WHAT, relating to identifying and sorting ideas and topics, using the three categories knowledge, attitudes, and actions, which originates from the three domains; the cognitive, socio-emotional and behavioural domain of learning objectives for SDGs (UNESCO, 2017) and HOW, relating to what pedagogical approaches is being applied to teach WHAT. The categories, knowledge, attitudes, and actions should not be understood as independent categories or learning objectives, but rather as a framework that provides educators with the opportunity and space to reflect on pedagogical choices regarding teaching activities for teaching the WHAT. From a post-digital perspective, and considering the entanglement of pedagogy and technology, where learners engage with technology in diverse, context-dependent ways (Fawns, 2019, 2022), it should also be acknowledged that online and on-site learning activities should not be seen as being inherently tied to either knowledge, attitudes, or actions.

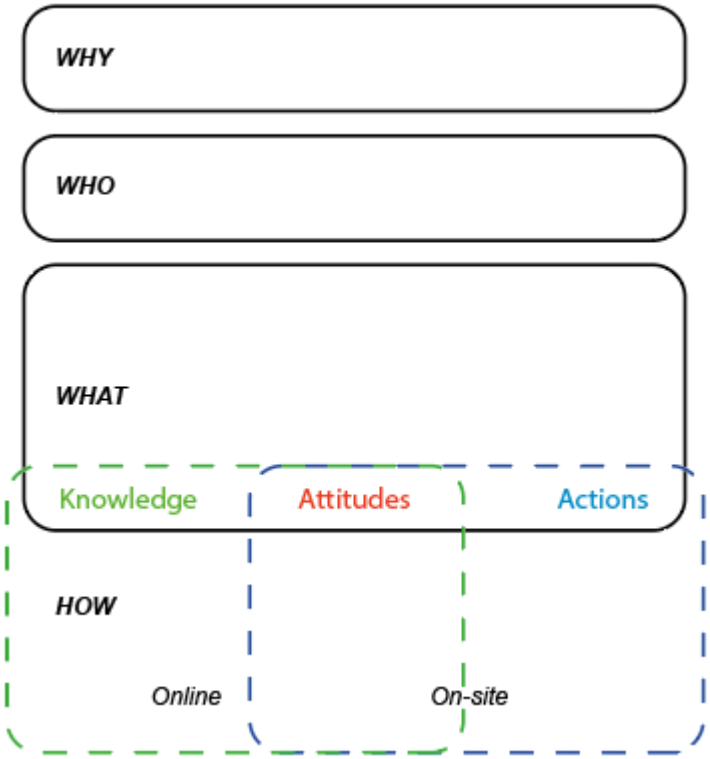


Figure 1: The B-ESD Framework (Jensen and Pilgaard, 2022)

2.1 WHY Key Sustainability Competencies in Education for Sustainable Development

There is general agreement that a fundamental transformation of education, supporting the attainment of key sustainability competencies, is an important element in achieving a sustainable future for all livings. Competencies are relatively abstract and encompass the ability to integrate and apply contextually-appropriate knowledge, skills, and psychosocial factors (e.g., beliefs, attitudes, values, and motivations) to consistently perform tasks and problem solve successfully in a given context (Sterling, Cullingford and Blewitt, 2004; Brundiers, Wiek and Redman, 2010; Wiek, Withycombe and Redman, 2011; Vare, Lausselet and Rieckmann, 2022). Key sustainability competencies are differentiated, while not necessarily distinct from (other) 'regular' competencies in different academic or professional fields, by their critical importance for sustainability. Thus, they require translation into specific learning outcomes to be operationalized, such as for curriculum

development or assessment. Significant work has been done within the academic community to define such key sustainability competencies (Vare, 2022; Bianchi, Pisiotis and Cabrera Giraldez, 2022; Rieckmann, 2012; Wiek, Withycombe and Redman, 2011). To aid educational institutions in operationalizing ESD, academic efforts have led to the development of several frameworks, such as the OECD's and UNESCO's descriptions of key sustainability competencies (UNESCO, 2017; Rieckmann, 2018). Recently, the European Commission introduced the GreenComp framework (Bianchi, Pisiotis and Cabrera Giraldez, 2022), which distinctively highlights the interdependence of humans and nature. Outlining 12 interrelated competencies across four areas; embodying sustainability values, embracing complexity, envisioning sustainable futures, and acting for sustainability. Describing a sustainability competence as follows: "*A sustainability competence empowers learners to embody sustainability values, and embrace complex systems, in order to take or request action that restores and maintains ecosystem health and enhances justice, generating visions for sustainable futures*" (Bianchi, Pisiotis and Cabrera Giraldez, 2022, p. 12). The GreenComp sustainability competency framework was taught in the educator training courses, investigated in the current article. When dealing with educating educators for ESD, there is an additional level to WHY, besides WHY the key competencies. It also includes WHY choosing specific pedagogical approaches to teach for the key sustainability competencies and support transformative learning.

2.2 WHO are the Drivers of the new Sustainable Future

There is a broad consensus that sustainability themes need to be embedded in lifelong learning, including in HEI and VET education programmes, as they educate the future workforce and professionals (UNESCO, 2021). The implementation of ESD in education places a high demand on educators and presupposes that they themselves have dealt with the concept of sustainability and ESD, as well as how transformative actions occur and align their pedagogical practice to teach within the ESD concept (Vare, Lausselet and Rieckmann, 2022). Therefore, it is imperative that ESD also extends to educator training, to build the capacity of educators, and to successfully implement ESD in HEI and VET. As always in designing education, attention to WHO the learners are is necessary, including the diversity of educators between and within HEI and VET.

2.3 WHAT and HOW it Should be Taught

Models and frameworks of educator ESD competency building support a dual focus on both subject matter content ("what should be taught") and pedagogical approaches ("how it should be taught") (Lozano et al., 2017; Lozano and Barreiro-Gen, 2022; Rieckmann and Barth, 2022). Addressing "what should be taught": Target 4.7 of the Sustainable Development Goal (SDG) 4, aims to ensure that all learners acquire the knowledge and skills needed to promote sustainable development (UNESCO, 2017), with SDG 4 being recognized as a pivotal goal, essential for the achievement of the other 16 SDGs. Hence, ESD should address the interrelated environmental, social, cultural, and economic sustainability aspects across various topics and disciplines, emphasizing their interactions and contingencies in time and space, at local, regional, and global levels. ESD should equip learners with the knowledge, skills, and attitudes to think, plan, and act to tackle interconnected global challenges, with sustainability in mind (Leicht, Heiss and Byun, 2018; Salas-Zapata, Ríos-Osorio and Cardona-Arias, 2018; Bianchi, Pisiotis and Cabrera Giraldez, 2022). Knowledge is frequently perceived as value-neutral grounded, however, our values and worldviews continuously shape our perception and understanding of the world, including our comprehension of sustainability issues. ESD should therefore, beyond simple declarative knowledge, aim to impart affective elements related to the know-how and skills specific to sustainable development, which are essential for initiating long-term behavioural transformation (Ssossé, Wagner and Hopper, 2021). In continuation of this, it is described how ESD places more emphasis on socio-emotional dimensions (values), together with crucial behavioural change practices (taking action) (Leicht, Heiss and Byun, 2018). Inspiring for developing agencies to act sustainably both as individuals and collectively, as well as both personally and professionally.

Addressing "how it should be taught": The choice of pedagogical approaches in teaching depends on the educational goals and the specific learning context, as well as addressing the diversity of the learners. There are ample proposals on pedagogical approaches for teaching the key sustainability competencies, with Lozano (2017) having proposed a framework linking these in HEI, aimed to support the design of ESD (Lozano et al., 2017, 2019; Lozano & Barreiro-Gen, 2021). As educators participating in educator training themselves are being taught how to teach ESD ("how to teach, how it should be taught"), it provides an additional (meta) layer to HOW that needs to be handled when designing and delivering ESD educator training. Despite the aforementioned myriads of pedagogical practices for teaching the key sustainability competencies and efforts to link these, previous studies have shown that designing ESD educator training is challenging and calls have

been made to reform or refine such programmes to equip educators with ESD teaching competencies (Rieckmann and Barth, 2022). Additional complexity is added with the demand for ESD educator materials, including digital resources (Leicht, Heiss and Byun, 2018), and previous research having shown that developing and delivering such digital ESD learning material and OLPs is difficult (Jensen, Baagø and Pilgaard, 2024). This together with teaching in a post-digital world, where digital technology is entangled with teaching and learning (Fawns, 2022), educators need to possess knowledge, relating to not only content knowledge (key sustainability competencies), but also pedagogical knowledge (making informed choices in pedagogical approaches to achieve these), and technological knowledge (how to approach and integrate such digital ESD resources). While TPACK (Mishra and Koehler, 2006) serves to delineate the broad domains of knowledge required by individual educators, entangled pedagogy is inherently a collaboratively enacted approach (Fawns, 2022), which should be kept in mind, when designing an OLP, to support ESD educator training.

3. Context

The TEACH4SD project involves HEI, VET, and industry partners from five professional domains (health, textile, construction, trade, and entrepreneurship) and countries. It aims to develop ESD practices, including developing an OLP for supporting educator training at HEI and VET. The research presented in this article investigates three educator training courses, developed and conducted as a part of the TEACH4SD project (Figure 2); One three-day international training course developed and carried out by project-appointed trainers. In succession, two five-day national educator training courses (National-HEI and National-VET), within the health domain, were developed and carried out by educators who had attended the international training course. Furthermore, educators from the National-HEI supported the National-VET educators in their planning and provided lectures during the National-VET course. The data collection was carried out from September to December 2024.

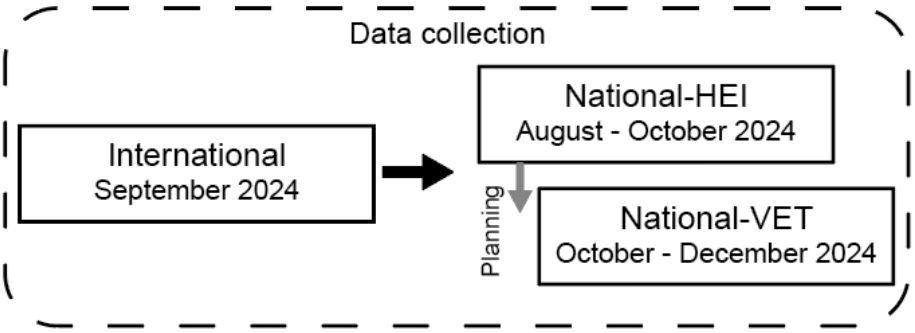


Figure 2: Timeline for the study

4. Methods

To address the research questions, the study draws on an ethnographic research approach studying the educator training courses (Figure 2). The authors coordinated their participation across the three educator training courses and collected the empirical data through field notes and photographs. Documents such as programs, slides, and handouts were also collected. The empirical studies and the documents were sorted and coded, focusing on identifying which aspects of sustainability and ESD were addressed, such as concepts, theory, and teaching methods. Furthermore, the teaching activities applied were sorted and coded, focusing on how they were introduced and conducted, and if any pedagogical arguments connected to the specific teaching activities were conveyed to the course participants. During the analysis, the authors identified and discussed the experiences, perceptions, and insights of how the courses were conducted; topics addressed in the course program, teaching activities conducted, teaching methods, materials, resources being used, and finally choice of locations.

5. Findings and Discussion

5.1 ESD and Key Sustainability Competencies

The overall aim of the TEACH4SD project is to develop, integrate, and scale ESD in HEI, VET, and GreenComp (Bianchi, Pisiotis and Cabrera Giraldez, 2022) was chosen as the sustainability competency framework for the project. It was observed that WHY ESD and GreenComp were addressed during both the international and

national courses. In both national courses, a lecture on WHY ESD, included a presentation of a scenario-building tool, adapting the use of the three key sustainability competencies, systems thinking, futures literacy and critical thinking to support addressing the need for developing ESD. The scenario-building tool was introduced to support educators in critically examining the origins of their values, professional orientation, and the pedagogical principles they apply. However, participants did not engage with the tool or reflect on WHY ESD is relevant to their own teaching and subject areas during the course. At the National-VET course the educators applied a teaching activity addressing WHY sustainability and ESD, where the course participants were instructed to construct something with small building blocks, representing "what they are grappling with". This was followed by a session where they presented their creations and shared their experiences and motivations for ESD and sustainability, both professionally and personally. During this teaching activity, it became evident that participants had a range of different reasons and motivations for enrolling in the ESD training course. Acknowledging this diversity may be relevant in the context of ESD educator training and could be considered a fundamental condition that should be addressed early in an ESD training course, to support continued engagement of the course participants.

Participants in the international course were from HEI and VET and different countries, representing different domains, thus constituting a heterogeneous group of WHO (are the learners). This introduced a diversity of WHO, including their previous knowledge of ESD and cultural understanding of education, ESD, etc. The observational data did not yield clear findings on how the course instructors responded to or managed this diversity among participants. Meanwhile, the WHO was a more homogenous group regarding educational and health sector background, in the National-HEI and National-VET courses. However, despite all participants being from the health domain and WHY ESD in the health sector was addressed during the courses, participants translation of sustainability and ESD into their own specific health education and profession still appeared difficult. At the National-HEI course, the participants themselves asked for group work during the course to take place within the specific health educational programmes, such as only occupational therapists in one group, to better support reflections on WHY, WHAT, and HOW in their own teaching, education, and professional context.

Learning resources addressing WHAT, such as the GreenComp framework (Bianchi, Pisiotis and Cabrera Giraldez, 2022) and literature on HOW and the pedagogical approaches for ESD, were provided as homework for the national courses. WHAT at the international course focused on a generic presentation of the key sustainability competencies. Due to the overarching nature of the GreenComp framework competencies, one WHAT focus on the national courses was on translating them into the health sector context. It can be argued that it is not possible to achieve in-depth experience with all key sustainability competencies during a three- or five-day course and due to the limited time and capacity available, three to four key competencies were selected to work with in-depth, while building a broad foundation in the others. At the same time recognizing, that not all competencies will be equally relevant for every educator. It was observed that system thinking, critical thinking, futures literacy and promoting nature were chosen throughout both the international and national courses, while others were only mentioned and some key competencies not addressed at all. It was not conveyed why these where chosen. However, it could be speculated that as these were the key sustainability competencies that were introduced in the international course, it might have been the reason for educators to choose them in the national courses, having attained them as competencies themselves. Observations on WHAT, from the national courses also revealed the inclusion of the concept 'being-competence', alongside with efforts to establish links between the key sustainability competencies and broader educational frameworks, including 21st century skills, together with the integration of technology, in both pedagogical and professional practice. The participants responded to this in varied ways; while some found the approach somewhat unclear, others appreciated it, as they were already engaged in implementing technology and 21st-century skills and perceived this as an opportunity to concurrently introduce sustainability and ESD. The variable interpretations of ESD and contextual interpretation of the key sustainability competencies in the courses could be claimed to be problematic to measurability and accountability, but could at the same time be argued to be necessary as competencies are culturally and context bound (Rieckmann and Barth, 2022). Either way, it should be considered when designing for HOW and choice of pedagogical approaches.

5.2 Pedagogical Approaches

ESD frameworks, including the GreenComp framework (Bianchi, Pisiotis and Cabrera Giraldez, 2022), provide a structured approach to understanding how transformative learning can be fostered, through engaging the cognitive, socio-emotional and behavioural domain and promoting a holistic educational experience. This ambition calls for learning theory to inform the design of ESD and should address knowledge, skills, attitudes

and actions toward future sustainable development. In the meantime, it is argued that breaking down (key sustainability) competencies into knowledge, skills, values, and so forth can lead to the idea that learning can be atomized and detailed inventories be made, which is antithetical to the holistic ethos of sustainability (Vare, 2022). However, to provide structure to reflect on WHAT and HOW and choice of pedagogical approaches, findings from the current study are discussed in relation to the categories knowledge, skills and actions inspired by the B-ESD framework (Figure 1)(Jensen and Pilgaard, 2022).

A body of research have identified several pedagogical approaches applied for teaching for key sustainability competencies, with some reported to be more effective for learning such competencies, such as problem-based learning and interdisciplinary team teaching (Lozano et al., 2017; Lozano and Barreiro-Gen, 2022). Acquiring new knowledge is interdependent with context and acting in the world and therefore enables knowledge to be acquired in various ways. It was identified in both the international and national courses that the most prominent teaching activity was knowledge dissemination through lectures, which is described to be one of the least effective ways to develop sustainability competencies (Lozano and Barreiro-Gen, 2022). It is not possible to conclude if this dissemination of knowledge affected the participants' attitudes towards sustainability. At the National-HEI course, futures literacy and system thinking were taught by lecturing, but also by hands-on teaching activities. However, this was done with simplistic exercises that the participants carried out. It was not related to the health domain or their own teaching or professional practice, which left it up to the participants to make this translation themselves. Nature was generally being highlighted as a WHAT by the course educators and as being very important, both vocally as well as through applying teaching activities situated in nature. As addressed earlier, nature has an importance in ESD, and this was vocalized at both national courses and some of the course days were at a location, which is embedded in nature and works with sustainability in different ways. The topic nature-connectedness and relations to health was addressed in lectures, with activities in nature including a guided walk, group discussions and reflection activities relating to other topics than nature. Nature served as a scenery for the teaching activities, and some course participants expressed that it was not easy to transfer HOW and the nature experiences to their own teaching and professional practice. However, during the walks, course participants were heard trying to make these professional and educational translations, discussing it with colleagues. During the national courses, it was observed that the participants were actively engaged, both during lectures delivered by sustainability experts and during visits to on-site real-world locations such as a hospital working strategically with sustainability. However, these sustainability experts were not educators but worked with sustainability in the public or private sector and no link was made to the key sustainability competencies, ESD or pedagogical approaches.

Findings across all courses revealed that learning theory and reflections and considerations on choice of pedagogical approaches for the teaching activities were rarely explicated for the participants, even though an intention to do so was vocalized in one of the national courses.

The course participants development of their own ESD during the course was an attempt at an action-oriented approach for ESD in educator training. During the national courses, time was allocated for participants, to design and develop an ESD initiative to implement in their own teaching. On the last course day, they pitched it to and received feedback from invited stakeholders, such as sustainability and ESD experts, educational leaders, and course educators. Key sustainable competencies should be framed as observable behaviors, but as the study did not follow the participants' journey in implementing ESD in their teaching, it was not possible to pursue this in the current study.

6. Conclusion

The ethnographic study presented in this paper was conducted as part of an international cross-disciplinary project focusing on developing, integrating, and scaling ESD in HEI and VET educational programmes, supported by the development and integration of an OLP. The study focuses on three courses carried out in the fall and winter of 2024. The aim of the training was for educators to learn about the European GreenComp competency framework (Bianchi, Pisiotis and Cabrera Giraldez, 2022), and empower them with knowledge and experience on how to approach the framework as a key for transitions toward teaching and designing for ESD. During the courses, various pedagogical practices and teaching activities were introduced as a means for course participants to develop key sustainability competencies and knowledge on how to teach for such competencies. The study identified a tendency to choose lectures for introducing the key sustainability competencies and challenges in bridging generic competencies such as system thinking and futures literacy explicitly to sustainability. Furthermore, the study showed challenges in explicating pedagogical choices for the design and teaching of the key sustainability competencies. These findings illustrate the complexity inherent in designing and teaching for

key sustainability competencies and designing for ESD. This calls for reflections on both knowledge on pedagogy, technology and the key sustainability competencies when designing for ESD, including an ESD OLP to support educator training. Serving as an argument for involving a learning designer in the design and development process to support the development of ESD and fostering pedagogically informed sustainable educational teaching and learning. In a post-digital perspective, where pedagogy and technology are deeply entangled, WHY, WHO, WHAT, and HOW can serve as the framework and structuring to support the critical reflections throughout the design process and guide the development of both online and on-site learning activities, with an awareness towards the interconnected nature of knowledge, skills, attitudes, values, and actions in teaching key sustainability competencies.

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Disclaimer

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Ethics Declaration

No ethical clearance needed

AI Declaration

AI has been used for checking grammar and spelling.

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From Scratch to Screen: Creating an Online Learning Centre

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Abstract: This paper describes the foundation and implementation of a free, online virtual learning centre, the Edith Lando Virtual Learning Centre (https://elvlc.educ.ubc.ca) in the Faculty of Education at the University of British Columbia, Canada from June 2021 until the present. As we are by now quite familiar with, the COVID-19 global pandemic ushered in rapid changes to the way education was being delivered, while laying bare deep inequities. Within this altered educational landscape are opportunities for teacher professional development that were neither possible nor prevalent prior to the pandemic. For example, use of video conferencing technologies like Zoom or Microsoft teams might have been a reality for many, but they certainly were not in ubiquitous use, nor was zoom a household name before the pandemic took hold, but during and after, for business and pleasure, we continue to use those video conferencing technologies. This paper will begin with a review of professional learning for K-12 teachers that has been primarily delivered in online settings. While that landscape has changed post-pandemic, documenting what has changed is relevant to showing how the Virtual Learning Centre has been able to thrive. And while quite a lot of that literature focuses on online pedagogies (and better online praxis), the focus of the centre is not online teaching. Instead, it delivers just-in-time high quality professional learning for teachers and other educators in an online setting. The review of related literature is followed by a description of the centre, its goals and priorities, and the work that it has been doing. Following that is an analysis of the impacts the centre is having in its local and extra-local communities, and a discussion of how this model might be adopted in other contexts, both small and large, with a view to sustainability.

Keywords: Online Professional Learning, Virtual Learning, Online Learning, Professional Development, Canada

1. Introduction

The first pandemic of the 21st century – COVID-19 - ushered in rapid changes to the way education was delivered and laid bare deep educational and other inequities. For example, a UNESCO global report on the pandemic persuasively argues, "Students from low- and middle-income countries show major systemwide learning losses…. Even in high-income countries able to quickly organize real-time online instruction, learning losses appear substantial" (The World Bank, UNESCO, and UNICEF, 2021, pp. 15-18). And other scoping review studies report as overall loss of progress for K-12 students despite income, location, or mode of pandemic delivery (c.f. Donnelly & Patrinos, 2022; Engzell, et al. 2021; Moscoviz & Evans). This has renewed calls for educational reform (Zancajo, et al., 2022) as well as new teaching strategies, more instructional time, more and other teacher professional development, new uses of technologies for instruction and learning, and the like.

Within this altered educational landscape are opportunities for teacher professional development that were neither possible nor prevalent prior to the pandemic. For example, use of video conferencing technologies like Zoom or Microsoft teams might have been a reality for many, but they certainly were not in ubiquitous use, nor was zoom a household name before the pandemic took hold, but during and after, for business and pleasure, we continue to use those video conferencing technologies. In the university where I work, we have gone from little to no hybrid options for participation in the everyday business of the university (never mind teaching) to nearly all hybrid options from thesis defences to departmental meetings to hiring committees. Indeed, prior to the pandemic, there would have been a learning curve for staff, faculty and students to join a new or unfamiliar video conference using a client like zoom or teams, but today, that is no longer a barrier for most. And in the intervening distance from the lock downs and isolation orders, many of us continue to use these tele-present technologies to support professional and personal aspects of our lives.

In 2021, with Canada and the world still grappling with COVID-19, it was clear that there were real needs in the educational community for skilled and professional learning supports (Hartshorne et al. 2020). I was appointed as the inaugural director of a fully online, never before realized virtual learning centre. I was invited to imagine the centre from the "ground" up, with a significant investment by a donor who was looking, not for a brick-and-mortar investment, but for something with potential impacts on education and learning more generally, especially as it was clear by this time that there would be lasting effects from the COVID-19 pandemic.

This paper begins with a review of professional learning opportunities for teachers that have been primarily delivered in online settings--- the imperative of a virtual learning centre. To be clear, the focus of the centre is on designing and delivering high quality professional programming for educators and teachers at a distance. *not* on training teachers in using technologies or how to better teach online—though we do model online pedagogies.

The related litearture focuses, therefore, on professional learning at a distance. That review of related literature is followed by a description of the centre, its goals and priorities, and an overview of the work that we have been doing. Following that is an analysis of the impacts the virtual learning center is having on our local and extra-local communities, and a discussion of how this model might be adopted in other contexts, both small and large. The paper concludes with a critical consideration of institutional sustainability, and the particular challenges of preserving a virtual creation whose existence is by definition insubstantial given it's only 'presence' is on the internet, and there is no formal means of preservation.

2. Related Literature: Professional Online Learning for Teachers

While professional learning for teachers in online settings has been around for some time (see Dede, et al. 2009), before the pandemic those online learning sessions had barriers for some in terms of software, hardware and internet connectivity (Johnson, 2019; Obizoba, 2016). During the pandemic the compulsory move to online learning for teachers and learners in North American meant for many that they have developed the skills, hardware, software, and connectivity necessary to participate in online professional learning. Online teacher professional development (oTPD) has expanded flexibility in terms of time and place (Morina et al. 2023; Sadler et al. 2020), supporting not just urban, but also rural educators (Maher & Prescott, 2016; Quinn et al. 2022). As well, oTPD allows for 'just-in-time' participation on the part of teachers (Parsons et al., 2019), fitting in with their busy schedules (Lay et al. 2020; Li et al. 2019).

A review of journal articles related to oTPD in the Canadian context from 2000-2020 found just 11 scholarly publications directly related to online teacher professional development (Beach et al., 2021). Using a thematic analytic approach, the authors' identified 4 themes across the 11 articles: "knowledge exchange" meaning simply that information and knowledge sharing was a priority in oTPD; "reflective practice", which involved the participating teachers' exploring their own learning and doing in relation to the oTPD; formal and informal oTPD, the informal mostly being driven by the move to social media; and "just-in-time" support, again, mostly professional learning that is networked, primarily through social media like former Twitter and/or Facebook. For the purposes of this paper, the first and fourth theme are particularly relevant as the virtual learning centre became a hub both for knowledge exchange and, as we show below, "just-in-time" support for the professional learning community developed since the center's inception.

3. No Bricks, No Mortar: Building a Virtual Learning Centre, a Methodology

In June 2021, when pandemic restrictions were beginning to shift as the COVID-19 vaccines were taking hold in Canada, universities remained mandated by their provincial governments to continue online learning, and while jurisdictions returned to in-person learning for K-12 education, hybrid options created during the pandemic remained in place for many students at all age levels. Within that landscape and catalyzed by a generous donation to the Faculty of Education at the University of British Columbia, I was invited to imagine the construction of a virtual learning centre, from the ground up, but without any actual ground to build on. . Here, I'll detail that process before moving on to describing the centre's activities and then analyzing its impacts thus far.

Imaging a virtual learning centre during an ongoing pandemic was certainly challenging – in part because so many of us in the education (and other) sectors were suffering from online fatigue, screen burnout, 'zoom fatigue' (Skylar, 2020) and the like. Was a 'virtual' learning centre even feasible at that time and what would it entail, how would we 'market' it, how would we get the word out that we were doing this work and if we built it, who would come? These questions swirled around as I and a small team of staff began the work of the centre, which started with the construction of a mission statement and goals that would help us lay its (virtual) foundations. Those goals became our building bricks in the establishment of the centre; its mortar was scoping activity which narrowed down the centre's audience, concentrating our efforts across five underserved communities: special needs education, Indigenous education, rural and remote education, early childhood education, and immigrant and refugee education. Those five areas are massive in and of themselves, but that focus allowed me as director to begin shaping our programming, and seeking out faculty, students, and staff with expertise in those areas to find out what needs were not being met (and especially as the pandemic was ongoing at the time).

Following the establishment of the foci of the centre, and the creation of an advisory board and terms of reference for the Board and the centre, I initiated an environmental scan to better understand what else (if anything) was 'out there' in terms of virtual learning centres, and to see if there were any such centers operating on a free, just-in time, learning model. In that 2021 scan, we found that virtual learning centres are primarily

either: 1) paid online learning programs that are typically private, such as teacher and teaching centred portals, training for law enforcement, and other practical and practice-based learning; 2) government sponsored resources for teachers and students that were free, but also limited to specific contexts; and 3) research-led learning centres that were most often affiliated with universities. The latter is closest to what we envisioned, with the caveat that we were not driven by a research agenda *a priori*, but rather were curating research and practice for a kind of knowledge exchange with the public and specifically the education sector, already present in resident expertise at UBC's Faculty of Education. That meant that we were working from existing expertise and were able to support programming that could make use of the infrastructure we had available through the virtual centre to grow and support initiatives. For example, a faculty member with a focus on rural and remote education received Ministry of Education funding to run a series of on-line workshops, focused on rural and remote professional development programming. We were able to leverage the centre's online infrastructure and expertise to create sign up forms, web pages, zoom links, exit polls, and the like to support the faculty member and their sponsors to run the workshops, 3 years later, that partnership is still in place and the workshops have reached now over a thousand rural and remote educators in British Columbia, and further afield.

Of course, an online, virtual learning centre needs a website, and I worked in tandem with a small marketing team in the Faculty of Education to develop the website as we were developing the centre's goals, mandate, terms of reference, advisory board, and initial online programming. The website had to follow university guidelines and constraints with respect to look and feel, and in terms of the back end architecture (Word Press), and other than that I was most concerned that the we have a reason to drive traffic to the website, so we delayed its launch until October 2021, when we were able to announce the above workshops to rural and remote educators, as well as other programming we had developed that first year, including a series of 3 workshops in early childhood education, and another three on Indigenous approaches to math education. The centre's website became the hub for all of our activities, including sign up pages, announcements for workshops, and so on. In 2024 alone, the centre's website had over 47,000 views.

Alongside this early programming, we promised to leverage some of the financial gift to build capacity in the Faculty of Education. This was another major pillar established early in the life of the centre – a grant to support the development of online and digital pedagogies. With this second pillar, we established a rolling (i.e. you can apply for it at any time) small grant, up to $10,000 CAD. This grant was designed to support the development of digital tools in the service of the goals of the centre, and with particular attention to the 5 areas of focus. The grants are adjudicated on a rolling basis, were small in scope, and were meant to support the experimentation with pedagogical approaches that use digital tools to enhance or support teaching and learning and/or experiment with leading edge digital technologies. Faculty, staff, or students (with faculty supervision) were invited to apply for the grant, and since its inception in late 2021, we have funded over 40 small-scale projects that have led in many cases to follow-on funding for the awardees. This funding, in tandem with a ramping up of free, online workshops as the centre became more established, represents a significant achievement in the virtual 'bricks and mortar' that established the Edith Lando Virtual Learning Centre (https://elvlc.educ.ubc.ca). In the next section, the centre's programming, aimed primarily at professional learning for educators in the pre-K and K-12 system, is described, as well as a few small, scale but highly impactful workshops.

4. Online, Synchronous, Virtual Professional Learning: A Results Snapshot and Discussion

At the time of this writing, we are going into year five of a five-year mandate for the centre. Over its short life course, we have run nearly 200 online, synchronous workshops,(*should you say somewhere that asynchronous learning is supported through the center's digital archiving of the synchronous events, and more of course? the vast majority of which were recorded, edited, and archived to the centre's YouTube channel, and made available in a growing database of videos, and workshop related materials (URL). We have continued to focus our workshops around our mandate to deliver just-in-time, online professional learning for educators around the five themes described above but have also had the flexibility to respond to professional development needs from our own learning communities, of which more below.

Nearly all the content is delivered in synchronous online sessions via zoom. Given the launch of the centre occurred during an ongoing global pandemic, one thing we were able to capitalize on is the nearly ubiquitous uptake of video conferencing tools in and for education. This meant removing a technical barrier to accessing the online programming we provided. This is no small matter, as Francis and Jacobsen (2013) note, technological know-how was in the past a deterrent to many who would have otherwise participated in online professional learning. For the centre, it also meant that we spent very little time providing *technical* support, but instead, were concentrating our efforts on key programming in the five focal areas and supporting facilitation of large and

small online sessions. That doesn't mean that we haven't run sessions focused on using current and developing technologies, such as generative Artificial Intelligence, but it means we were able to reach a larger, interested, and already zoom-savvy audience, which has meant we have had a bigger impact than we might have prior to a pandemic. As all of the content for the centre is publicly available, and while I will not detail every workshop or series, I want to highlight here the kinds of impactful programming that was run by the centre (see Figure 1), and to showcase projects both small and large.

4.1 Professional Learning for Early Childhood Educators

Early in the life of the centre, it was brought to my attention that early childhood educators (ECE) educators, and especially those in rural and remote communities, were struggling to fulfill their mandated number of professional development hours (e.g. ECE educators in British Columbia are required to participate in 40 hours of professional development every 5 years) in part also due to the pandemic cancelling in person sessions. We partnered with the Early Childhood program, housed also in the Faculty of Education, to support a series of online, professional learning opportunities for ECE educators. Our first session, organized and developed by ECE specialists, and was a first foray for them into delivering content in through online video conferencing. This was just a month and a half after we completed the development of the centre's website (little more than a "landing pad") and was the second session in our nascent lineup. While this first session, took quite a lot of effort on the part of the ECE team to put together, it was very well attended with over 100 registrants and over 70 people in zoom. I mention it as it was the start of a very successful, three-part series that had nearly 500 registrations in the end, and between 70 and 115 people in attendance. One video from this series that is now three years old, "Engaging with Critical Reflection in Early Childhood" has over 3,200 views on YouTube, remarkable given that we did not continue to promote that content. It confirms that a need in the community that could be met with online, free, just-in time professional learning was certainly one the centre could meet. Programming e continues meeting that with additional ECE workshops, the last of which was a 3-part series on sustainable pedagogies for ECE educators, which had over 100 attendees for each session.

4.2 Numeracy and Literacy Series

A second opportunity was built from the networks and communities of a rural educator who is also a faculty member, Dr. Leyton Schenllert, and he and his colleagues, along with a math educator, Dr. Cynthia Nichol, deliver numeracy and literacy professional learning for rural and remote educators, with funding and support from the BC Ministry of Education and Child Care, and a rural school district (Greater Victoria School Board) in British Columbia. Their work has attracted the largest ongoing audiences with over 500 registrants and at least 100 or more attendees in each workshop. The series topically engages with questions, problems, and matters of concern related to literacy and numeracy, and a focus on equity, inclusion, and social justice with Indigeneity at its heart. What the centre has contributed to this powerhouse workshop series is an infrastructure to support and promote these workshops, for example, creating the web pages, registration forms, sending out emails and reminder emails, ensuring a facilitator is present for each workshop, editing the videos post-workshop, posting the videos, and curating workshop content for the centre's digital archive.

4.3 Feminist Pedagogies & Digital Literacies for Seniors

Because we are able to run free, collaborative workshops online, it has meant that we have been able to support smaller scale, but just-in-time initiatives driven by faculty, staff, and students. Two such initiatives, one led by a PhD candidate, and the other by an undergraduate student, are of note. The first, a series of 10 workshops, was supported through a collaboration with Vancouver Community College and targeted to adult English language learners taking mid-level English language courses (levels 3 and above). While we invited both men and women to the workshops, in the end only women attended, likely because there was the word 'feminist' in the title. The series was set up by the PhD candidate to accomplish two things: 1) to give English language learners access to university professors and students who focus their analyses on women and girls, and 2) to create a space for free, English language instruction and practice online (and when all of their classes were still online due to the pandemic). In the end, this was a small scale, but intensive project that reached 6 women who attended regularly with a low of 3 in attendance at one point, and a high of 8 at another. This small group allowed the women to also raise issues they couldn't in other settings such as intimate partner violence, patriarchy in their home countries, an exploration of gender fluidity and trans-related issues, and intersectional oppression such as class, ethnicity, disability, sexuality, as well as gender. When hearing from participants in the last session, we learned

of the meaningful impacts it had had in their lives, and that many of them were sharing the recordings of the sessions with friends and family.

4.4 Digital Literacies for Seniors

The second smaller initiative was a series "Digital Literacies for Seniors" that was created by an undergraduate student, and constructed a series of six short, factual, how-to videos: passwords 101, keyboard short cuts, using an internet browser, and how to use Netflix, for example. The workshops came out of our discussions with people in the immigration and refugee education community, who said they were finding that some of their adult learners needed more support for their online activities. An explicit goal for the student was to create 'how-to' videos that were clear and accessible to seniors. To date, the "how to use Netflix" video has been viewed over 8,200 times. To be clear, the centre does not spend any money on advertising – people find us through the internet, word of mouth, our listserv, and formerly our tweeting on X. And while we know a little bit about our audiences, we don't really know who is seeking out help for using Netflix, though the number of views indicate there is a need.

While the sheer volume of the work we have done in the centre prevents detailing all of it in this paper, one other initiative deserves detailing as it connects to the special needs learning mandate of the centre. The centre's Digital Pedagogy Lab grants being open to students opened space for them to pursue their unique interests in creating potential online learning resources. Two students in the Master of Education and Technology online program, Joe Kwan and Joyce Lo, applied for a grant to create resources for teachers, teaching assistants and the public who are caring for students with complex learning needs who are also non-verbal. They created a series of videos that address those challenges and suggestions for how to support those learners in classrooms and in home environment. One of the videos in their series has over 12,000 views on YouTube. In addition to those fantastic video resources, the students run an in-person summer camp, supported by centre staff, resources, and funding. The PANDA AAC Camp, is a camp designed specifically for children with exceptionalities whose primary mode of communication is AAC (augmentative and alternative communication). The camp was hosted for four years in partnership with the BC Association for Advancing Communications (BCAAC), "a non-profit organization focused on promoting literacy for everyone and supporting AAC users, educators, and families in British Columbia". The camp includes parents and caregivers of these special needs children, and hosts between 14 and 18 families each year, including siblings and extended family members. The camp also hosts over 60 volunteers and has Speech Language Pathologists on hand to lead activities. This camp has had a significant impact on this community, and in 2025 alone raised over $37,000 CAD to support its work.

4.5 Workshop Database/Archive

One final resource worth mentioning is the workshop database that was created. Here we house all of the videos of the synchronous workshops, how-to videos that were created (e.g. digital literacies for seniors) and the additional, related content that was referred to in the workshops. This has allowed us to build out resources related to the five themes of the centre and warehouse the content that we have created to date. As an archive of the work, the database means that content will remain accessible to support a-synchronous learning long after the centre's activities have wound down.

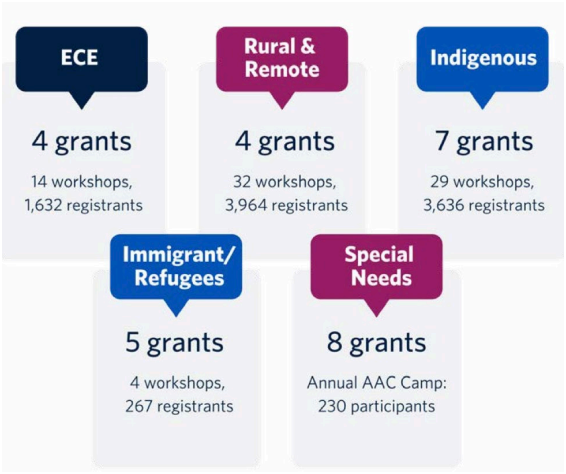


Figure 1: 4-Years of Programming (2020-2024)

5. Conclusion: Digging in and Down, Addressing a Clear Need

Free, online, synchronous professional development and other educational programming post-pandemic remains a need for the communities we reach and who have found us. There are three pieces to this work that are worth emphasizing. First, rural and remote teachers are under-served when it comes to professional learning opportunities whether in person or online, and providing them online, and just-in-time professional development opportunities helps remediate that lack of opportunity. Second, and relatedly, the professional learning we are delivering is driven by the expertise, interests, research, and communities that are resident in the Faculty of Education writ large – faculty, staff and students: the Centre serves as infrastructure for reaching a public audience. While the number of attendees registered for sessions varies from around 10 to over 1,000, and those attending can be half those numbers, the centre continues to generate interest in ECE and K-12 education sectors, as well as higher education.

The challenge present throughout the life of the centre is sustainability: how does the Faculty of Education continue its engagement with the professional learning communities we have developed over the past few years? To continue the free, online, just-in-time professional development that the centre has been so successful at takes some future investment, as its donated funding comes to an end. Right now, with the fiscal deficits in higher education in Canada, including UBC, there is a lack of vision about how a university can discharge its responsibilities to "service" and :community engagement" as part of faculty work to contribute specialized knowledge and abilities not only within but also beyond the academy, when in reality it takes very little actual cash investment once a virtual learning centre has established communities, structures, and activities. Even when something is as insubstantial as a "virtual learning center", given the University's departure from its educational mission in the embrace of monetization and profit-generation, as successful as this centre has been in providing educational resources at no cost to its communities, and at institutional costs the slightest fraction of its brick and mortar counterparts, and notwithstanding the university's stated commitment to knowledge mobilization and community outreach, the Edith Lando Virtual Learning Centre is unlikely to survive once cost its donated funds come to an end. However, it *should* be able to be sustainable namely because it provides invaluable knowledge transfer to the communities the faculty of education, its staff, students, professors, and instructors work within. That work is written into the fabric of government funded research in Canada, and part of the outreach expected of publicly funded work, and the centre was able to not only support but amplify that outreach through its virtual communities. To conclude, the work of the centre has created has reached local, extra local, and national education communities in Canada and has, for many become a go to site for professional learning.

Ethics Declaration

There was no ethics clearance required to write this paper.

AI Declaration

No AI was used tool was used to develop or write this paper.

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Where Technological Literacy and Literacy Meet: New Terms for Old Competencies

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Abstract This paper presents a study of how, where, and what a group of young people (12-25 years of age) read and write and how their literacies and the affordances of their technologies affect the communicative networks that emerge, and the nomenclature utilized to describe reading and writing. The participants have very few arenas that demand long-form writing and reading. Just a few decades ago, reading and writing were the only sources for long-form input (books, newspapers, journals etc.). Traditional literacy (read books/letters, write on paper) has been a panacea for generally improving living conditions; however, it seems that the concept of literacy is changing and the technologies for reading and writing may have altered the general state of literacy. This study asks the questions; which arenas demand the ability to read longform, linear texts and which real-life context require long-form writing skills? Where is the relevant arena that demands traditional reading and writing skills? What is reading and writing to the youth of today, where do the youth utilise reading and writing skills? Which technological affordances are exploited to communicate in ways that foster learning, community and friendship? We map out and study the arenas, practices and technologies for reading and writing to understand possible changes in the pupils' and students' needs and purposes for literacy. The findings are presented in three cases that collectively show the arenas that emerged in the data. We raise the question, whether there is a discrepancy between the notion of what reading and writing is in school and maybe in education in general and the pupils' and students' actual need and purpose for literacy in technology-rich everyday lives? We suggest the concepts of the 'rhizome' and 'arborescence' to describe new and traditional literacies.

Keywords: Technological Literacy, Reading, Writing, Affordance, Rhizomes

1. Background

This paper presents a study of young people's reading and writing practices and how their linguistic register and technological affordances affect the communicative networks that emerge, and how the nomenclature utilized to describe reading and writing develop into something else and where these new literacies are necessary and applied in a communicative practice. The inspiration for the investigation is to contest the public and political notion that young people don't read (fiction) and write as much as the used to, and that this development represents a problem. Hence the Minister for Culture implemented a national strategy for improving young people's desire to read fiction in Denmark (2024). The minister motivated the strategy and the accompanying funding by the following statement form the press release:

> *"Unfortunately, our children are reading less and less. A sad development that we must do everything we can to reverse. One way to boost the joy of reading is to get more people to read a physical book." (Kulturministeriet, 2024)*

In a national report mapping out young people's fiction reading habits Hauer (2024), it is stated that 17,9% of the population in Denmark (above the age of 12) never read fiction, 48,5% read less frequently than weekly. This indicates that reading fiction may not be the main arena for developing literacy anymore. Therefore, we wanted to map and understand the general reading and writing arenas of young people, and to understand when they are reading and writing, the modality/medium and how they do it developing the skills to read and write has been a mainstay in school for centuries. Learners across the globe spend hours learning to decode letters into words, into meaning, and the other way round they learn to bring voice to thoughts through writing. This study asks the question:

Which arenas for reading and writing appear in the communicative practices of young people (12-25 years) and which literacies do young people learn and need?

It is, thus, important to note that this is not a study of literacy, multimodality, reading or writing as such. It is a study of how literacies are applied, and which technologies, purposes, practices and arenas require the ability to read and write in the traditional sense.

2. Method

We speak about language in school, and we implement a meta-language for linguistics, and we develop an academic nomenclature in the subjects. However, outside of the language classroom, language use is mostly a tacit phenomenon, and the data for this project suggest it is a covert and internal process that mainly emerge as investigable expressions when we ask for reading comprehension or when we read somebody's writing efforts. Thus, we don't have direct access to the mental process of reading and writing (in any modality). To overcome this methodological issue, we utilise the method of the 'Go-Along-interview' (Harvey, 2024; Kusenbach, 2016). In practice, we have developed an interview guide to scaffold and systematise the participants expression of what, how, why, when they read and write while the participants show us their arenas for writing and reading. In addition to the Go-Along we designed a background survey consisting of both a qualitative and a quantitative section. The survey asks questions in relation to defining reading, writing and to investigate the arenas and technologies utilised in. The survey precedes the Go-Alongs and, thus, it informs and qualifies the interview/observation guide designed for conducting the Go-Alongs.

2.1 Population of Investigation

The project is designed as a cascading investigation of the reading and writing arenas of, first, teacher students and, then 6th and 8th grade pupils in school. This cascading design was designed to map differences between the pupils' and the teacher students' reading and writing arenas to lay bare potential discrepancies between those learning to read and write and those about to teach reading and writing. The third wave of the cascading investigation was for the teacher student to take the research design into their placement to do their own investigation of their own pupils' reading and writing arenas (not presented in this paper). The purpose of the cascading investigation was to develop a new way of disseminating the findings of a research project directly into the practice investigated.

2.2 The Survey

The mapping of the field was commenced by designing and distributing a survey to the population of 6thand 8th graders and teacher students. The survey produced data on the population's definition of reading and writing and gave insights into what the population regard as reading and writing and where and how they read.

2.3 The 'Go-Along-interview'

The Go-Along interview method allows for the collection of rich, contextual data that reflects the participants' lived experiences. Additionally, it facilitates a deeper understanding of the spatial and social contexts that influence reading and writing behaviours (Kusenbach, 2016, 2018; Risko et al., 2013). This method also helps to build rapport between the researcher and participants, fostering a more relaxed and open dialogue (Risko et al., 2013). However, the main reason why Go-Along interviews were chosen as the prime method for producing data for this research was that it was a way to force an explication of phenomena that would otherwise only reside in the participant's mind.

The participants showed us how they use their devices for communication at the university/school, or at home. We ask open-ended questions to elicit detailed descriptions of their experiences, preferences, and challenges related to reading and writing.

The practice of doing the Go-alongs were:

1. Research question formulation
2. Designing a background survey with the same questions as the Go-along interview with an added quantitative section
3. Design of an interviewguide based on the research questions and on the survey responses
4. Conduct the Go-alongs. Ask the participants to show their reading and writing arenas on their devices (apps), textbooks/books/cartoons/places, while using the interviewguide to structure the conversation. We utilised the questioning technique 'probing' to lead investigation trajectories in alternative directions if they presented themselves (Scott & Usher, 2011)
    a. Audio/transcript
    b. Video of arenas
5. Coding/analysing and interpreting data

The lead-in process of the Go-Alongs was to ask a series of defining questions, similar to the questions in the survey, so that we could compare the interviewees expresses understanding of reading and writing to their shown practice of applying literacies to their reading and writing arenas.

The Go-Alongs are used to make exemplary cases that show three different stories of reading and writing arenas that emerged in the data. Thus, the findings are qualitative and particular to this study's population. However, the cases report common traits among the majority of both Go-Along interviews and survey responses, so the cases are exemplary and valid in the context of this study's population and in relations to the way Flyvbjerg (2006) describes exemplary cases. Which means that the cases are 'deep', 'paradigmatic' and strategically selected to show the findings in relations to reading and writing arenas and the research question in general.

2.3.1 Data

The data that supports this study consists of a background survey and 16 Go-Along interviews with participants in the age group 12-25 years of age. The data was produced in the period from 1/9 2024- 1/3 2025. The groups represented in the population are chosen based on getting a, potentially, broad spectre of reading and writing arenas. The youngest participants (12 years) were chosen because the represent that first age group to be legally on social media and because they, statistically, should have automated reading and writing to a level of proficiency (Cooper et al., 2024). Therefore, we asked 37 6-8 grades to answer the survey of whom 6 also took part in Go-Alongs. The 20–25-year-old participants were chosen because they were teacher students expected to play a pivotal role in developing relevant literacy skills in pupils in their future practice. 99 teacher students answered the survey, 10 of them participated Go-Alongs.

For this paper the Go-Alongs represent the main empiric data aimed to describe cases, the survey is only used to support the findings.

Table 1: Data production

	Age 12-15 Group A	Age 20-25 Group B	Total
Survey	N=31	N=99	N=130
Go-Along	N=6	N=10	N=16
Participants	N=37	N=119	N=146

The bi-variate analysis of the survey data showed that the two age groups are active in the same arenas for reading and writing. The table below shows if they strongly agree or agree that the specific reading and writing arena is acknowledged as reading or writing.

Table 2: Positive identification of acknowledged reading and writing in specific media, shown in percent points (pp)

	Age 12-15 Group A	Age 20-25 Group B	Difference
Text (SMS)	89%	86%	3 pp
Messenger	55%	85%	30 pp
Snapchat	89%	38%	41 pp
Facebook	Data missing	38%	Data missing
Language models (prompting/replies)	33%	58%	25 pp
Video, shorts, YouTube	89%	25%	64 pp
Books (paper)	83%	100%	17 pp
Shorts texts (posters, adds)	34%	85%	51 pp
Subtitles	94%	81%	13 pp
Reading comments in SoMe	78%	69%	9 pp
Blackboard in class	78%	Data missing	Data missing
Understanding emojis	72%	Data missing	Data missing

The main differences between the two age groups are that Group B (teacher students) is more prone to regard 'messenger' as reading and writing, while Group A (pupils) is more prone to regard 'snapping' as reading and writing. Furthermore, Group A is more prone to regard shorts as reading and writing, conversely, Group B is more prone to acknowledge text on adds and posters as reading and writing. These slight differences are interesting, but probably to be expected and, thus, not part of the analysis and finding of the paper.

2.3.2 Describing and Selecting Cases

The specific Go-Alongs, selected for case description, were chosen because they represent reoccurring, exemplary anecdotes from the participants that present pivotal and seminal traits that are traceable in some form in most Go-Alongs (15/16) and surveys, but the traits are clear, collected and distinct in these three specific anecdotes. These traits are present in most of the 16 Go-Alongs but in a more scattered form, hence we chose the 3 specific Go-Alongs as cases for analysis and presentation in the paper. The one Go-Along, that doesn't show any of the traits, is of a 13-year-old boy, who doesn't use TikTok or YouTube and only rarely uses Snapchat. He uses his phone for texting friends and family. Instead, he reads comic books and plays football. He would have been a great choice for an extreme case for another paper.

3. Theory

The data indicate that the participant rarely 'just' read or write. They normally interact in networks of many modalities and technologies. Thus, we analyse the data as 'rhizomatic' processes (Parr, 2010). A 'rhizomatic' process is a networked, ahierachical exchange of information. The rhizome is a metaphor from biology, where it represents a rooted network that some robust plants have (ex. weeds). The rhizome roots form networks where nutrition is exchanged where a path is possible and needed. The metaphor is used by Deleuze (Deleuze, 1986; Deleuze & Guattari, 1987; Holland, 2013) to describe the process of thinking. It is often utilised to describe the internet because the internet and its users seem to find ways of spreading and getting information, despite attempts to organise and limit how information spread on the internet, much like weeds in the garden. The use of the hashtag (#) and handles (@) across platforms are examples of how rhizomes are formed by actual needs for exchange that emerge when needed and disappear when the conditions and needs for communication pass. Deleuze describes this process as a 'line of flight', which is a channelling of information through the 'plateaus of intensity' that serve as hubs for further transport of the information. A 'plateau of intensity' could be a subreddit, a hashtag (#metoo), a handle (@Banksy), but it could also be the space around the coffeemaker in the workplace or the kitchen in a home.

We understand traditional reading and writing as 'arborescent' processes that are hierarchically determined by external conventions and protocols/grammar that the data shows are generally ascribed to education. Conversely, we find that the reading and writing processes of the participants are mostly 'rhizomatic'. Deleuze defines reading as hovering over a text like a hawk, to stoop down into the text, where the text provides a 'plateau of intensity', that is, a passage of condensation and importance (Deleuze & Parnet, 1987). Deleuze emphasizes that reading involves a form of encounter where the reader interacts with the text to produce something new. This approach to reading leads to the notion that decoding leads to a 'becoming', the emerging of something that wasn't here before (Deleuze, 1994), where reading is a dynamic process that transforms both the reader and the text. Today, the rhizomatic approach to reading describes a fragmented process of assembling inputs from multiple, eclectic sources into a meaningful unit that can serve as a plateau for thinking and formulating utterances in speech and writing to form new connections (Cormier, 2008; Ovens et al., 2016). This notion lends itself to the aggregated inputs that the participants show in the Go-Along interviews, and it contrasts the traditional understanding of reading and writing as linear processes of decoding and encoding letters into coherent texts.

We also use the term Technological literacy, it is defined: 'as the ability to 'use, manage, assess, and understand technology' (Hasse, 2017; Hayden, 1989). Conversely, the participants show a merger, an assemblage, of literacies and an extensive technological literacy that utilise their reading and writing skills and develop new skills and tacit practices (Kjærgaard, 2016 p. 106).

4. Findings

The most protruding finding is that the participants in both survey and Go-Alongs express traditional views on reading and writing while, conversely, they show completely different practices of combining literacy and technological literacy in their arenas for reading and writing in the Go-Along.

In the beginning the interviews the pants express reading as

Reading and writing, is understood as decoding and encoding of grammatically and syntactically correct utterances in text and speech and the participants defined it as:

- Writing: The majority of the participants assess that writing is encoding of text over more than half a page (1200 characters).
- Reading: The majority of the participants assess that reading is decoding of text over more than half a page (1200 characters)
- Nomenclature of literacy
    - The majority describe writing activities in other verbs. The protruding verbs for writing are:
        - To post, to snap, to DM, to text, to message, to comment,
        - All of which include encoding letters, sounds, videos, images, smileys and memes into multimodal, coherent texts.
    - The majority describe reading activities in other verbs. The protruding verbs for reading are:
        - To watch, to scroll, to check, to share,
        - All of which include decoding letters, sounds, videos, images, smileys and memes into multimodal, coherent meaning.

The assessment gauge of half a page seems to be the threshold that defined when their definition of reading and writing goes from recognition graphics and word-images into actual, systematic reading based on grammar. Above the threshold of half a page reading and writing is understood as the formal, traditional and arborescent definition of grammatical writing and linear reading. Below the threshold of half a page the rhizomatic network of literacies are expressed in completely other terms than reading and writing.

The interesting scope of investigation, then, is utterances/texts between 1 and 1200 characters. These texts are text multimodal assemblages of images/audio/video/text/diagrams/hyperlinks/experiences (stories), places (snaps). These utterances all require specific affordances from the technologies that deploy the utterances and technological literacy to utilise the potential of the technology for their communicative needs. The objective affordance is the total potential of the technology (Gibson, 1977), conversely, the subjective affordance is what the user may be able to do with the technology (Gaver, 1991). In this study the participants have all developed a needs-based technological literacy, they do and learn what is necessary to utilise the technologies needed to engage with education (ex. TEAMS, email), friends (ex. Messenger, Snapchat, Instagram), family (ex. Messenger, email, texting), hobbies (Messenger, email) and, in some cases, work (ex. AULA, email, Messenger).

They describe a series of communicative arenas all of which have different purposes, participants, registers and practices.

4.1 Case 1 Interconnected Technologies

The participant (male, 22) explains how he has set-up an arena for communication that is compiled of a smartphone, a smartwatch and a computer. They are all interconnected, and they all potentially enable him to communicate. However, the smartphone is the anchor that gives him a status of all his communication from the university, work, friends, hobbies and family. Furthermore, the smartphone is the main technology for media consumption (reading, watching, interaction). The smartwatch is what he refers to as 'nice to have'. It gives him a quick and effortless status of things and it tracks his pulse and activity, both of which he finds helpful. He has, carefully, chosen which notifications should be on the watch, and which should only be on the phone. He filters the notifications because he gets distracted by the notifications on the watch.

The computer is his main technology for production, he primarily uses the computer for educational purposes. However, he also uses the computer for long-form contributions to reddit.

He operates at least 3 different linguistic registers for communication.

- One that has grammatical punctuation, orthography, careful editing in MS Word on the computer utilised for education.
- One that aims for correct grammar and orthography in short clauses with limited use of smileys, utilised in texts and Messenger with family and hobbies.
- One that requires context and consist of smileys, memes, acronyms, netspeak, with a limited use of words, utilised in Snap, Instagram, TikTok, Messenger with friends

Case 1 also uses reddit for long reads and for reading news and discussions of topics he finds interesting.



Figure 1: Participant explicating a complex arena for reading and writing consisting of interconnected technologies

4.2 Case 2 Long Reads and TL:DR

The participant (male, 24) communicates in similar arenas as Case 1, however, he explains in more detail how he uses Reddit for getting deeper into subjects. He reads longer threads about the topics he finds interesting and, as a general observation, he and the other participants, are prone to follow the threads into serendipitous rhizomes of posts that take him/them into unexpected 'rabbit-holes' on reddit. He explains the reading and writing practice of Reddit as a democratic, 'open source' development of the initial post. He also explains, that if is the initial post is regarded too long and tedious to read, then the commenters will post the acronym TL:DR, which is short for, 'too long, didn't read'. If the TL:DR is upvoted in the comments, then the author of the initial post might write an abstract of the post or one of the commenters will write a summary for the rest of the community.

This reading and writing arena is fairly traditional in the way it utilise linguistic traits of writing.

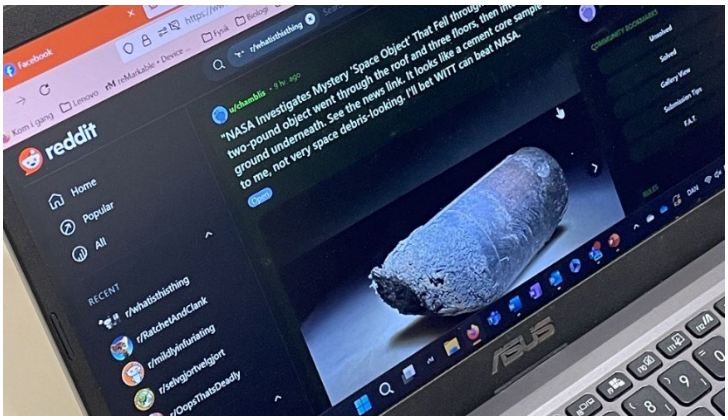


Figure 2: In depth subreddit on astronomy

However, some of the subreddits, that he uses to explicate his points, use an 'in group' lingo that is mostly meaningful for the users of the subreddit or those familiar with the topic. The 'in group' lingo consist of different spellings and acronyms, and it requires an effort to understand and an even bigger determination to be able to engage in.

4.3 Case 3 Rhizomes of Reading and Writing

All participants, of all age groups describe and show rhizomes of reading and writing, they describe a communicative practice, where information travels across platforms and people and forms rhizomatic networks of peers, friends, family, chatbots, search engines, websites, social media, web shops, technologies, protocols, servers and places and the connections between the plateaus that emerge.

The data contains several accounts like the following story. This case is chosen because it compiles the traits of all the stories in one story. A female participant (age 23) (S1) describes a situation where her sister (S2) sends her a snap, asking about what their mother's wishes for her birthday and where and when the celebrations is,

they decide that S1 should text their mom asking for wishes and details about the time and place of the celebration. S1 sees the snap on her smartwatch and replies on her smartphone. S1 shares the mom's answer in a group chat in Messenger that includes their brother (B). Then they individually go on search engines to look for possible gifts and good offers. They share deep links to web-shops and decide on a present, and B buys it. S2 agrees to write a greeting card. She asks a Chatbot for help and edits the Chatbot's suggestion and shares the wording of the greeting card in the Messenger chat. Finally, they wrap the gift, print the greeting card and attend the birthday party.

These rhizomes of reading and writing requires both traditional literacies and technological literacies and the competency to write and read in multiple registers and in both English and Danish.

The initial snap is comprised for of almost equal amounts of words and smileys, however the snap lacks punctuation. The snap has the added affordance of showing if they have read the snap, and where in the physical world they are situated, which leads to the decision that S1 should 'text' their mother, since S2 is at work and S1 is on a morning walk, utilising her watch to both get notifications and to track her activities.



Figure 3: Smartwatch as a reading arena and tracking device

The 'text' to their mother utilises a traditional register with punctuation, orthography and only one smiley. The 'text' doesn't show if it has been read or where the recipient is.

The messenger group chat combines the registers from the snap and the 'text'. There are more smileys than in the 'text', but they do use punctuation more precisely than in the snap. They don't have location/GPDdata of each other; however, they do get information that the other participants in the chat are active in the chat and that they have read the messages.

The search for the gift and the gift card writing requires technological literacy and literacy. They are all aware that if they search for products, then their SoMe feeds get cluttered with advertisements for that type of products, hence, the search in 'Incognito mode/Private', which allows them to search without leaving traces of their web search and website visit to potential advertisers. Getting a good offer requires the skill to apply the appropriate search phrases to search for a particular website's offers. It also requires the skills and practice of 'lateral reading' to read across reviews and offers from different sites to make a safe and cheap decision.

Finally, they share the bill in Mobile pay, which also requires technological literacy.

The rhizome, that this decision-making-conversation forms, is determined by access to technology, literacy to express and understand the utterances in the rhizome and the technological literacy to engage in the rhizome with the appropriate technology.

4.4 Analysis Of Cases

The cases progress from private literacy practices, technological literacy and technology use (case 1) to specific areas for reading and writing (case 2) to a community of people, technologies, arenas and technologies that share literacies to complete a collaboration task (case 3).

All participants, in all age groups have a computer and smartphone, 15 out of 16 participants use their technologies extensively. They regard the smartphone as an extension of themselves, while the computers are primarily for school/studies/work and for watching series and films, thus, substituting a television for most participants. The literacies to utilise their smartphones are self-taught through trial and error and/or

YouTube/TikTok tutorials, or through peer-learning in their communities. There has been no teacher/parental influence in gaining technological literacy on the smartphone, which means that the in-built intentionality of the phone/apps have free reign to unfold in the hands of the young users in this study. The computer programmes, mainly GeoGebra, Word/Docs and Excel/sheets, have been included in the courses, where they were exemplary and useful. On the smartphones the arenas for reading and writing have emerged as the apps and practices of peers have developed. A repeat example of that is the 'snap map'. The 'snap map' facilitates the emergence of a rhizome that connects the virtual reality to the actual reality leaving users with a new modality to consider when snapping each other. The map acts as a tool to keep track of the community, however, it also reveals where you are and with whom. It appears as if the snap map represents a 'point of no return' for the users, since once it is turned on, it is difficult to turn off again without being confronted with questions why they are 'hiding' from their peers.

4.4.1 Rhizome of Affordance and Need

Case 1 shows how the technologies (smartwatch, smartphone and computer) act as plateaus of intensity for the user forming both an individual and personal rhizome and a shared and community-based rhizome. It also lays bare a business-model that promotes sticking to one brand. Especially Apple-products contain contingencies that make them work more fluently if all the user's technologies are Apple-products. They still work in connection with other brands, however, not as extensively, since services such as iCloud, Lighting-socket, AirDrop, Universal Clipboard and iMessage only work between Apple-products. Therefore, Case 1 (and 6/16 other participants) have only Apple-products in their tech-arena. Case 1 is very aware of this business-model and how it has made him make Apple-oriented decisions buying devices. Convenience beats critical thinking in the case of interconnected Apple-product. As he says, 'it just works'. His tech-arena allows him to form reading and writing arenas that suit where he is (place), what he is doing (time/activity/community) and how he is doing it (affordance). He explains that if he gets a notification on his watch while running in the forest, he records a 'speech to text' reply on the spot, not because it is necessary but because it is possible and convenient. Case 1 has a reading/writing arena that consist of traditional writing, posting, speech to text, snapping, texting, messaging, DM'ing. All these verbs cover encoding of information, however, only writing a coherent text longer than half a page is regarded as writing to Case 1. The other verbs utilise, a complex combination of letters, sounds, Smilies, acronyms, alternate spellings, memes and 'stickers'. There is a disconnect between what he calls writing and the other verbs for encoding he uses to express how he encodes his thoughts into communication. He has learned to write in school; however, the other competencies are learned in a literacy practice that includes real communicative needs and technological affordance.

4.4.2 Case 2 Rhizome of Reading for Information

The acronym TL:DR represents a low patience with longer texts with unnecessary details, redundancies and tangents in writing. Case 2 uses Reddit a lot (5/16 other participants use Reddit), it is main SoMe pastime, he reads most posts in the subreddits he follows, upvotes often, and posts occasionally.

Case 2 shows an extremely low threshold for prolix and circumlocutory wording, it is referred to as 'bad writing'. Case 2 appreciates the democratic, shared process of sharing a reading arena (subreddits) with a community of likeminded (astronomy interest). He likes the affordance of reddit that allows him to evaluate posts through upvoting and using the acronym TL:DR. He sees reddit and the reading arena, that it represents for him, as a direct and better alternative to ChatGPT/CoPilot. The democratic process of curating information in a subreddit in combination with lateral reading to support the information given in the subreddit is his prime arena for reading. He assesses that it improves his access to useful information, and it enables a knowledge building process that is based on the analysis of many sources and reading in many genres and registers and in both Danish and English.

Conversely, he claims that he is bad at reading in the traditional sense. He doesn't read books and in Danish class he was assessed as a mediocre reader. Nonetheless, he has empowered himself to investigate complex and complicated matters through a combination of traditional literacy and technological literacy.

4.4.3 Case 3 Rhizome as the Practice of Task Solving

Buying a gift is a task that would involve meeting up, phone calls and going to shops just 20 years ago. Today the task is an immediate emergence of a rhizome made from plateaus of intensity and lines of flight (text/messenger/snap/GPS/web shopping/smartphones etc.). It is an intersection of literacy and technological

literacy that allows for time, place and joint enterprise to meet in several linguistic registers and in several technological literacies with different affordances. The reading and writing arenas that come into play in this case are simple when seen in isolation, according to the participant, however the rhizome that the case describe is very complex (not complicated). It requires a series of simple skills and the competency to combine them in a complex rhizome that leads to buying the right gift at the right price, at the right time to be delivered at the right place. The linguistic registers are applied in relation to field (topic), tenor (relation to recipient) and mode (means of communication) (Lee, 2001). This indicates that the literacies, technological and linguistic, needed to complete this task by far exceed what the participants have learned in school. Thus, the traditional assessment and evaluation criteria for assessing literacy, utilised in education to understand a learner's literacy aptitude (PRILS, PISA, RERF etc.), doesn't include the learners' ability for engage in rhizomes of communication or the learners' ability to code-switch between registers (Alvarez-Cáccamo, 2013). The siblings in Case 3 show a seamless flow thru 4 different registers and 2 different languages, displaying an elaborate technological literacy and literacy even though the sibling participating in this study says that either one of them are good at reading or writing and that they have a low level of technological literacy.

5. Conclusion

The data generally tells the story of a disconnect between an educational understanding of reading and writing and the reading and writing practices in actual communication between the participants in this study. These practices occur both in school and outside of school. The traditional arenas for reading and writing have changed and there are very few arenas for writing and reading longer texts outside of language class. Thus, traditional literacy may have lost its arenas (books, letters, emails, newspapers, magazines etc.) and, consequently, it may lose its relevance as an isolated competency. However, this study indicates that reading and writing has shifted position in the literacy-hierarchy and have become more of a supporting and upholding literacy that fixates the other modalities in the meaning making process. The participants say, that when they scan their communication for facts and documentation (meeting times, prices, numbers, names, facts etc.), they mainly look for words and numbers and secondarily at other modalities. Contrarily, they look for other modalities first when they read for the digest of a message (scanning for smileys, memes, pictures, acronyms etc.). They don't refer to either of those processes as reading, though. The three cases show the emergence of different rhizomes that rely on a complex understanding of the affordances of the technologies that the participants use for school (chromebook, smartphone), education (computer, smartphone and smartwatch) and how to engage in the rhizomes for pragmatic and noncritical purposes. The only explicitly critical participant is the 13-year-old boy that has chosen not to be part of SoMe, while enjoying comic books instead, he explained that he thinks it is difficult to anticipate the effects of being on SoMe. He doesn't feel that he's missing out and he can't grasp the consequences of being on SoMe. He is rejecting developing technological literacy for now, however, he expressed confidence that he would be able to acquire technological literacy when it may become needed.

He sticks to a traditional nomenclature for literacy, reading is reading books, however, he also uses the term reading to refer to leafing through a comic strip, even though the actual number of words is as low, or lower, than in memes/TikToks/Stories. He calls it reading mainly because it is a leaflet printed on paper. Based on the data, we conclude that the technology generally dictates the verbs used in the collocation associated to the technology, according to our data:

- paper=reading/writing,
    - Arena; language class, in school
- smartphone=watching/checking/scrolling/posting/replying/commenting/upvoting/snapping/DM
    - Arena; in school, outside of school
- computer=reading more than half a page, preferably PDF, writing more than half a page, preferably in Word/Docs
    - Arena; in school, outside of school (older demographic, 20–25-year-olds)
- SoMe platforms= watching/checking/scrolling/posting/replying/commenting/upvoting/snapping/DM
    - Arena; in school, outside of school

The nomenclature for traditional literacy has changed and the technology for literacy has changed. Literacy and technology now form a rhizome of connections between people with intentions and needs, technologies with affordances and information that is expressed in other verbs than reading and writing. Thus, the cases show a disconnect between the quote from the Minister of Education in the first section of the paper and the multimodal and technological literacies that the participants actually need to express themselves, communicate

and learn. The communicative arenas and practices that the participants have shown us show an extremely complex kind of literacy that includes a lot of traditional reading and writing, however, not in the traditional sense. Therefore, we suggest further research into intersections between literacy and technological literacy, and, also, how the literacies may be dialectically connected. So, they read and write a lot, they just don't read books.

Ethical Deceleration

This study does not require an ethical declaration

AI Declaration

No AI tools, apart from spell/grammar-check, were used to write this paper.

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Connecting Disciplines Through COIL and PBL: Industrial Safety and Mathematics Education Synergies

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Abstract: In an era of digitalization, globalization, and complex societal challenges, universities are called to prepare students not only with disciplinary expertise but also with transversal competences such as critical thinking, teamwork, communication, intercultural understanding, and digital collaboration. Project-Based Learning (PBL) offers a well-established pedagogical approach for developing these competences through engagement with authentic, real-world problems. This paper explores how PBL can be enriched through Collaborative Online International Learning (COIL), focusing on interdisciplinary collaboration between students of industrial safety (HSE) and mathematics education. The proposed COIL initiative connects students from different disciplinary and national backgrounds, offering them opportunities to collaborate in international teams on shared project topics that integrate both pedagogical and technical perspectives. Future mathematics teachers contribute structured, abstract thinking, didactic skills, and inclusive communication strategies. While HSE students bring applied knowledge in areas such as risk management, machinery and system safety, occupational hygiene and ergonomics, and incident prevention. This collaboration fosters reciprocal learning, where mathematics becomes more tangible and relevant, and safety expertise is adapted for educational settings. Rather than prescribing fixed themes, the initiative encourages exploration of thematic intersections – such as risk modelling, safety data analysis, communication, or the co-design of teaching materials for technical content. Assignments are intentionally designed to promote active engagement, mutual respect, and the co-creation of meaningful outcomes, while supporting transversal competence development. The paper outlines the pedagogical rationale, competence mapping, and project ideas, emphasizing the potential of combining PBL and COIL. This integrative approach mirrors real-world collaboration across disciplines and borders and offers a flexible, inclusive model of internationalization at home. It enhances students' readiness for professional environments where interdisciplinary teamwork, digital literacy, and cross-cultural cooperation are essential. The initiative is part of the Erasmus+ project COLOSH, which promotes innovative, digital, and international learning in Occupational Safety and Health (OSH) and related fields.

Keywords: Collaborative Online International Learning (COIL), Project-Based Learning (PBL), Interdisciplinarity, Mathematics Education, Industrial Safety, Higher Education

1. Introduction

The increasing complexity of today's world, shaped by digitalization, globalization and rapid social change, challenges universities to prepare students not only with expert knowledge but also with transversal competences such as critical thinking, teamwork, digital literacy, communication and intercultural awareness (ILO 2021, OECD 2018, UNESCO 2015). Frameworks like the *Key Competences for Lifelong Learning* (EUCO 2018), *Global Citizenship Education* (UNESCO 2015) and the *OECD PISA Global Competence Framework* (2018) highlight the importance of collaboration across disciplines and cultures, active citizenship and ethical responsibility. Although not universally defined, transversal competences are widely recognized as essential for personal development, employability and addressing complex global challenges.

In this paper, we explore how higher education can foster these competences through interdisciplinary and international collaboration between two distinct student groups with different career paths but shared developmental needs.

Students of industrial safety (Health, Safety and Environment – HSE), typically educated at technical universities, develop expertise in areas such as risk management, machinery and system safety, incident prevention, occupational hygiene and ergonomics. As future safety professionals, they are expected to apply systematic approach to designing and implementing effective measures that protect health, safety and well-being in the workplace (INSHPO 2017, IOSH 2019).

The core of mathematics teacher education lies in developing a deep understanding of mathematical concepts and the ability to mediate them didactically. Prospective teachers learn to present mathematical ideas, use multiple representations, and foster critical thinking. Central to this process is a deep understanding of concepts, problem-solving, and the capacity to explore the nature of mathematical reasoning. Given that mathematics is

widely regarded as the universal language of science and technology, mathematics teachers play a crucial role in shaping students' attitudes toward these disciplines and motivating them to pursue further study and professional careers in science and engineering.

Despite their disciplinary differences, both groups need to operate in digitally connected, intercultural and problem-based environments. Their strengths are complementary. Mathematics students bring analytical thinking and didactic competencies, while HSE students contribute applied knowledge and real-world relevance. These qualities create opportunities for meaningful mutual learning.

We propose that combining Project-Based Learning (PBL) and Collaborative Online International Learning (COIL) provides a powerful and inclusive platform for interdisciplinary collaboration. PBL engages students in authentic, real-world challenges, promoting the practical application of knowledge (Condliffe et al. 2017). COIL fosters virtual collaboration across institutions and cultures, making international learning accessible without physical mobility (Hackett et al. 2024). Together, they integrate experiential learning with global perspectives, mirroring the realities of today's professional environments, where communication, critical thinking, and co-creation across disciplines are essential. This approach supports competence development and inclusive, future-ready mindsets.

The following sections present the pedagogical rationale (Chapter 2), map shared and complementary competences (Chapter 3), propose joint project themes (Chapter 4), and discuss implications for higher education innovation and internationalization (Chapter 5).

2. Bridging Theory and Practice Through PBL and COIL

The integration of Project-Based Learning (PBL) and Collaborative Online International Learning (COIL) presents a powerful pedagogical strategy for bridging the gap between theoretical knowledge and real-world application. While PBL emphasizes experiential, student-centered learning rooted in authentic problem-solving, COIL introduces an intercultural dimension by facilitating virtual collaboration across institutions and national borders. Together, they offer a flexible, inclusive, and competence-oriented approach well-suited to the needs of contemporary higher education.

2.1 Project-based Learning for Real-world Challenges

Project-Based Learning (PBL) is grounded in constructivist and experiential learning theories (Kolb 1984), emphasizing active student engagement in solving complex, authentic problems over extended periods. Research shows that PBL deepens disciplinary understanding while simultaneously fostering transversal skills such as critical thinking, communication, teamwork, and self-regulated learning (Bell 2010, Thomas 2000).

In the context of industrial safety education, PBL enables students to simulate real-world challenges such as risk assessment, incident analysis, and safety management. It supports the development of practical competences critical for professional practice. This approach has been systematically implemented in projects like RiskMan (Building Competence in Risk Management of Future HSE Professionals) (Kocurkova et al. 2022) and OshDigit (Competent university teachers for digital learning in OSH) (Kocurkova et al. 2023), which promoted PBL integration into safety-related curricula and produced publicly available teaching resources.

PBL plays a dual role in the preparation of future mathematics teachers. First, it supports the development of their ability to apply mathematical knowledge to solve real-world problems and to identify meaningful interdisciplinary connections. This fosters an understanding of mathematics as a tool for structuring and interpreting complex phenomena beyond the classroom. Second, PBL itself becomes a model of teaching practice, aligned with constructivist principles, that future teachers are expected to adopt in their own classrooms. By engaging in PBL as learners, student teachers experience the design of meaningful, inquiry-based, and student-centered tasks that encourage exploration, critical thinking, and collaboration. Through this dual perspective, PBL not only enhances their subject-matter and didactic competencies but also prepares them to facilitate similar forms of active, inquiry-driven learning in their future teaching (Capraro et al. 2013, Darling-Hammond et al. 2017, Jumaat et al. 2017).

2.2 Collaborative Online International Learning for Internationalization at Home

COIL is an educational model that links students and educators from different countries and disciplines through structured online collaboration. Pioneered by the SUNY COIL Center, it offers "internationalization at home" by

providing global learning opportunities without the need for physical mobility (Beelen and Doscher 2022, Hackett et al. 2024). It supports the development of intercultural awareness, global citizenship, digital literacy, and collaborative learning (de Wit et al. 2015, O'Dowd 2018).

In our current COLOSH initiative (International Collaborative Learning in OSH) (VSB 2024), we build upon the foundations of RiskMan and OshDigit projects to incorporate COIL methodology into interdisciplinary and safety-related education. COLOSH supports university educators in designing and facilitating COIL projects, with a focus on digital pedagogy and intercultural collaboration. Upcoming pilot activities will bring together students of industrial safety and mathematics education, offering them shared projects with global relevance and mutual learning opportunities.

COIL is an effective tool in the preparation of future mathematics teachers to integrate internationalisation into higher education curricula, while also fostering the development of intercultural and professional competences. As the European Commission notes, international mobility is still relatively rare in initial teacher education (EC 2019). The inclusion of COIL activities may therefore serve as a suitable strategy for implementing the so-called mobility window – a period in the study plan without compulsory courses, designated for international mobility or other forms of curriculum internationalisation. A key added value of COIL is that it provides prospective mathematics teachers with the opportunity to engage in the design, implementation, and evaluation of interculturally oriented projects focused on mathematics and mathematics education. Research also suggests that participation in COIL has a positive impact on motivation and engagement in initial teacher education (Quintana-Ordorika et al. 2023).

2.3 The Synergy of COIL and PBL

The combination of PBL and COIL creates a unique educational model that integrates applied, project-based learning with international and interdisciplinary collaboration. While PBL ensures that students engage with real problems in context, COIL adds the dimension of cross-cultural exchange and digital communication. This synergy reflects the demands of modern workplaces, where professionals must co-create solutions across disciplines and cultures.

Both methods align with the EU's Key Competences for Lifelong Learning (EUCO 2018), particularly in promoting communication, learning-to-learn, cultural awareness, and digital skills. They also support the development of numeracy, scientific, and technological competences, i.e. pillars of STEM education (EC 2025), which are essential for understanding and solving complex societal and environmental problems.

The integration of mathematics education and industrial safety within COIL-PBL projects exemplifies the value of STEM-based collaboration. By combining analytical reasoning with applied knowledge, such interdisciplinary experiences help future teachers and safety professionals develop transversal competences and translate expertise across professional and cultural contexts.

This integration mirrors real-world collaboration and shows how students from fields like industrial safety and mathematics education bring complementary strengths. The next chapter explores this synergy through a competence-based lens.

3. Competence Mapping of Shared Needs and Complementary Expertise

Students of industrial safety and mathematics education follow different disciplinary paths, but both groups require transversal competences such as communication, critical thinking, digital literacy, and collaboration. These competences are essential for effective participation in interdisciplinary, multicultural, and digitally supported learning and work environments. At the same time, each group brings distinct domain-specific strengths that can enrich mutual learning. This section compares relevant competence domains to highlight shared needs and complementary expertise as a basis for interdisciplinary collaboration through COIL.

3.1 Frameworks for Competence Development

To understand the common ground and complementarity between the two student groups, this comparison draws on several recognized competence frameworks:

For industrial safety (HSE) students:

- The INSHPO OHS Professional Capability Framework (INSHPO 2017) defines global standards for OSH professionals and practitioners, outlining core knowledge, skills, and responsibilities.
- The IOSH Competency Framework (IOSH 2019) reflects best practice in OSH and sets the standards for the skills, knowledge and behaviours of OSH professionals.
- ENSHPO (2025) supports the mutual recognition of OSH managers and OSH technicians in Europe and promotes shared standards for competence and certification.
- National systems like the Czech National Register of Qualifications (NRQ) provide pathways for recognizing OSH qualifications, including validation of non-formal and informal learning (NRQ 2025a, 2025b).

For mathematics education students:

- The Competency Framework for Graduates of Teacher Education Programs (MŠMT 2023) is nationally binding document that defines the shared professional profile of all prospective teachers in the Czech Republic. As an annex to the national framework for study program accreditation, it must be explicitly reflected in all initial teacher education curricula and serves as a reference point for the self-evaluation and improvement of teacher training institutions.
- The European Qualifications Framework (EQF) (Europass 2025) provides a general reference for education and professional qualifications across Europe, including teaching. It defines learning outcomes in terms of knowledge, skills, and autonomy. Teacher qualifications typically correspond to levels 7 or 8.
- DigCompEdu (Punie and Redecker 2017) is a framework focusing on digital competences of educators, including pedagogical use of technology, digital content creation, and learner engagement.

3.2 Shared Transversal Competences

The European Reference Framework on Key Competences for Lifelong Learning (EUCO 2018) defines eight key competences necessary for personal development, active citizenship, social inclusion, and employability. These competences are highly relevant not only for general education, but also for structuring interdisciplinary and collaborative learning environments in higher education.

In both study programs, industrial safety and mathematics education, the following transversal competences emerge as particularly relevant:

- Digital competence: Confident, critical, and responsible use of digital technologies for communication, collaboration, and problem-solving.
- Personal, social and learning-to-learn competence: Self-regulated learning, resilience, teamwork, and constructive interaction with others.
- Citizenship competence: Acting responsibly within society, with attention to ethics, sustainability, and social well-being.
- Entrepreneurship competence: Creativity, initiative, teamwork, and the ability to plan and manage projects with real impact.
- Mathematical and scientific competences: Structured thinking, data analysis, modelling, and evidence-based decision-making across both fields.
- Communication in native and foreign languages: Essential for collaborative work, intercultural dialogue, and dissemination in COIL settings.

These shared competences form a solid foundation for joint learning in digital, interdisciplinary, and intercultural contexts. Through the combined use of PBL and COIL, students are challenged to actively apply and further develop these skills in authentic, real-world inspired projects.

3.3 Complementary Competence Domains From Industrial Safety Students

Although transversal competencies are shared, industrial safety (HSE) students bring distinct expertise that can enrich interdisciplinary collaboration. In particular, in supporting future maths teachers in areas related to health, safety, and well-being in school environments.

Based on the OSH-related Competency Framework (IOSH 2019, INSHPO 2017), three competence domains stand out:

A. Health and Safety Awareness
   - Risk Management: Identifying hazards, assessing risks, and applying appropriate control measures in classrooms, during school trips, and in other educational settings.
   - Emergency Response: Responding to incidents, administering first aid, and conducting basic investigations to prevent recurrence.
   - Health and Well-being: Recognizing risks related to musculoskeletal and mental health and applying straightforward strategies for prevention.

Relevance: Supports future teachers in creating safer, more supportive learning environments and in responding effectively to both physical and mental health concerns.

B. Organisational and Planning Competence
   - Safety Culture: Promoting responsibility, inclusion, and proactive safety attitudes within the school community.
   - Stakeholder Awareness: Understanding the roles, needs, and expectations of pupils, parents, colleagues, and school leadership.
   - Ethics and Sustainability: Embedding ethical, inclusive, and sustainable practices into everyday teaching.

Relevance: Strengthens future teachers' ability to create a positive classroom climate and contribute to broader health and safety efforts throughout the school.

C. Communication and Education in Safety
   - Risk Communication: Effectively communicating safety-related information during lessons, activities, and school events.
   - Awareness Raising: Creating simple, age-appropriate materials on topics such as ergonomics, mental health, and first aid.

Relevance: Encourages future teachers to integrate safety concepts into everyday teaching and develop relevant didactic tools.

These competences demonstrate how HSE students can offer relevant insights and tools to mathematics education peers, supporting mutual learning in COIL projects. Table 1 summarizes these strengths and their relevance.

Table 1: Competence strengths of HSE students and their relevance for mathematics teacher education

Competence Area	HSE Student Expertise	Value for Mathematics Education Students
Risk Management	Hazard identification, risk assessment, and risk control in classrooms, school trips, and other settings	Safer planning of lessons, excursions, and classroom layouts
Emergency Response	First aid, incident handling, and basic investigation	Greater confidence in managing injuries and emergency situations
Health and Well-being	Recognition and prevention of musculoskeletal and mental health risks	Promoting well-being and resilience among pupils and teachers
Safety Culture	Promoting responsibility, inclusion, and proactive safety attitudes	Modelling safe, inclusive, and responsible classroom behaviours
Stakeholder Awareness	Understanding diverse roles and expectations within the school community	Supporting communication and collaboration with pupils, parents, and colleagues
Ethics and Sustainability	Applying ethical and inclusive practices, awareness of sustainability	Embedding values into daily teaching practice
Risk Communication	Explaining safety topics clearly during lessons, events, and activities	Integrating safety thinking into lesson content and communication strategies
Awareness Raising	Creating materials on ergonomics, mental health, and first aid	Inspiration for relevant and accessible didactic tools

3.4 Complementary Competence Domains From Mathematics Education Students

Future mathematics teachers contribute valuable competences to interdisciplinary collaboration. Their ability to analyse and structure complex problems, facilitate understanding of mathematical concepts, and design meaningful learning activities complements the technical expertise of students in the field of occupational safety and health. These strengths enhance the clarity, inclusiveness, and educational value of joint projects.

Drawing on national and European frameworks (MŠMT 2023, Europass 2025, Punie and Redecker 2017), the following competence domains are particularly relevant:

A. Mathematical Reasoning and Use of Representations
   - Conceptual Understanding and Modelling: Ability to abstract and model complex situations using mathematical language, representations, and tools.
   - Didactic Transformation: The ability to communicate content in a clear and factually accurate manner, using appropriate methods, representations, and tasks, in alignment with learners' educational needs and levels.

Relevance: Enhances clarity in problem formulation and supports the creation of effective instructional and training materials.

B. Learning Design and Reflective Practice
   - Design of Meaningful Tasks: The development of learner-centred activities, tasks, tools, and models that create meaningful learning opportunities and are clearly aligned with defined educational objectives.
   - Reflective Practice: The ability to critically evaluate the processes of teaching and learning and to use feedback to improve instructional effectiveness.

Relevance: Supports structured planning, iterative development, and critical reflection throughout team-based project work.

C. Inclusive Pedagogy, Communication, and Ethical Awareness
   - Creating Supportive Environments: Promotion of equity, psychological well-being, and safe collaboration spaces.
   - Ethical and Professional Conduct: Capacity to act responsibly, empathetically, and respectfully within diverse interdisciplinary teams.

Relevance: Strengthens teamwork, sensitivity to mental health and well-being, and awareness of the social and ethical dimensions of safety in both educational and workplace settings.

These competence domains illustrate that mathematics education students can serve as facilitators of structure and clarity within interdisciplinary teams. Their skills in analytical thinking, didactic reasoning, and inclusive communication contribute to the success of COIL-PBL projects and foster mutually beneficial learning.

Table 2: Competence strengths of mathematics education students and their relevance for industrial safety students

Competence Area	Mathematics Education Student Expertise	Value for HSE Students
Conceptual Understanding and Modelling	Ability to abstract and model complex situations using mathematical language, representations, and tools	Enhances accuracy in problem formulation and supports the development of effective training materials
Didactic Transformation	Ability to communicate content clearly and accurately, using appropriate methods, representations, and tasks, in alignment with learners' educational needs and levels	Facilitates communication of technical topics and contributes to accessible dissemination of domain-specific content at an appropriate level
Design of Meaningful Tasks	Development of learner-oriented activities, tasks, tools, and models that create opportunities for meaningful learning and are aligned with defined educational objectives	Supports structured planning and enhances the didactic quality of training materials and other project outcomes
Reflective Practice	Ability to critically evaluate teaching and learning processes and to use feedback to improve instructional effectiveness	Promotes team development through self-reflection and adaptive approaches

Competence Area	Mathematics Education Student Expertise	Value for HSE Students
Creating Supportive Environments	Promotion of equity, mental well-being, and psychologically safe spaces for collaboration	Strengthens team collaboration and increases sensitivity to psychosocial risks in educational settings
Ethical and Professional Conduct	Capacity to act responsibly, empathetically, and respectfully in diverse interdisciplinary teams	Reinforces ethical awareness in relation to safety and supports culturally sensitive and responsible communication

4. Designing Joint COIL Project Topics

Based on the competence mapping in Chapter 3, joint COIL projects are designed to connect the strengths of industrial safety and mathematics education students. The aim is to foster active, interdisciplinary learning through authentic, real-world challenges that benefit from both technical and pedagogical expertise.

Each proposed topic seeks to:

- Address relevant problems in education and safety.
- Promote equal, respectful collaboration between disciplines.
- Develop transversal skills such as teamwork, communication, digital literacy, and ethical thinking.

Table 3 outlines suggested project themes, highlighting their purpose and value for both student groups.

5. Conclusion

Innovation in higher education is essential, and COIL offers a flexible and inclusive way to support this transformation. By making international and interdisciplinary collaboration accessible to all students, regardless of their discipline or mobility opportunities, COIL enables broader participation and richer learning in a global context.

Combining COIL with Project-Based Learning (PBL) creates powerful opportunities for competence development. Through real-world, co-created projects, students engage deeply with professional and transversal competences while learning from and with peers from different disciplines and cultural backgrounds.

Our analysis showed that students of industrial safety and mathematics education bring complementary strengths. Future mathematics teachers offer strong analytical thinking, abstract reasoning, and pedagogical skills, while HSE students contribute applied expertise and real-world contexts for safety and health-related challenges. Mathematics serves as a foundational instrument for understanding technical disciplines, while didactic skills of future teachers can enhance the training role of HSE professionals. In turn, HSE students provide practical settings and problem scenarios that give deeper meaning to mathematical thinking.

The competence mapping in this paper was conducted at a generic level due to the lack of compatible frameworks. Still, we used established sources (e.g. INSHPO 2017, IOSH 2019, MŠMT 2023, Punie and Redecker 2017) to identify overlaps and complementary areas. A more detailed mapping would support future COIL designs and maximize mutual learning potential.

Our next step is to pilot COIL projects during a “mobility window” semester, supported by staff training and outcome evaluation. We believe this approach can foster inclusion, innovation, and internationalization and contribute to a more connected and future-ready higher education landscape.

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Ethical Statement

The submitted manuscript is original, has not been published elsewhere, and is not under review by another journal or conference. All authors contributed significantly and all sources are properly cited. The research is based solely on anonymous or publicly available data. According to Czech legislation and institutional guidelines, no ethical approval was required.

AI Statement

During the preparation of this paper, the authors used ChatGPT (OpenAI 2024) as a supportive tool for checking logical consistency, eliminating redundancy, editing language, and reducing text length. All content suggestions provided by the tool were critically reviewed and revised by the authors. No generative AI was used for content creation, data analysis, or interpretation of findings. Table 3: Proposed COIL topics with aims and learning opportunities

Topic	Main Aims	Learning Opportunities for HSE Students	Learning Opportunities for Mathematics Education Students
1. Risk assessment in educational settings	Risk assessment and control in various school environments (e.g. classroom, school in nature)	Apply risk assessment tools to unfamiliar settings; practice non-technical communication	Understand risk concepts; apply safety thinking in planning school events or lessons, and prepare didactically appropriate materials for communication with both students and teachers
2. Emergency preparedness plan and training	Develop school-wide emergency procedures and conduct training activities	Design structured emergency response procedures tailored to specific scenarios	Revise proposed procedures using critical and algorithmic thinking, prepare clear graphical representations, communicate them appropriately at the student level, and reflect on inclusion and psychological safety
3. OSH awareness training for teachers	Design a professional training module on key OSH topics	Apply technical expertise in an educational context	Transform technical content into didactically appropriate formats for peer learning or teacher training
4. First aid education and training toolkit	Create school-based first aid procedures and learning materials	Link first aid knowledge to communication and training tasks	Co-create teaching materials using analytical and algorithmic thinking, including appropriate visual representations
5. Mental health and well-being in schools	Address stress, resilience, and mental health support for students and teachers	Reflect on psychosocial risks and health promotion in schools	Explore mental health awareness and support strategies for learners
6. Ergonomics and MSD prevention in the classroom	Identify and address ergonomic issues for pupils and teachers	Apply ergonomic principles to school environments	Analyse real-life ergonomic problems; propose mathematically informed classroom adaptations, mathematically interpret available data from studies
7. Simulation and modelling of safety scenarios	Use data and simulations (e.g. evacuation modelling, injury trends) to support safety planning	Explore safety modelling; engage in interdisciplinary interpretation	Use modelling and abstraction to interpret data; support interdisciplinary problem-solving
8. Analysis of school safety data	Investigate incident trends and propose improvements based on real or simulated data	Develop skills in root cause analysis and formulating evidence-based recommendations	Apply analytical skills to interpret real-world data; connect safety themes to curriculum goals
9. Evaluation of VR-based vs. traditional OSH training	Compare learner outcomes, engagement, and usability across formats	Evaluate training effectiveness; analyse feedback	Gain insight into technology-enhanced learning and instructional design, compare pedagogical implications of technology use; reflect on learner engagement and outcomes
10. Development of a digital tool for	Co-create a prototype of a simple, school-	Translate expert knowledge into user-friendly systems	Participate in user-centered design and digital tool co-development, contribute to user-centered design;

Topic	Main Aims	Learning Opportunities for HSE Students	Learning Opportunities for Mathematics Education Students
school risk assessment	specific risk assessment tool		apply structuring skills to support intuitive digital tools

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3D Technologies in Teacher Education: Reflections and Didactic Potential

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Abstract: This paper presents findings from a qualitative study conducted within a university-level course on technical education for pre-service teachers. The course was innovatively enhanced by integrating the topic of 3D modelling and printing (3DMP), with a focus on exploring its educational applications in the context of school teaching. The aim of the study was to analyze how future teachers perceive and reflect on the use of 3D technologies in education. Students participated in hands-on training using Tinkercad and learned the basic operation of 3D printers. They were also introduced to examples of how 3DMP can be applied across different school subjects, such as mathematics, science, and technology education. As a final project, students worked in small groups to design a 3D model, print it, and develop a detailed methodological plan for its use in the classroom. The collected data included project documentation, lesson proposals, and students' written reflections, which were analyzed through qualitative content analysis. The results indicate a generally positive perception of 3D technologies among pre-service teachers. Students appreciated the creative and interdisciplinary possibilities of 3D modelling, while also critically reflecting on technical and didactic challenges. Many participants highlighted the motivational potential of 3D printing for young learners and its usefulness for visualizing abstract or complex content in an accessible way. This study contributes to the growing body of research on educational technology in teacher preparation by emphasizing the need for meaningful, practice-oriented integration of digital tools. It also points to the importance of developing technological-pedagogical thinking in future educators, fostering both innovation and critical awareness in their professional development.

Keywords: 3D Printing, Teacher Education, 3DMP, Tinkercad, Educational Technology.

1. Introduction

The integration of emerging technologies into teacher education has become an increasingly important area of focus in the digital era. As classrooms evolve to include digital tools, educators must be prepared not only to use technology effectively but also to understand its pedagogical implications (Koehler and Mishra 2009; Tondeur et al. 2017). This is particularly relevant in the context of initial teacher education (ITE), where the foundations of professional identity and instructional reasoning are being formed. Despite the growing emphasis on digital competence, many teacher education programmes still offer limited opportunities for students to engage with hands-on, creative, and design-oriented technologies (Instefjord and Munthe 2017).

3DMP have gained increasing attention as innovative tools in education. Their capacity to visualise abstract concepts, support spatial reasoning, and foster learner engagement has been widely recognised (Ford and Minshall 2019; Lavicza et al. 2023; Trust and Maloy 2017). In school settings, 3D technologies can be used across disciplines—from mathematics and science to geography, arts, or special education—yet their use by teachers remains relatively rare (Bull et al. 2015). Introducing such tools in pre-service training may not only expand teachers' technical skillsets, but also stimulate constructivist thinking, multimodal design, and inclusive pedagogical strategies (Piaget 1973; Papert 1980).

While prior research has explored the use of 3D modelling in STEM education and design-based learning (Beauchamp 2016), comparative insights into how future teachers from different educational cultures approach 3D technologies are still lacking. There is a need to examine how pre-service teachers conceptualise and implement 3DMP within diverse didactic frameworks, and how this reflects their evolving pedagogical thinking.

This paper presents findings from a comparative qualitative study involving two groups of pre-service teachers—one from Slovakia and one from Austria—who participated in a university course integrating 3DMP. The aim of the study was to analyse students' final projects, including their 3D models, written documentation, and reflections, in order to identify key thematic patterns in their didactic design, use of technology, and pedagogical reasoning.

By comparing the outputs of the two groups, this study seeks to contribute to the growing body of research on technology-enhanced teacher education, with a particular focus on the creative and critical use of digital fabrication tools. The findings offer insights into how pre-service teachers conceptualise educational technologies in different contexts, and what this reveals about their emerging professional identities.

2. Theoretical Background

The integration of 3DMP into teacher education requires a theoretical framework that connects digital competence with pedagogical reasoning. In this study, three conceptual lenses are used to inform the analysis: the TPACK framework, constructivist learning theory, and the 5E instructional model. Together, they provide a foundation for interpreting how pre-service teachers conceptualise, design, and reflect on 3D-based educational tools.

2.1 Technological Pedagogical Content Knowledge (TPACK)

The Technological Pedagogical Content Knowledge (TPACK) model (Koehler and Mishra 2009) describes the dynamic interplay between teachers' knowledge of content, pedagogy, and technology. In the context of 3D modelling, pre-service teachers are required to blend technical skills (e.g., understanding software, working with the printers) with pedagogical strategies (e.g., student engagement, instructional scaffolding) and curricular content (e.g., mathematics, science). This framework offers a valuable lens for assessing how students reflect on the role of digital tools in their didactic planning and implementation (Chai, Koh, and Tsai 2013; Voogt et al. 2013).

2.2 Constructivism and Inquiry-Based Learning (5E Model)

Secondly, the study draws on constructivist learning theory, which emphasises active, learner-centred knowledge construction. In line with Piaget (1973) and Vygotsky (1978), educational applications of 3D modelling are particularly suited to constructivist practices, as they encourage exploration, manipulation, and co-construction of meaning through artefact creation (Resnick 2006). When pre-service teachers design tools with learners in mind, they often reveal their understanding of how knowledge emerges from interaction, context, and sensory experience.

To further conceptualise the design and sequencing of learning activities, the study references the 5E instructional model—Engage, Explore, Explain, Elaborate, Evaluate (Bybee et al. 2006)—widely used in science and technology education. This model aligns well with 3D-based instructional design, as it encourages inquiry-driven learning and facilitates a structured yet flexible environment for experimentation. The model also supports the analysis of how students anticipate learner needs, plan task sequences, and evaluate learning outcomes.

2.3 Digital Fabrication and the Educational Potential of 3D Printing

Digital fabrication, particularly through 3DMP, is increasingly recognised as a transformative tool in education. It allows learners to move from abstract concepts to tangible artefacts, thus bridging cognitive and sensory experiences (Blikstein 2013). In teacher education, 3D printing has been explored not only as a technical skill but also as a means to foster design thinking, creativity, and interdisciplinary problem-solving (Martinez and Stager 2013; Tejera et al. 2025).

The educational value of 3D printing lies in its potential to support inquiry-based, hands-on learning experiences that are aligned with constructivist pedagogies. When pre-service teachers engage in the creation of 3D learning objects, they are challenged to consider learner needs, curricular goals, and didactic strategies in an integrated way. Moreover, the process of translating educational ideas into printable forms reinforces spatial reasoning, iterative thinking, and material awareness (Lavicza et al. 2023; Marshall and Harron 2018).

From a pedagogical standpoint, digital fabrication promotes both cognitive engagement and motivation, especially in STEM-related subjects. Research has shown that the use of 3DMP in schools can enhance understanding of abstract or invisible phenomena, support differentiated instruction, and increase student agency (Bull et al. 2015). For future educators, learning to design and justify the use of 3D tools within authentic teaching scenarios is a valuable step toward technological-pedagogical fluency.

This study adopts the perspective that digital fabrication is not merely an add-on to educational technology curricula, but a pedagogically rich environment in which pre-service teachers can develop and articulate their didactic identities. The integration of 3D printing within teacher preparation provides a lens for examining how future educators conceptualise innovation, practicality, and learner-centred instruction.

These three frameworks not only informed the creation of the initial qualitative codebook, but also supported the interpretation of students' choices, reflections, and design rationales. Together, they provided a theoretical structure for analysing the interplay between technological tools, didactic thinking, and learner engagement, which lay at the core of this comparative study.

3. Methodology

3.1 Research Questions

This study was guided by three research questions aimed at understanding how pre-service teachers from two educational contexts engage with 3DMP in their professional preparation:

- **RQ1:** How do pre-service teachers from Slovakia and Austria conceptualise and engage with 3D technologies in the design of educational tools?
- **RQ2:** How do pre-service teachers from both contexts integrate constructivist learning principles when designing teaching activities involving 3D-printed artefacts?
- **RQ3:** In what ways do Slovak and Austrian pre-service teachers reflect on the practical feasibility of using 3D models in real classroom settings, including considerations of learner engagement, accessibility, and logistical constraints?

These questions align with the theoretical framework of the study (TPACK, constructivist learning theory, and the 5E model) and provided the analytical lens for interpreting the qualitative data collected from students' projects and reflections.

3.1.1 Research Design

The study employed a comparative qualitative research design to explore how pre-service teachers from two European universities conceptualise and apply 3DMP in the context of classroom practice. The aim was to analyse students' design artefacts, didactic rationales, and written reflections to identify patterns in their technological-pedagogical thinking.

3.2 Participants and Context

The participants were two cohorts of pre-service teachers enrolled in university courses focused on technical and digital education—one at a Slovak university (n = 20), and one at an Austrian university (n = 27). Both courses were conducted during the 2024/2025 academic year and featured a practice-oriented approach to integrating 3DMP. The Slovak course was part of a broader educational technology module; the Austrian course was an elective seminar within the teacher education program.

All participants received training in Tinkercad, explored educational use cases of 3DMP, and were guided through the basics of 3D printing workflows. As part of their final course assignment, students worked in small groups to:

1. design a 3D printable educational object,
2. develop a written methodological plan for classroom use, and
3. reflect on the didactic value and challenges of 3D technologies in education.

3.3 Data Collection and Types of Student Outputs

The data corpus consisted of a total of 18 group projects (8 Slovak, 10 Austrian), which included:

- Technical documentation of the 3D models (images, schematics, .stl files),
- Written teaching scenarios and lesson plans,
- Open-ended written reflections (1–2 pages per group).

All materials were collected in digital format and anonymised prior to analysis. The data were rich in descriptive, procedural, and evaluative content, allowing for in-depth thematic interpretation.

3.4 Development of the Codebook

To analyse the collected data from both the Slovak and Austrian groups of pre-service teachers, a qualitative content analysis approach was applied. A joint codebook was developed as a conceptual and analytical tool to identify recurring themes, didactic reasoning, and patterns in students' 3D model designs, lesson planning, and reflective writing.

The development of the codebook followed a hybrid strategy that combined both deductive and inductive procedures. Deductive codes were drawn from three interrelated theoretical frameworks:

- the **TPACK framework** (Technological Pedagogical Content Knowledge; Mishra and Koehler 2006),
- the **5E Instructional Model** (Bybee 1997),
- and **constructivist approaches** to learning and teaching (Piaget 1973; Vygotsky 1978; Papert 1980).

These frameworks informed the initial conceptual categorisation, allowing the researchers to anticipate key areas such as technological fluency, pedagogical intention, and inquiry-based learning.

At the same time, inductive codes emerged from a close reading of the actual student materials, including group reports, lesson plans, and written reflections. Codes were formulated to capture not only technological and pedagogical dimensions but also students' reflections on feasibility, motivation, and learning design.

The final codebook was constructed through iterative testing and refinement across both national groups. It was designed to be flexible enough to accommodate differences in language, educational context, and design choices, while remaining consistent in its core structure and interpretive focus.

The codebook includes four main thematic categories:

1. **Didactic Orientation** (Pedagogical-Content Layer) – focusing on subject-specific goals, interdisciplinary use, visualisation support, and motivational potential.
2. **Technological Engagement** (Technological Layer) – covering tool mastery, technical challenges, and collaborative aspects of using 3D technologies.
3. **Constructivist Learning Design** (Constructivist Layer) – identifying students' reflections, learning-by-doing experiences, and didactic planning strategies.
4. **Practical Implementation Reasoning** – reflecting concerns about classroom realities, feasibility, and innovation proposals.

Each category includes 2–4 subcodes, accompanied by **operational definitions and authentic examples** from student work. This structure enabled a nuanced yet consistent interpretation of the artefacts and written narratives, and supported the comparative analysis of pedagogical thinking across the two cohorts.

The complete version of the codebook is presented in **Tables 1–4**, with subcategories and illustrative excerpts from the data.

Table 1: Didactic Perspective (Pedagogical-Content Layer)

Code	Label	Definition	Example (from data)
PCK-GEO	Geometric Content	Clearly defined goal related to teaching geometry	"The model helps pupils visualise different types of triangles."
PCK-INT	Interdisciplinary Integration	Connecting the 3D tool with other school subjects (e.g. history, science, arts)	"We will use the medieval castle model in history lessons."
PCK-VIS	Visualisation Support	The tool helps visualise abstract or complex content	"It helps pupils imagine what crossing the tens boundary means."
PCK-MOT	Motivational Effect	Highlights learner engagement, excitement or enjoyment	"The children were excited about printing something themselves."

Table 2: Technological Perspective (Technological Layer)

Code	Label	Definition	Example (from data)
TK-USE	Tool Mastery	Describes the process of using Tinkercad, slicers or printers	"We had to resize the model in Tinkercad."
TK-PROB	Technical Difficulties	Technical issues or challenges with software, printing or modelling	"We had to reinstall the software – our file didn't save."
TK-COLL	Technical Collaboration	Collaboration in technical aspects of the work	"One of us did the modelling, the other searched for inspiration."

Table 3: Learning and Reflection (Constructivist Layer)

Code	Label	Definition	Example (from data)
CON-EXP	Learning through Exploration (5E: Explore)	Pupils engage in experimentation, discovery or hands-on trial	"The children discovered which parts fit together by trying them."
CON-REF	Reflection by Student Teachers	Reflections on teaching practice or digital tool use	"I realised not everything can be turned into a 3D model effectively."
CON-DES	Didactic Task Design	Description of how the learning activity was intentionally designed	"We made sure pupils would touch the model first before solving tasks."

Table 4: Implementation and Practical Reasoning

Code	Label	Definition	Example (from data)
IMP-REAL	Real-World Constraints	Time limits, class size, material needs, feasibility	"With 20 pupils in the class, I don't think we can finish this in one lesson."
IMP-INOV	Innovation and Improvement Ideas	Suggestions for how to enhance, adapt or expand the activity	"I would also use this tool in speech therapy."

3.5 Analytical Strategy

The analysis followed a qualitative content analysis approach (Mayring 2014; Schreier 2012), combining deductive and inductive coding strategies. Deductive categories were derived from the theoretical frameworks introduced in the previous section—namely TPACK (Koehler and Mishra 2009), constructivist pedagogy (Piaget 1973; Vygotsky 1978), and the 5E model (Bybee et al. 2006). Inductive codes emerged through close reading and iterative examination of student texts and artefacts.

The student outputs were diverse in both form and function. The designed 3D models included didactic tools such as geometric manipulatives, anatomical structures, interactive puzzles, ecological dioramas, and symbolic artefacts for narrative-based instruction. These were often accompanied by illustrative images, schematics, and STL files prepared for 3D printing. Each model was conceptually framed within a detailed methodological plan, in which students justified its pedagogical relevance, integration into specific subject areas (e.g., mathematics, natural science, language education), and its alignment with intended learning outcomes.

In addition to the physical artefacts and teaching scenarios, each group submitted a written reflection in which they discussed their creative and technical process, challenges encountered, and perceived educational value of their project. These reflections were particularly rich in metacognitive insights and pedagogical reasoning.

The coding process was conducted using manual annotation and supported by matrix-based categorisation and thematic synthesis. Codes were applied collaboratively and cross-validated across cases to ensure consistency, analytical rigour, and fidelity to the original meanings expressed by participants.

4. Findings

This section presents the results of the qualitative content analysis of final course assignments created by pre-service teachers from Slovakia and Austria. The analysis followed the thematic categories derived from the joint

codebook and focused on students' pedagogical thinking, technological engagement, and reflections on feasibility. Findings are presented separately for each national group, followed by a comparative thematic synthesis.

4.1 Slovak Student Group

The analysis of submissions from Slovak pre-service teachers revealed consistent patterns across four thematic domains: didactic orientation, technological engagement, constructivist learning design, and practical reasoning.

Students demonstrated a strong alignment with curriculum goals, particularly in mathematics and geometry. Their 3D models often served to support spatial reasoning, number sense, or shape recognition. Interdisciplinary extensions were also present, such as historical models or phoneme tools for literacy instruction. In their reflections, students frequently emphasised the motivational potential of 3D-printed artefacts, attributing learner excitement to the novelty and interactivity of the tools—even though these assumptions were largely anticipatory rather than based on classroom experience.

In terms of technological engagement, Slovak students actively used Tinkercad and slicers, showing competence in basic modelling operations. Several groups documented technical challenges such as calibration errors, print failures, or filament issues. Collaboration during modelling was common, with teams distributing tasks efficiently. However, deeper pedagogical reflection on the use of digital tools was limited, suggesting a focus on functional rather than integrative use of technology (i.e., more TK than TPK).

From a constructivist perspective, many groups designed activities that invited pupils to manipulate and explore the 3D artefacts. Their lesson plans included clear sequences and scaffolding strategies, promoting discovery and hands-on learning consistent with the "Explore" phase of the 5E model. Some students reflected on their own learning process, noting moments of insight or unexpected challenge during the task.

Practical reasoning was present in most reflections, particularly in relation to time constraints, equipment access, and pupil readiness. Some students adapted their original designs to make them more feasible or suggested alternative uses across different subjects or learner populations (e.g., special education). These reflections indicate an emerging awareness of classroom realities and a willingness to balance creativity with pragmatism.

4.2 Austrian Student Group

The Austrian pre-service teachers produced outputs that reflected a strong focus on learner diversity, sensory engagement, and inclusive design. The analysis revealed four key thematic areas aligned with the joint codebook, yet the orientation and emphasis often differed from the Slovak group.

Many projects were developed with attention to accessibility and imaginative learning. Models included tactile globes for visually impaired students, 3D numerals for children with dyscalculia, or artefacts that combined cultural and ecological content. Interdisciplinary thinking was prominent, with connections across geography, biology, and arts. While links to specific curricular goals were less explicit, students articulated broader developmental intentions such as motor skills development or emotional engagement.

Technological aspects were generally underdeveloped in students' reflections. Although all groups used 3D software (usually Tinkercad), few described the modelling or printing process. There was little mention of slicing, calibration, or design revisions. This suggests either a shift in instructional focus towards pedagogical goals, or limited student ownership of the technical process. As a result, Technological Knowledge (TK) was present at a basic level, but TPK thinking remained implicit.

Despite minimal formal lesson planning, the submitted materials frequently showed strong constructivist tendencies. Most models invited manipulation, assembly, or play—supporting exploratory and multisensory learning. Students often described their tools as "fun," "interactive," or "engaging," relying on their assumed motivational value. Activities supported discovery-based learning, aligning with the "Engage" and "Explore" phases of the 5E model, even if the terminology was not explicitly used.

Reflections on feasibility focused less on classroom logistics and more on affective outcomes. Students emphasised enjoyment, inclusion, and learner-centredness, often proposing cross-curricular or therapeutic applications. Practical constraints such as time or resources were rarely discussed, but many submissions suggested a belief in the transformative potential of material and sensory learning experiences.

4.3 Comparative Thematic Synthesis

A cross-case comparison of the Slovak and Austrian student groups revealed shared pedagogical intentions, yet also highlighted divergent orientations shaped by context and emphasis.

4.3.1 Didactic Orientation

Slovak students tended to align their 3D models with curriculum-based goals, especially in mathematics and science. Their designs often included explicit learning objectives and step-by-step lesson planning. In contrast, Austrian students focused on inclusivity and learner engagement. Their projects frequently targeted diverse needs—such as visual impairments or dyscalculia—and emphasised cross-curricular connections and sensory learning. While less anchored in formal curriculum, their outputs reflected a broader developmental perspective.

4.3.2 Technological Engagement

Slovak students showed stronger engagement with the technical aspects of 3DMP. Their reflections often included challenges with slicing, design revisions, or collaboration during the modelling process. Austrian students, while competent users of design tools, rarely commented on the technical workflow. Their focus remained on pedagogical intent, suggesting a product-oriented rather than process-oriented view of technology use.

4.3.3 Constructivist Learning Design

Both groups embraced constructivist principles, though expressed differently. Slovak students structured their scenarios with didactic sequencing, aligning with inquiry-based learning phases. Austrian students, on the other hand, designed artefacts that promoted free exploration, play, and sensory engagement, often without rigid instructional framing. Their learning designs leaned toward learner autonomy and emotional connection.

4.3.4 Implementation Reasoning

Slovak reflections often addressed logistical feasibility—time constraints, class size, or material limitations. Austrian students rarely discussed such constraints but instead reflected on motivational potential, inclusion, and learner diversity. Their reflections revealed an aspirational mindset, focusing on engagement and affective outcomes over operational planning.

Slovak students demonstrated a more structured, curriculum-aligned, and technologically reflective approach, indicative of growing professional reasoning within known educational parameters. Austrian students revealed greater openness to innovation, emotional engagement, and inclusive design, even if less focused on classroom logistics. These complementary perspectives suggest that effective teacher preparation can benefit from a balance of technical precision and empathetic, learner-centred creativity.

5. Discussion

This study explored how pre-service teachers from Slovakia and Austria engaged with 3DMP as part of their teacher education coursework. Guided by three research questions, the findings illustrate how students conceptualised the pedagogical role of 3D technologies, integrated constructivist learning principles, and reflected on the feasibility of using such tools in actual classrooms. The discussion situates these findings within the four analytical categories and links them to prior research and theoretical frameworks relevant to technology-enhanced teacher education.

5.1 RQ1: Conceptualising and Engaging with 3D Technologies in Educational Design

The first research question addressed how pre-service teachers conceptualised and engaged with 3D technologies in designing educational tools. The findings revealed different emphases between the two national contexts, reflecting broader patterns in teacher education cultures and curricular traditions.

Didactic Orientation: Slovak students largely embedded their 3D models within specific curricular areas, particularly mathematics and science, aligning their designs with structured learning objectives. This is consistent with previous studies showing that novice teachers often view technology as an extension of existing curriculum frameworks rather than a transformative medium for new forms of learning (Koehler and Mishra

2009; Chai et al. 2013). In contrast, Austrian students displayed more interdisciplinary thinking, using 3D tools to design resources that spanned multiple subjects or addressed diverse learner needs, such as tactile maps for visually impaired pupils. This approach resonates with Trust and Maloy (2017), who argue that digital technologies can foster broader, inclusive pedagogical practices when teacher education creates space for flexible and creative use.

Technological Engagement: Slovak students frequently documented their technical workflow, reflecting a procedural engagement with design tools and the challenges of 3DMP. This aligns with Voogt et al. (2013), who highlight that developing technological-pedagogical content knowledge (TPACK) requires explicit opportunities for teachers to reflect on how technology functions and interacts with pedagogy. Austrian students, while successfully using the technology, focused less on technical aspects and more on the artefacts' imaginative or communicative value. Their treatment of technology as a creative medium echoes Bull et al. (2015), who suggest that digital fabrication can support meaning-making and narrative design in education. However, the absence of technical reflection suggests a potential gap in building integrated TPACK knowledge, where technology understanding remains implicit rather than consciously articulated.

These findings underline that pre-service teachers' engagement with 3D technologies is shaped not only by individual skills but also by the pedagogical framing of coursework. Slovak outputs reflect a curriculum-driven and process-oriented mindset, whereas Austrian outputs suggest a more learner-centered and expressive orientation, albeit with less focus on technical reasoning. This echoes Tondeur et al. (2017), who emphasise that institutional contexts strongly shape how future teachers develop their digital competence and pedagogical reasoning.

5.2 RQ2: Integration of Constructivist Learning Principles in 3D-Based Teaching Activities

The second research question examined how students embedded constructivist learning principles into their designs. Findings highlighted constructivist orientations in both groups, but with distinct levels of structure and learner agency.

Constructivist Learning Design: Slovak students generally developed step-by-step instructional plans, emphasising guided discovery and structured scaffolding. These designs reflect the "Explain" and "Elaborate" phases of the 5E instructional model (Bybee et al. 2006), ensuring clear pathways for concept acquisition. Such approaches align with research suggesting that novice teachers often prefer structured methods to manage uncertainty in new pedagogical environments (Tondeur et al. 2017).

Austrian students, on the other hand, designed open-ended, exploratory tasks that encouraged learners to manipulate artefacts freely, experiment, and co-construct knowledge. These scenarios align with Piaget's (1973) notion of active exploration and Papert's (1980) constructionist vision of learning-by-making, where tangible artefacts foster personal meaning-making and creativity. This approach also mirrors Resnick's (2006) argument that digital fabrication supports playful experimentation and non-linear larning paths.

The contrast between guided and exploratory designs highlights a tension documented in previous studies on technology integration: pre-service teachers often oscillate between structured, teacher-led activities and more open, learner-driven models (Beauchamp 2016). This may reflect their own prior schooling experiences, differing emphases in national curricula, and varying levels of confidence in facilitating inquiry-based learning. Both approaches have pedagogical merit, but teacher education must help students understand how to balance structure with opportunities for autonomy, particularly when leveraging new technologies that invite experimentation.

5.3 RQ3: Reflections on the Practical Feasibility of Using 3D Models in Real Classroom Settings

The third research question explored how pre-service teachers reflected on the feasibility of implementing 3D-based activities in authentic classroom contexts. The findings revealed two complementary dimensions of feasibility reasoning.

Practical Implementation Reasoning: Slovak students frequently considered operational constraints—lesson time, equipment availability, class size—and proposed concrete adaptations to make activities manageable. This pragmatic focus aligns with findings by Instefjord and Munthe (2017), who note that teachers' digital competence is strongly shaped by perceived barriers in school environments. Such reasoning illustrates the beginnings of professional thinking that seeks to balance innovation with classroom relities.

Austrian students focused more on the motivational and inclusive potential of 3D artefacts, considering how these tools could enhance learner engagement, accessibility, and participation for diverse learners. This reflects Bull et al. (2015), who highlight the role of technology in promoting equity and inclusion, and suggest that some students conceptualised feasibility not only as logistical but also as affective and social viability.

Both forms of reasoning demonstrate that pre-service teachers understand that technology integration is not purely a technical decision but involves pedagogical, organisational, and relational dimensions (Koehler and Mishra 2009). The findings point to the need for teacher education programmes to support students in bridging aspirational visions of engagement and accessibility with operational realities of time, resources, and institutional constraints.

5.4 Implications for Teacher Education

The comparative analysis of Slovak and Austrian students' projects suggests several implications for the design of teacher education programmes seeking to integrate 3DMP effectively.

1. **Balancing Technical and Pedagogical Reflection:** Teacher preparation should explicitly foster TPACK development by prompting students to reflect not only on their pedagogical intentions but also on how technological processes shape design outcomes (Voogt et al. 2013). This ensures that 3D modelling is not treated as a mere functional task or a black-boxed process but as part of informed instructional reasoning.
2. **Integrating Curriculum Alignment with Accessibility:** The Slovak group demonstrated strong curriculum-linked designs, while Austrian students emphasised inclusion and multisensory engagement. Combining these orientations can help future teachers design tools that are both content-rich and equitable (Trust and Maloy 2017), addressing the dual mandate of relevance and diversity in education.
3. **Strengthening Constructivist and Inquiry-Based Pedagogies:** 3D modelling naturally supports constructivist learning, but students displayed varying degrees of openness and scaffolding. Programmes should link design activities explicitly to frameworks like the 5E model (Bybee et al. 2006), helping pre-service teachers understand how to structure exploratory, learner-driven experiences while maintaining conceptual clarity (Resnick 2006; Papert 1980).
4. **Bridging Aspirational and Operational Thinking:** Opportunities for testing, iterating, and adapting designs in authentic or simulated classroom settings can help future teachers reconcile creative aspirations with practical limitations (Instefjord and Munthe 2017). Such experiences strengthen their ability to plan realistic, scalable uses of emerging technologies.
5. **Promoting Cross-Cultural Perspectives in Teacher Education:** The contrasts observed suggest that national or institutional contexts shape pedagogical reasoning about technology. Collaborative, international design experiences could broaden students' conceptions of how digital tools can serve different educational purposes (Tondeur et al. 2017), fostering more flexible and reflective professional identities.

Overall, this study shows that integrating 3DMP in teacher education stimulates multiple dimensions of pedagogical thinking. Students demonstrated creativity and sensitivity to learners' needs, but their designs revealed varying emphases on curriculum alignment, technological reasoning, constructivist openness, and practical feasibility. These variations reflect both individual and contextual factors and align with broader literature on the complex, situated nature of developing digital competence in initial teacher education (Koehler and Mishra 2009; Tejera et al. 2025; Tondeur et al. 2017).

Embedding digital fabrication in pre-service training holds promise not just for technical skill acquisition but for cultivating a deeper understanding of how technologies shape teaching and learning. To fully leverage this potential, teacher education must provide structured opportunities for reflection, experimentation, and cross-contextual dialogue, preparing future teachers to integrate emerging technologies in ways that are pedagogically sound, inclusive, and feasible within real classroom conditions.

6. Conclusion

This study explored how pre-service teachers from Slovakia and Austria engaged with 3DMP in a university-level educational technology course. Through a comparative qualitative analysis of student-created teaching tools,

reflections, and design documentation, the research identified four key thematic areas: didactic orientation, technological engagement, constructivist learning design, and practical implementation reasoning.

The findings reveal both shared and context-specific patterns. Slovak students demonstrated a strong focus on curricular alignment, structured lesson planning, and explicit reflection on technological processes. Austrian students, in turn, emphasised inclusive design, sensory engagement, and learner motivation, often with less attention to technical or logistical details. These differences point to the diverse pedagogical orientations and cultural priorities present within teacher education across contexts.

Despite these contrasts, both groups showed promising levels of creativity, empathy, and educational insight. Their 3D models reflect the potential of digital fabrication technologies to support active, hands-on, and meaningful learning experiences. Importantly, students across both groups were able to connect digital tools with their developing teacher identities—whether through structured planning or intuitive exploration.

The study contributes to the growing body of literature on educational technology in initial teacher education by demonstrating how 3D technologies can be leveraged not only as tools for instruction but as catalysts for pedagogical thinking. The comparative perspective offers valuable insights for programme designers, suggesting that combining structured instructional strategies with open-ended, learner-centred creativity may yield the most impactful results. Future research may further explore longitudinal impacts on classroom practice or investigate collaborative, cross-cultural design experiences among pre-service teachers.

Ethics Declaration

All participation was voluntary, with informed consent obtained in line with recognised ethical guidelines and the institutional requirements of the authors' universities for research involving human participants.

AI Declaration

During the preparation of this paper, the authors utilised the ChatGPT language model developed by OpenAI to enhance academic English through improvements in clarity, coherence, and stylistic consistency. All AI-assisted content was critically reviewed and substantively revised by the authors, who take full responsibility for the final text and its scholarly content.

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AI in the Classroom: Didactical Misalignments in Geometry Between Czech and Anglo-Saxon Contexts

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Abstract: As artificial intelligence (AI) tools—such as chatbots and large language models—become increasingly accessible in educational settings, both teachers and students are relying on them more during the learning process. These tools provide various pedagogical benefits. However, their integration also introduces didactical risks, particularly when their outputs reflect implicit assumptions and educational paradigms that diverge from those in specific national curricula. This paper explores such risks in the context of lower secondary mathematics education (ages 11–15), focusing on geometry instruction in Czechia. The study builds on the differing conceptualizations of square and rectangle in Czech and Anglo-Saxon didactics. In the Anglo-Saxon tradition, a square is typically regarded as a special type of rectangle, emphasizing hierarchical classification. In contrast, Czech didactics treats these shapes as categorically distinct. This difference reflects broader didactical orientations: Czech mathematics education often emphasizes analytical decomposition and local precision, while Anglo-Saxon approaches favor structural generalization and class inclusion. These contrasting tendencies are mirrored in curricular goals, instructional strategies, and classroom expectations. This divergence becomes especially problematic when AI models—trained largely on English-language data—produce responses that implicitly reflect Anglo-Saxon conventions, which may conflict with the Czech didactical contract. The study uses a comparative, non-experimental methodology to analyze responses from multiple AI systems, including ChatGPT, Gemini, Claude, Copilot, and Mistral. Prompts were administered in both Czech and English to assess the consistency and contextual adaptability of the models. Findings suggest that AI tools may inadvertently reinforce foreign conceptual frameworks, creating tension in cross-cultural educational contexts. The paper highlights the importance of contextual sensitivity, critical digital literacy, and pedagogical oversight in the integration of AI into mathematics instruction. By revealing how culturally embedded definitions in geometry—shaped by language and curriculum—can clash with AI-generated content, this paper offers a relevant perspective for educators facing misalignment between linguistic training data and local didactical norms.

Keywords: Artificial Intelligence in Education, Didactical Contract, Geometric Concepts, Language Models and Educational Contexts, Cross-cultural Misalignment

1. Introduction and Theoretical Background

In recent years, large language models (LLMs) have been increasingly integrated into mathematics classrooms, both globally (Pepin , Buchholtz, and Salinas-Hernández , 2025; Stefanova and Georgiev, 2024; Korkmaz Guler et al., 2024) and in national contexts such as Czechia (E-Bezpečí, 2023). These tools offer benefits like instant explanations and personalized feedback, yet also pose didactical risks when their outputs reflect educational assumptions embedded in one tradition but are deployed in another. This paper explores such tensions through the lens of geometry instruction in Czech lower-secondary education.

This paper focuses on a specific terminological and conceptual misalignment concerning the classification of rectangles. Unlike English, Czech possesses a distinct term—obdélník—which refers to a right-angled quadrilateral with unequal adjacent sides. In this framework, obdélníky form the complement of squares within the broader set of right-angled quadrilaterals. However, in practice, the term obdélník is often equated with pravoúhelník (rectangle in the broad sense), a conflation influenced not only by Anglo-Saxon terminology but also by everyday usage and instructional simplification (Vízek, Samková and Star, 2023). This divergence reflects broader curricular and linguistic differences and may lead to misalignments when students interact with AI systems trained predominantly on English-language data.

To analyze these issues, we draw on the concept of the didactical contract (Brousseau, 2002), which refers to the implicit norms and expectations governing classroom interactions. This contract is culturally embedded, shaping how knowledge is presented and interpreted. In Czech classrooms, students are generally taught that a square and rectangle are mutually exclusive categories, aligned with the local terminological system distinguishing *čtverec* and *obdélník*. Conversely, most LLMs default to inclusive definitions based on hierarchical classification, risking conceptual conflict when applied in Czech settings.

Differences in shape classification also connect to theoretical models like the van Hiele model (van Hiele, 1986), which highlights how students understand geometry in stages, initially recognizing shapes by visual features. At

these early stages, treating squares and rectangles as distinct is developmentally appropriate. This is further supported by Fischbein's theory of prototypicality (Fischbein, 1993), which explains students' tendency to form mental representations based on typical visual features—a square appears more symmetric and less elongated than a rectangle. Czech didactics supports this perceptual distinction through distinct terms and definitions, whereas English-language AI tools often override it.

These tensions are not merely linguistic. Studies have shown that students often reject the inclusive definition *a square is a rectangle* due to its conflict with visual intuition (Tsamir, Tirosh and Levenson, 2008). The Czech system accommodates this by emphasizing partitive classification, often found in resources like Mikulčák (2025), which explicitly exclude squares from the definition of rectangles.

Existing literature on AI in mathematics education reflects similar concerns. While LLMs can support problem-solving and conceptual clarity (Ergene and Ergene, 2025; Awang, Yusop and Danaee, 2025), they may also reinforce misconceptions if not critically mediated by teachers (Daher and Gierdien, 2024; Dilling and Herrmann, 2024). In cross-cultural settings, the risk intensifies: Yan et al. (2024) and Pepin, Buchholtz and Salinas-Hernández (2025) emphasize that language models reflect the conceptual defaults of their training data.

In summary, this study applies the concept of the didactical contract to assess the risk of definitional mismatches introduced by AI systems in the specific context of classifying squares and rectangles within Czech geometry education. It situates this issue within broader theoretical, linguistic, and empirical research on both geometry instruction and the educational implications of LLMs.

2. Methodology

This section describes the design of the study, including the structure of prompts, rationale for their formulation, the selection of AI models, and the analytical focus. The aim was to explore how current large language models respond to culturally dependent geometry questions—especially the classification of squares and rectangles.

2.1 Structure and Content of Prompts

To explore how AI systems handle culturally contingent definitions in mathematics, we designed a structured three-question prompt sequence simulating typical student–AI interactions. Each prompt pair was submitted in a fresh session to avoid contextual contamination.

The first question—our main focus—had four phrasings (V1–V4), all reflecting ways a Czech lower-secondary student might ask whether a square is a type of rectangle. Though similar in tone and wording, they differed slightly to capture natural variation. Each was followed by two identical prompts: one asking for similarities and differences between the shapes, and a final one referencing a Czech teacher to test contextual awareness and whether the model would adjust its earlier answer to match Czech teaching practices.

All three-question sequences were posed in both Czech and English, resulting in 8 unique language–prompt combinations (4 Czech + 4 English). These 8 combinations were each submitted to 7 different AI models (described in section 2.3), yielding a total of 56 AI interactions for analysis, see Table 1.

Table 1: Prompt structure

Prompt Variant	Czech	English
Initial Q1 – V1	Je čtverec obdélník?	Does a square count as a rectangle?
Initial Q1 – V2	Může mít obdélník všechny strany stejně dlouhé?	Can a rectangle have all its sides the same length?
Initial Q1 – V3	Může mi vyjít čtverec, když se v úloze ptají na obdélník?	Can I get a square if the question is about rectangles?
Initial Q1 – V4	Můžeš mi vysvětlit, jestli je čtverec taky obdélník nebo ne?	Can you explain if a square is also a rectangle or not?
Follow-up Q2	Dobře. Co ještě mají čtverec a obdélník společného a co mají různé?	OK. What's the same and what's different between a square and a rectangle?
Follow-up Q3	Souhlasil by s tím učitel matematiky v České republice?	Would a math teacher in the Czech Republic agree with that?

Note: Full transcripts of the AI model responses (all 56 interactions) are available from the authors upon request.

2.2 Justification of Prompt Design

Our prompt sequences were designed to test how AI systems interpret seemingly simple math questions with culturally specific implications. Rather than addressing student misconceptions, the prompts focused on how models handle genuine definitional differences—particularly the contrasting treatment of *square* and *rectangle* in Czech vs. Anglo-American curricula.

The first prompt in each sequence plays a central role. It simulates a spontaneous question that a Czech lower-secondary student might pose when working independently or with AI assistance. We created four natural-sounding phrasings to capture variations in tone and formulation, thus testing whether differences in wording or language affect the model's initial classification. This setup allowed us to observe whether the AI defaulted to an Anglo-Saxon interpretation—typically classifying a square as a special case of a rectangle—or whether it demonstrated sensitivity to the Czech curricular convention, where the two shapes are defined as mutually exclusive.

The second prompt was included to explore the internal consistency of the model's reasoning. By asking about shared and differing properties between the two shapes, we encouraged the system to articulate the geometric basis of its classification.

The third prompt added a cross-cultural layer by referencing a Czech teacher, inviting the model to reconsider whether its earlier answer aligns with local educational standards.

2.3 Models Used

We tested seven large language model configurations from five AI systems: ChatGPT 3.5, ChatGPT o3 (GPT-4), Gemini, Claude, Copilot (Quick Nuance and Deep Thinker), and Mistral. These models reflect tools accessible—or likely accessible—to upper-secondary students in Czechia. All are free or integrated into common platforms, except GPT-4, which was included for performance comparison.

ChatGPT was evaluated in its free-tier 3.5 and premium o3 (GPT-4) versions. Both are trained primarily on English-language data and follow Anglo-American educational norms, potentially limiting alignment with Czech curricula.

Gemini (Google DeepMind), tested in its Gemini 2.0 Flash version, supports multiple languages but often reflects international textbook logic. Claude 3 (Anthropic) offers clear, pedagogical responses but also mirrors Western didactic assumptions.

Microsoft Copilot, based on GPT models, was tested in Quick Nuance (fast) and Deep Thinker (detailed) variants. Both produce fluent English-language responses, with varying depth, but lack strong adaptation to local curricula.

Mistral Le Chat, based on the Mistral Large model, was included for contrast. As a European open-weight model with strong multilingual capabilities, it shows potential for better adaptation to less dominant languages like Czech.

The AI systems tested vary in their handling of Czech, depending on multilingual training data and sensitivity to linguistic variation. ChatGPT o3 (GPT-4), both Copilot variants, and Mistral Large perform well in Czech, generating fluent responses with few translation artefacts. Mistral, developed in a European context, shows strong results in less dominant languages, though no formal Czech benchmarks confirm this yet. Claude 3 also handles Czech well but was primarily trained on English data, which may shape its structure and style. Gemini 2.0 supports multiple languages but often reflects English syntax, especially in complex prompts—suggesting its internal models are influenced by dominant training languages. ChatGPT 3.5 performs less consistently in Czech, occasionally producing phrasing resembling literal English translations, likely due to limited Czech training data. These differences align with multilingual benchmarks such as HELM (Liang et al., 2023), MMLU (Hendrycks, Mazeika and Woodside, 2023), and MT-Bench (Zheng et al., 2024), which show variation in language-specific performance across LLMs.

2.4 Analytical Focus

The analysis focused on three dimensions, each corresponding to one of the three prompts. The first examined whether models classified squares as a subset of rectangles (inclusive framing) or treated them as distinct (exclusive framing), and whether their reasoning was logically consistent. The second explored how many and

which geometric features the models identified when comparing squares and rectangles. The third assessed whether models demonstrated awareness of Czech curricular norms when asked whether a local teacher would agree with their explanations.

While several types of problematic output phenomena were noted during data collection (e.g., terminological inconsistencies, factual errors), these were not analyzed systematically in this study and are reserved for future work. This includes deeper content analysis of Q3 responses, which revealed a richness of interpretation and implicit assumptions about teacher reasoning that warrant separate investigation.

3. Results

This section presents how large language models (LLMs) responded to culturally shaped geometry questions. The analysis followed the three-question structure outlined in the methodology: (Q1) classification of square vs. rectangle, (Q2) similarities and differences between the shapes, and (Q3) recognition of Czech curricular norms. Each question served to assess different aspects: conceptual alignment, explanatory breadth and curricular awareness.

3.1 Consistency and Framing in Responses to Q1: "Is a Square a Rectangle?"

The first question examined whether AI models adhered to the inclusive (Anglo-American) or exclusive (Czech) interpretation of the square–rectangle relationship, and whether their answers were logically consistent.

3.1.1 Conceptual Framing: Inclusive Versus Exclusive Definitions

All 56 responses to Q1 consistently reflected the Anglo-American inclusive view—that a square is a type of rectangle with four equal sides. This was true across all models, languages (Czech/English), and prompt phrasings. Only GPT-4 (ChatGPT o3) acknowledged, briefly and only in Czech, the existence of an alternative (exclusive) definition, but framed it as outdated or informal. No model explicitly recognized this exclusive definition as the Czech standard (see Section 2.2), underscoring a major didactical misalignment when students receive AI-generated definitions.

3.1.2 Logical Contradictions in Tesponses to "Can a Rectangle Have all Sides the Same Length?"

A second finding concerns logical inconsistencies within individual responses, especially those triggered by Q1 variant V2: "Can a rectangle have all its sides the same length?"

Here, several models displayed a pattern of internal contradiction. They began by stating: "A rectangle cannot have all its sides the same length and still be classified only as a rectangle…," (ChatGPT-3.5, EN) implicitly assuming the exclusive definition. Yet later in the same response, they added: "A square is a special type of rectangle…" thereby invoking the inclusive definition. This contradiction undermines the internal coherence of the explanation and may confuse learners—especially when the distinction between generic and special cases is left unstated.

Notably, this inconsistency was more frequent in Czech-language responses. Claude 3, Copilot Quick Nuance, and Mistral exhibited the contradiction only in Czech, while their English responses remained logically consistent. ChatGPT 3.5, by contrast, showed the inconsistency in both Czech and English, making it the only model to do so systematically across both languages. This pattern may reflect weaker internal reasoning alignment in Czech, or broader variability in how different models apply inclusion logic depending on the language context.

3.2 Feature Richness and Conceptual Scope in Responses to Q2: "What's the Same and What's Different?"

This question served to assess how well models identified geometric features. We analyzed the number and nature of features mentioned, and how responses varied by language and prompt variant.

3.2.1 Clustering Language Models by Geometric Feature Mentions

To visualize model responses to Q2, we created a clustermap (Figure 1) showing which geometric features each language model mentioned. This helps us compare how models conceptualize *square vs. rectangle* and what explanations they prioritize or omit.

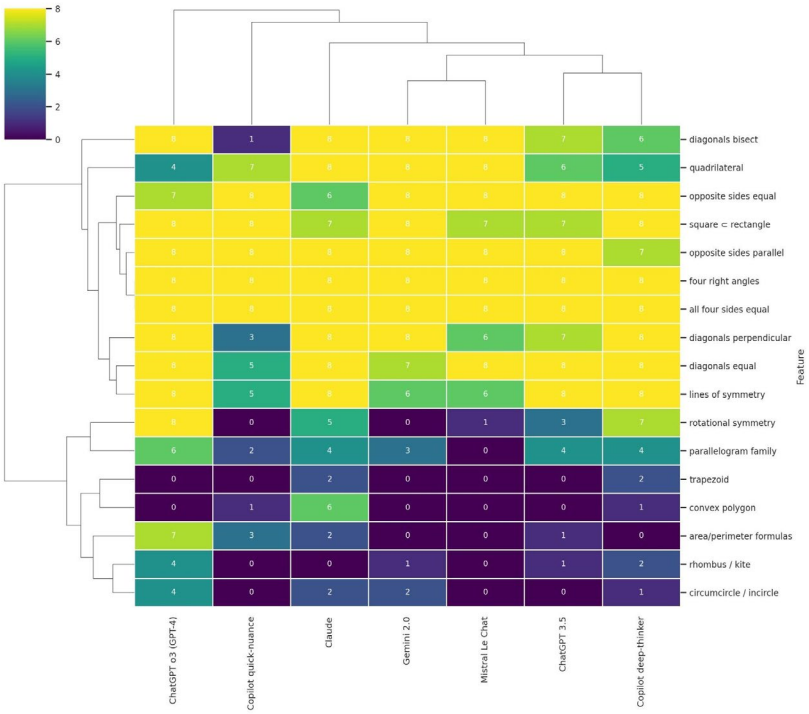


Figure 1: Clustermap of geometric feature mentions across language models

Models are listed on the X-axis, features on the Y-axis. Each cell is color-coded: yellow indicates frequently mentioned features, blue-green indicates rarely or never mentioned ones.

Across all models, several core concepts are consistently cited: *four right angles*, *opposite sides parallel/equal*, *square as a subset of rectangle*, *equal diagonals*, and *all four sides equal*. These align with geometry curricula for ages 11–15, showing that LLMs have internalized textbook-level definitions.

Less commonly mentioned terms (e.g., *parallelogram family*, *trapezoid*, *rhombus/kite*, *circumcircle/incircle*) appear mainly in responses from Claude 3, GPT-4 (o3), and Copilot Deep Thinker. Models like Gemini, Mistral, and Quick Nuance typically omit these, offering a simpler, more age-appropriate response. This has didactic implications: some models risk overwhelming younger learners, while others stick to essential content. Educators should choose models or apply filters accordingly.

The dendrogram shows GPT-4 and Copilot Quick Nuance clustering together despite differences in verbosity. Both omit advanced features similarly, suggesting shared norms on age-appropriateness but different expression styles—useful for researchers studying instruction tuning.

Feature clustering reflects curricular logic: basic properties group together, symmetry terms form a second cluster, and broader classifications like quadrilaterals appear on a separate branch. This structure mirrors didactic models and hints that LLM behavior may help in curriculum mapping.

The clustermap shows that large language models reproduce core textbook facts and reflect elements of curricular structure. This can aid quick reviews or scaffolded explanations but also underscores the need to align the model's output with the learner's developmental stage. Some models keep explanations age-appropriate, while others use advanced terms too early. For educators, this means choosing an AI model is not just technical but also a didactical decision, as model choice, prompt design, and context all impact the quality of explanations students receive.

3.2.2 Effect of Language on Feature Richness in Model Responses

Most language models gave more detailed responses in Czech than in English. Six of seven systems included more geometric features in Czech, omitting two to nine features in English. Mistral was the only exception, performing slightly better in English. Copilot Quick Nuance showed the largest drop, skipping nine features. Basic geometric features were stable across languages, but advanced or less common terms were more often left out in English, suggesting reduced precision or depth.

Figure 2 shows a dumbbell plot comparing each model's Czech and English feature counts. Most lines slope downward, showing consistent information loss in English; only Mistral slopes upward.

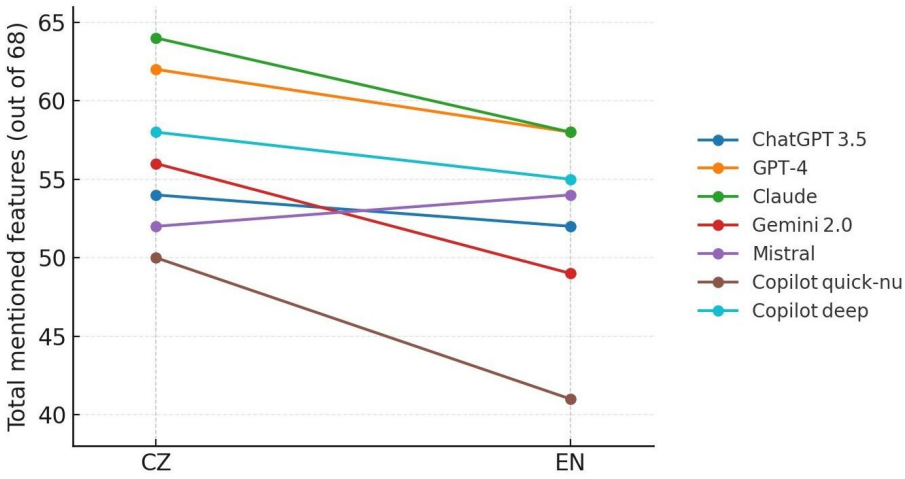


Figure 2: Dumbbell plot comparing feature counts in Czech vs. English responses across models

To test the trend's significance, a two-sided Wilcoxon signed-rank test was applied to paired feature count differences ($n = 7$). The test evaluates whether models tend to behave consistently in favoring one language over the other. At a significance level of $\alpha = 0.05$, the computed statistic ($W = 1.5$) fell below the critical value ($W = 2.1$), allowing us to reject the null hypothesis. We therefore conclude that Czech responses contain significantly more geometric features than English ones.

This analysis captures overall language trends, not individual model differences. Exploring model-specific effects would require a different approach and remains for future work.

Although English prompts were direct translations, Czech responses were often more elaborate. This likely reflects not just style, but how models interpret prompts across languages. Czech may trigger overcompensation, with models adding detail to ensure clarity in a lower-resource language. Also, Czech lacks many idiomatic shortcuts common in English, leading to more explicit wording. These factors help explain the higher detail in Czech outputs.

3.2.3 Prompt-wording Variants and Feature Count

The four wording variants of the initial question (Q1) led to measurable differences in the richness of responses to the follow-up question (Q2) about similarities and differences between squares and rectangles. Although Q2 was identical across sequences, the phrasing of Q1 influenced how many geometric features the models included.

Figure 3 illustrates this with a boxplot comparing feature counts across Q1 variants. Variant V3 elicited the richest responses (highest median and upper quartile), while V4 produced the leanest. V1 and V2 fell in between. The trend suggests that prompt phrasing affects conceptual scope.

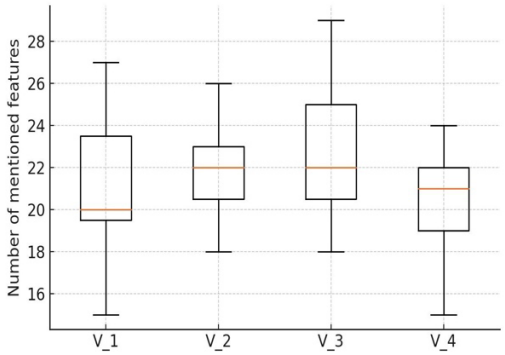


Figure 3: Boxplot showing impact of Q1 wording on number of features mentioned in Q2

A Friedman test was applied to test statistical significance, treating each model as a block ($n = 7$). The result, $\chi^2(3) = 8.91$, exceeds the critical value of 7.82 at $\alpha = 0.05$, allowing us to reject the null hypothesis: prompt wording significantly affects geometric detail in responses.

This may stem from the cognitive framing of each Q1. V3 sets up a classroom-like scenario and hints at a conceptual edge case, prompting broader elaboration in Q2. In contrast, V4 asks a direct classification question, leading to more concise answers.

In sum, subtle changes in prompt wording can influence not only accuracy but also the depth of AI explanations—highlighting the importance of thoughtful prompt design in educational contexts.

3.3 Context Awareness in Responses to Q3: "Would a Czech Math Teacher Agree?"

The third question in each sequence of prompts explores how the model "thinks" about the thinking of Czech teachers. We analyzed the types and frequencies of responses produced by different models in both language versions. Particular attention was paid to the depth and breadth of the responses to this open-ended question.

Our analysis showed no significant differences between the Czech and English outputs, with one exception: the GPT-4 model. Its responses stood out in terms of both richness and caution.

All responses began with a similar phrase: "Yes, a math teacher in the Czech Republic would agree with this explanation." However, they varied in detail and contextualization. In general, the English responses tended to be more elaborate than their Czech counterparts.

The content analysis revealed a notable richness of ideas. This inspired the formulation of several research questions and hypotheses that reflect our expectations. However, given the scope of this article, we do not address these findings in detail here.

4. Discussion

As large language models become more accessible in education, their use in math teaching presents complex challenges. While they offer benefits like quick definitions and explanations, they risk didactical misalignment—especially across cultural or curricular lines. This study highlights three key tensions: the demands of Czech math instruction, risks of unguided AI use, and the challenge of applying global tools in localized educational contexts.

4.1 Implications for Mathematics Education in the Czech Context

Our results show that language models almost universally apply the inclusive definition of a rectangle, treating a square as a special case. While this definition reflects formal mathematics and is common in international discourse, it differs from how the relationship between squares and rectangles is typically taught in the Czech educational system—including primary, lower-secondary, and often also upper-secondary levels—where these shapes are usually presented as distinct and mutually exclusive categories.

This discrepancy can lead to mismatches between what students learn through AI tools and what is expected in schools. If students encounter AI-generated explanations that conflict with textbook definitions, classroom language, or assessment criteria, the result may be not only confusion, but a weakening of curricular coherence. This places new demands on teachers, who must increasingly act as interpreters between digital content and local curriculum goals. In practice, this means helping students recognize that some mathematical terms are context-dependent, and that definitions can vary across educational traditions—even when they are mathematically consistent.

To meet this challenge, teacher education should include not only basic AI literacy, but also training in didactical mediation: how to recognize when an AI-generated explanation might introduce conflicting conceptual structures, and how to respond to such moments constructively within the classroom context.

4.2 Risks of Student Reliance on AI Without Teacher Mediation

Challenges grow when students use AI tools without teacher guidance. While LLMs can offer useful information, they may also provide oversimplified, incomplete, or contradictory explanations—especially with ambiguous prompts or language switches. Younger students may lack the skills to evaluate such output critically.

Without teacher mediation, students risk internalizing inconsistent or curriculum-incompatible definitions. In geometry, where precision is vital, these misconceptions can persist and hinder future learning. Viewing AI as always correct may further entrench misunderstandings, making later correction more difficult for teachers.

4.3 Global Tools Versus Culturally Situated Education

These findings reveal a key tension: globally trained AI tools often conflict with nationally grounded curricula. Though LLMs support multiple languages, their reasoning reflects dominant cultures—mainly English-language math education.

This raises a critical question: should curricula adapt to AI, or should AI align with national pedagogy? Didactically, preserving cultural and curricular specificity is vital. Students need tools that match their educational context.

This calls for a more intentional approach to digital tool integration—one that respects local curricular norms while leveraging the flexibility of AI. It also suggests that developing students' and teachers' critical digital literacy will be just as important as technical access. AI can enrich learning, but only when used with awareness of the cultural and curricular frame in which learning takes place.

5. Conclusion

This study examined how large language models respond to geometry classification questions shaped by different didactical traditions. LLMs often use inclusive definitions that diverge from Czech classroom practices, offering coherent but overly general answers that may not align with the local curriculum and sometimes show inconsistencies—especially in Czech.

While LLMs can support math education, their use requires careful guidance. Teachers are essential in interpreting AI outputs and helping students identify which parts are relevant to their learning. Without this support, students risk adopting technically correct but educationally misleading definitions.

5.1 Limitations of the Study

This study used outputs from publicly available large language models as of early 2025. Given potential future updates, changes in prompt interpretation, or system-level settings (e.g., reinforcement learning), results may vary. Since AI outputs are probabilistic, identical inputs can yield slightly different responses across sessions, limiting generalizability and replicability. The study focused on a specific topic—geometry and square–rectangle classification—within the Czech lower-secondary context, which may not reflect other content areas or education systems. Future research should address broader topics and cross-language dynamics in other subjects.

5.2 Future Directions

One promising way to address observed inconsistencies is through localized or semi-localized AI assistants configured with regional curricula and pedagogical norms. Customized GPTs have already demonstrated improved coherence and alignment in mathematics education (Kwon, 2024). Context-aware tools can enhance clarity and reduce didactical ambiguity, especially in language-sensitive areas (Nyaaba, 2024).

Another important direction is investigating language effects. Our data showed that some Czech prompts often produced more detailed responses than English ones, indicating a potential interaction between language, model behavior, and conceptual depth. Whether this applies across other domains and languages remains an open question.

Future research could examine the qualitative nature of linguistic and conceptual issues in AI-generated explanations. This study noted recurring problems—such as terminological mismatches, stylistic ambiguities, factual inconsistencies, and prototype-based framing—but did not analyze them in depth. A more systematic investigation could offer deeper insights into the didactical impact of AI tools and inform the design of more context-aware systems.

Finally, the integration of AI into mathematics education invites a renewed look at classic didactical theory. The concept of the didactic contract, originally formulated by Brousseau, has been expanded by recent authors to encompass digital and technology-mediated settings. For instance, Hortelano and Prudente (2024) show how

such contracts still govern expectations in online and asynchronous learning environments. Teachers play a key role in shaping digital milieus—whether through interface design or classroom framing—and in helping students navigate the implicit norms of algorithmic explanations (see also Pierce, Stacey and Wander, 2010 or Daher, Baya'a, and Jaber, 2022).

In this sense, integrating AI into education is not only a technical challenge, but also a deeply pedagogical task. It requires teachers, curriculum designers, and researchers to engage critically with the affordances of AI—balancing its global power with local meaning.

Ethics Declaration

This study did not involve human participants or personal data and therefore did not require ethical approval.

AI Declaration

ChatGPT (OpenAI) was used to assist in data collection (via parallel prompt submissions), visualization (e.g., clustermap, dumbbell plot, boxplot), and formulation of selected English text passages. All AI-generated outputs were critically reviewed and edited by the authors to ensure accuracy and disciplinary relevance.

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A Case Study Investigating Feasibility of VR Implementation for Training in the Pharmaceutical Industry

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Abstract: This case study explored the feasibility of implementing Virtual Reality (VR) technology as a training solution in the pharmaceutical industry, specifically focusing on Quality Control using Ultra-Performance Liquid Chromatography (UPLC) equipment. Utilizing the TELOS framework, we evaluated technical, economic, legal, operational, and scheduling aspects, revealing that VR training significantly enhances task performance, user confidence, and overall satisfaction compared to traditional methods. The economic feasibility analysis indicated a total one-time cost of 51,425.00 DKK for implementing the VR solution, with projected annual costs of 269,000.00 DKK/year for maintenance, alongside 1,249.00 FTE hours for setup and 221.05 FTE hours needed annually for support. While these findings underscore the investment required for effective VR integration and identify areas for cost optimization, challenges such as organizational changes, user adaptation, and a small sample size in the usability study may affect generalizability. The limited research on VR training in industrial contexts highlights the need for ongoing exploration. Overall, this study contributes valuable insights into the effectiveness of VR training and supports further investment in innovative training solutions to improve operational efficiency and employee development in the pharmaceutical sector.

Keywords: Virtual Reality, Feasibility, Pharmaceutical Industry, Digital Training Technology

1. Introduction

The adoption of Virtual Reality (VR) technology for training purposes has been investigated in both educational and industrial settings (Howard et al. 2021; Doolani et al. 2020; Langendorf & Khalid 2025). However, the implementation of VR training is often marked by its resource-intensive nature, raising important considerations for organizations seeking to integrate such technology effectively. The success of any innovation and technology is dependant on its desirability, viability and feasibility (Brown 2009). Industrial projects are generally focused on viability (Pabst et al. 2020), leading to a lack of empirical research investigating feasibility of innovation projects in a number of industries (Noghabaei et al. 2020). Feasibility studies investigating economic, technological and operational feasibility have been done for large scale VR implementation efforts in non-training contexts (Shelke & Chakraborty 2021), and in the context of physical or general competency training (Li et al. 2023; Park et al. 2020; Li et al. 2020; Yang et al. 2025), but has to the best of the authors knowledge not been performed in the highly regulated context of pharmaceutical production. This paper aims to address this deficiency by providing a comprehensive feasibility analysis grounded in a case study conducted at a Danish pharmaceutical firm.

2. Background

2.1 Feasibility of Industrial Training

Feasibility assesses the practicality and implementation potential of a project within existing constraints, while viability examines its long-term sustainability and economic prospects, and desirability evaluates its appeal and user demand (Brown, 2009). Various methodologies can be employed to measure feasibility, which can be categorized into multiple aspects including technical, economic, legal, operational, and schedule considerations, in addition to political factors (Hall 2008). Research on feasibility has been conducted across different industries for project management (Ibbs & Young, 2000) and for transitioning individuals from educational settings, such as universities or trade schools, into industrial positions (Kang & Kim, 2020). Furthermore, it has been explored in the context of extensive training programs within the healthcare sector (Hooley et al., 2020; Brownie &

Thomas, 2014); however, there is a notable gap in the literature regarding feasibility studies specifically focused on industrial training technology.

2.2 Feasibility of VR in Industry

Most studies investigating the potential of VR for industrial training focus on usability. Several of these studies have been carried out for operator training within highly regulated contexts such as vehicle production and maintenance (Ganier et al. 2014; Kalkan et al. 2021; Söderlund et al. 2024), pharmaceutical production (Wismer et al. 2021) and nuclear energy production (Masiello et al. 2022). Additionally other industrial studies focusing on other professions such as nurses (Zhang et al. 2022; Jeon et al. 2020) and electricians (Tanaka et al. 2023) along with students preparing to work in industry (Yang et al. 2025). While these studies all include feasibility aspects, feasibility has not been the primary focus in most cases.

2.3 History of VR at the Company

Since the 2010s, Novo Nordisk has explored the application of Virtual Reality (VR) and extended reality (XR) technologies to address training challenges (Langendorf & Khalid, 2024). The company's VR initiatives are primarily categorized into two uses: Design Use and Training Use. Design Use involves "sandboxes" that integrate 3D models, allowing teams to visualize complex configurations and identify design flaws before physical implementation. For instance, a design review in a 3D virtual environment uncovered 30 issues compared to just four in traditional assessments. These virtual spaces also enable interactions for operators and personnel at expansion sites with environments not yet physically constructed. Training Use extends from these sandboxes by incorporating defined procedures and performance monitoring systems. Several training projects are underway at Novo Nordisk, including the one presented in this paper. Additionally, experiments with Augmented Reality (AR) using Microsoft HoloLens were conducted but discontinued following Microsoft's support shutdown in late 2024. Detailed discussions on the feasibility challenges of earlier VR and AR projects will follow in this paper.

2.4 The Case

This project focuses on developing a VR training solution for Quality Control using Ultra-Performance Liquid Chromatography (UPLC) equipment, which is essential for laboratory technicians to ensure product safety. Currently, UPLC training relies on a brief instructional video and infrequent in-person sessions, leading to significant knowledge gaps and accessibility issues. New employees face considerable delays if they miss these monthly sessions, affecting both individual productivity and overall team efficiency. Therefore, there is a critical need for a more flexible and engaging training solution to improve onboarding and learning quality, justifying the allocation of resources for a VR training setup. Two different versions of a VR training setup were developed, one custom built in Unity and one built using Synergy XR.

3. Methodology

3.1 Framework

In this study, the TELOS framework will be employed as a comprehensive tool for evaluating the feasibility of digital systems. The TELOS (Technical, Economic, Legal, Operational, and Schedule) mnemonics serve to guide the investigation through varied dimensions of feasibility (Hall 2007). TELOS has been extensively utilized in digital systems evaluation (Ningsi & Nuzul 2023; Perdana et al. 2022; Avan et al. 2016). This study will focus on qualitative assessments rather than quantitative metrics, to focus on understanding each relevant aspect of feasibility without the constraints of numerical evaluation.

3.2 Technical Feasibility

Technical feasibility will be assessed through usability tests, which analyze whether the system performs as intended (Martin & Hannington 2012). The user journey has been investigated through practical tests to evaluate the system's functionality and technical aspects, ensuring that the organization possesses the necessary resources for implementation (Polaine et al. 2013).

3.3 Economic Feasibility

The evaluation of economic feasibility will follow the assessment of technical and operational feasibility, aligning with established practices in previous studies (Bause et al. 2014). Key economic metrics will encompass Total Cost of Ownership (TCO) (Ellram 1995) and Return on Investment (ROI) (Brealey 2017), both of which are critical in gauging viability of a project, but can also serve feasibility investigation purposes as in this study.

3.4 Legal Feasibility

The legal feasibility of the project will be investigated through expert assessments (Ritchie 2003) by the developers and management, which will provide insights and recommendations regarding compliance with relevant laws and regulations.

3.5 Operational Feasibility

To determine operational feasibility, usability tests employed in previous studies will be leveraged, as high usability predictors often correlate with high acceptance from users and organizations (Broderick et al. 2023; Yen & Bakken 2011; Pravitno et al. 2023). The Kirkpatrick model will be utilized to evaluate whether training aligns with organizational goals and its overall impact on performance. Additionally, user flow tests will assess whether the system can effectively integrate within existing processes, as well as ascertain the maturity of the organization's technological capabilities (Masiello et al. 2022).

3.6 Schedule Feasibility

The schedule feasibility assessment will also rely on expert assessments (Ritchie 2003) by the developers and management, providing an informed outlook on the practicality of project timelines and deadlines in relation to organizational objectives and resource availability.

3.7 Additional Data Collection

Key findings from previous VR projects at the company were collected through interviews with responsible project managers (n=3) (Ritchie 2003). These findings along with the legal and schedule feasibility analysis will be included in the discussion section.

4. Results

4.1 Technical & Operational Feasibility

4.1.1 Usability Testing

The usability evaluation included three groups of five laboratory technicians in each who had no prior process experience, with each group receiving training through one of the following methods: the existing classroom setup, a custom virtual reality (VR) solution, and a VR solution built on an established platform. The assessment criteria encompassed task performance, user satisfaction—measured using the Usability Metric for User Experience (a shortened version of the System Usability Scale)—and post-training confidence. The results revealed that participants trained with VR achieved task completion rates of 8.4/9 and 7.2/9 for the two VR setups, significantly surpassing the 2/9 completion rate of the classroom-trained group. Furthermore, the confidence levels of the VR-trained groups were notably higher (8/10 and 7.4/10) compared to the classroom group (3.4/10). Although no significant differences were detected in training duration, the statistical analysis indicated that the VR training methods are more effective than the traditional classroom approach. Performance between the two VR solutions showed no significant difference. Satisfaction scores for the VR groups were higher (85 and 82.5) in comparison to the classroom group (67.2), though these differences were not statistically significant. Given the limited sample size and lack of long-term impact evaluation, these findings provide initial insights into potential performance improvements, but did find significant difference in performance between the two VR solutions. Due to the faster development process involved with the Synergy XR solution, this option was selected for continued economic feasibility investigation.

4.1.2 User Journey (Practical Tests)

4 iterations of the setup were developed and tested with users. Throughout this iterative process of the VR training solution, several key challenges were identified:

1. Access and Navigation Issues:
    - Challenge: Users struggled with accessing training materials on SharePoint (internal platform) and found the navigation confusing, particularly with videos opening in new tabs.
    - Solution: Subsequent iterations focused on streamlining access to information, and the eventual transition to Degreed (LMS) aimed to create a clearer, step-by-step user flow.
2. Overwhelming Information:
    - Challenge: The initial training content was perceived as overly complex, resulting in user confusion and difficulty in comprehension.
    - Solution: Iterative feedback led to the simplification of instructional materials and the consolidation of content into an intuitive e-learning module using Articulate Storyline 360, reducing information overload.
3. Language Barriers:
    - Challenge: Training materials primarily in Danish posed challenges for non-Danish speaking users.
    - Solution: New video content was created in English to accommodate non-Danish speakers, broadening accessibility.
4. User Support and Training Setups:
    - Challenge: Users expressed a strong desire for in-person assistance during training sessions due to uncertainties in using VR technology.
    - Solution: The introduction of VR supervisors for 1:1 training sessions provided hands-on support, enhancing user confidence and ensuring a smoother onboarding process.
5. Booking Confusion:
    - Challenge: The original booking process for VR rooms caused considerable confusion among users.
    - Solution: Clearer guidelines were established for booking procedures, and users were encouraged to use familiar software, such as Outlook, for scheduling.

The findings from each iterative testing phase emphasized the importance of user feedback, leading to significant changes in training delivery and structure. This approach resulted in the development of an effective VR training solution flow, shown in figure 1. The final version of the room utilized for the training can be seen in figure 2. In regards to technical aspects, the Meta Quest 3 headset was chosen for its superior rendering capabilities and ability to maintain a stable frame rate, which effectively minimizes discomfort and enhances the overall virtual reality experience. In addition to the headset, several supporting tools were integrated to improve the training environment and gather user insights. Microsoft Forms was utilized for collecting feedback, while Degreed served as a tracking system for learning activities. Furthermore, design software such as Canva, Fusion 360, and Blender contributed to the development of engaging training materials. Although the HTC Vive was initially considered for its high rendering capabilities, it was ultimately set aside in favour of the Meta Quest 3 due to its more user-friendly implementation.

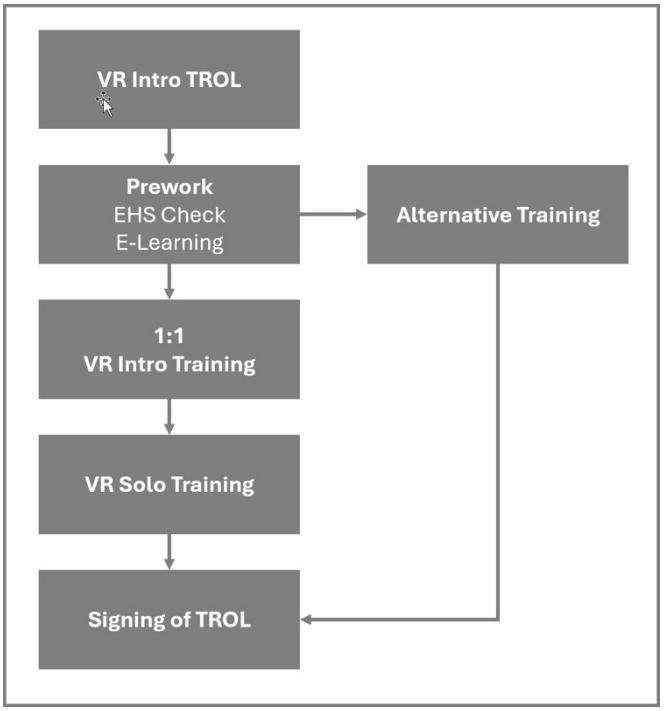


Figure 1: VR Training Flow



Figure 2: VR Room Setup

4.2 Economic Feasibility

4.2.1 Total Cost of Ownership

This calculation is based on the assumption of having a total of 2 builder licenses (the integrated license plus 1 additional builder license) and 1 active VR room with 15 users for training each year. Additionally, it assumes the acquisition of 4 VR headsets—2 for use in the VR room and 2 for development and testing purposes.

Direct Costs:

- SynergyXR License: 224,000.00 DKK/year for 2 builder licenses and 100 users.
- Extra Builder Licenses: 45,000.00 DKK/year for each additional builder license.
- VR Headsets (with elite strap and accessories): 18,200.00 DKK for 4 units.
- UV Cabinet: 32,725.00 DKK for one unit used for equipment sterilization.

- Charging Station: 500.00 DKK for one unit.
- Development Cost: 1,224 FTE hours for content preparation and testing.
- Installation Cost: 25.00 FTE hours for setting up the training room.
- Maintenance and Support: 100.00 FTE hours/year for ongoing support.

Indirect Costs:

- Ambassador-Related Activities: 129.00 FTE hours/year for 3 ambassadors, covering both training and related activities.
- Downtime: 10.05 FTE hours/year for training time per trainee (estimated at 15 trainees).

Intangible Costs:

- Employee Productivity Loss: 0.00 FTE hours/year; no expected loss in productivity.
- Compliance Risks: 0.00 FTE hours/year; deemed non-relevant as it is Non-GxP.

Environmental Considerations:

- CO_2 Emissions from Development: 257.04 kg CO_2 (fixed).
- CO_2 Emissions from VR Equipment: 443.48 kg CO_2/year for one active training room.
- Total CO_2 Savings from Travel: 511.25 kg CO_2/year from saved travel (1 flight per VR room).
- Net Total CO_2 Emissions: 189.27 kg CO_2/year.
- Projected Net Total CO_2 Emissions (after one year): -67.77 kg CO_2/year.

Summary:

- Total One-Time Costs: 51,425.00 DKK
  This includes all one-time expenses associated with the implementation of the VR training solution.
- Total Annual Costs: 269,000.00 DKK/year
  This encompasses all recurring costs required for maintaining the VR training system annually.
- Total One-Time FTE Hours: 1,249.00 FTE Hours
  This reflects the total full-time equivalent hours allocated for the initial setup and development of the VR training solution.
- Total Annual FTE Hours: 221.05 FTE Hours/year
  This represents the estimated total full-time equivalent hours required for ongoing maintenance and operational support of the VR training solution each year.

4.2.2 Return on Investment

The Return on Investment (ROI) calculation evaluates the potential performance metrics associated with implementing enhanced training solutions for Ultra-Performance Liquid Chromatography (UPLC) processes within this part of the organization, focusing on data for the year 2024. This analysis is grounded in several key assumptions: 1). Of the total 873 re-runs recorded in 2024, 673 are attributed to equipment failure, which can potentially be mitigated through the implementation of VR training. 2). It is assumed that 15% of these re-runs (approximately 101) are caused by human mishandling of equipment, a figure derived from consultations with multiple Subject Matter Experts (SMEs). 3). On average, a Full-Time Equivalent (FTE) employee spends an additional 6 hours on each re-run.

- Status Quo: The current UPLC training processes lead to 606 FTE hours required annually for re-runs, with 101 re-runs and 66 equipment breakdowns each year.
- Minor Change (2.5% Improvement): With minimal adjustments, re-run hours decrease to 591 FTE hours, resulting in 98 re-runs and 64 breakdowns.
- Moderate Change (5% Improvement): Further enhancements reduce re-run hours to 576 and the number of re-runs to 96, alongside 62 breakdowns.
- Significant Improvement (10% Improvement): Substantial upgrades yield 545 FTE hours saved on re-runs, 91 total re-runs, and 59 breakdowns annually.
- High Improvement (15% Improvement): Improved training approaches potentially save 515 FTE hours for re-runs, with 86 re-runs and 56 breakdowns.
- Maximal Improvement (20% Improvement): The best-case scenario predicts a decrease to 485 FTE hours, 81 re-runs, and 52 breakdowns each year.

4.3 Legal & Schedule Feasibility

The legal and scheduling aspects were deprioritized as they were not applicable to this project. Management did not establish a specific timeline since the project also had an exploratory purpose. The issues with the current training program were so significant that no timeline requirements were imposed on the project team. The pilot was developed over a six-month period during which hardware and software were selected, and the technical competencies needed to create the complete instructional materials were established. Following this design and development phase, scaling the instruction to include the entire training framework was estimated to require an additional four months. The VR training serves as a substantial enhancement to the existing training setup without altering the underlying Standard Operating Procedures (SOP) or Job Instructions (JI). Since all participants are company employees obligated to complete this training and no personal information would be collected on them, no GDPR concerns were identified, leading to the conclusion that there would be no legal challenges.

5. Discussion

5.1 Comparison to Previous Projects at the Company

Feasibility challenges for VR and AR projects at Novo Nordisk, identified through stakeholder interviews, include various technical, organizational, and user-related issues. Technical limitations of devices like the Hololens affected performance, with users experiencing frustrations from calibration difficulties and 3D model rendering errors.

Organizationally, the complex device enrollment process created significant barriers; it was more intricate than for traditional PCs, complicating compliance and enterprise readiness. Security transitions requiring multi-factor authentication further hindered operator accessibility. User acceptance was affected by perceptions of wearing AR or VR headsets as a weakness, leading to reluctance in engaging with VR and AR training. Additionally, inconsistent training resources and the need for super users to assist with onboarding complicated implementation.

Logistical challenges included managing inter-team communication and ensuring all technical aspects met user requirements. Overall, the combination of technological constraints, procedural complexities, and the necessity for user acceptance highlighted the need for sustained effort for successful integration.

5.2 Comparison to Previous Studies in Industry

Due to the limited number of studies in general investigating the use of VR for training in industry (Langendorf & Khalid 2025), the amount of studies we can compare to is limited. A previous study focusing on industrial assembly tasks for factory workers found a 27.9% improvement in performance, and 89% reduction in assembly flaw rate (Kalkan et al. 2021), when compared to peer training. A previous study carried out at Danish trade schools specializing in pharmaceutical production operators found a significant improvement in theoretical knowledge, perceived learning, practical skills and self efficacy when compared with traditional SOP reading (Wismer 2021), but found that on multiple parameters peer training outperformed the VR setup. In the context of vehicle maintenance training, participants who underwent both conventional and virtual training demonstrated comparable performance levels when tasked with executing procedures in actual environments. According to Ganier (2014), both training methods resulted in improved outcomes regarding successful task completion, efficiency in task execution times, the duration spent referring to job instructions, and the frequency of instructor guidance provided. Aligning with these findings, our usability evaluation revealed significant improvements in task performance for VR-trained participants, who achieved task completion rates of 8.4/9 and 7.2/9 for the VR solutions, far exceeding the classroom-trained group’s rate of 2/9. Additionally, similar to Wismer's results, we observed enhanced confidence levels among VR-trained individuals, indicating a positive impact on their perceived readiness for work. This suggests that, despite mixed results in comparison to peer training noted in other studies, the effectiveness of VR training in fostering essential skills and confidence cannot be overlooked.

One feasibility study investigating the potential for construction safety training found that VR training significantly improves students' performance across all measured outcomes (Yang 2025), emphasizing its effectiveness in enhancing safety awareness and operational skills. Additionally, the reduction in variability among students’ learning outcomes suggests that VR training promotes consistent performance, which is crucial

for educational equity. Furthermore, students scoring higher in self-evaluation showed increased motivation and engagement with VR technology compared to their peers.

5.3 Sources of Error

The pioneering nature of this project within the company introduces potential sources of error, particularly in speculative economic estimates that may not accurately reflect future conditions due to limited historical data. Ongoing organizational changes, such as expansion and reorganization, could significantly alter workflows and challenge initial resource assumptions. Additionally, the small sample size in the usability study limits the ability to generalize findings and may overlook diverse user needs, affecting the assessment's accuracy. Rapid technological integration may also lead to adaptation challenges for inexperienced users, impacting usability ratings. To mitigate these issues, ongoing research, a larger participant base, and continuous reassessment of the project's feasibility are essential as it progresses.

5.4 Future Work

To enhance the virtual training initiative, it is essential to finalize the training setup, ensuring all components are fully operational and integrated. Conducting a large-scale study will allow for the assessment of the VR training solution's impact on performance metrics across a wider user base. Additionally, evaluating the long-term viability of the VR training will be crucial for understanding its sustainability and adaptability to future changes. Finally, ramping up the training setup across the organization is necessary to provide all employees with access to this innovative training method, ultimately fostering skill development and improving operational efficiency.

6. Conclusion

This case study has explored the feasibility of implementing Virtual Reality (VR) technology as a training solution within the pharmaceutical industry, specifically focusing on Quality Control using Ultra-Performance Liquid Chromatography (UPLC) equipment. By employing the TELOS framework, we assessed technical, economic, legal, operational, and schedule aspects, leading to valuable insights on the practicality of VR training within a highly regulated environment. Our findings indicate that VR training significantly enhances task performance, user confidence, and overall satisfaction compared to the current training setup. The economic feasibility analysis revealed a total one-time cost of 51,425.00 DKK for the implementation of the VR training solution and projected total annual costs of 269,000.00 DKK/year for ongoing maintenance. The analysis also indicated a total of 1,249.00 FTE hours for setup and development, along with 221.05 FTE hours required annually for support of the approximately 1 hour long instruction. These findings underscore the investment required for successful VR integration while highlighting potential areas for cost optimization as the program matures. Despite the promising results, challenges such as organizational changes, user adaptation, and the small sample size of the usability study highlighted potential sources of error that could affect the generalizability of our findings. The lack of extensive prior research in VR training for industrial contexts further emphasizes the need for ongoing exploration in this area.

Ethics Declaration

No ethical clearance was necessary.

AI Declaration

Scite.Ai was used for identifying related works. ChatGPT was used to assist with writing in the form of rephrasing, corrections and shortening of paragraphs.

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Teaching and Learning via Video Conferencing Platforms: Issues Across Three Asian Countries

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Abstract: Video conferencing platforms have become essential tools for facilitating remote teaching and learning, particularly in the aftermath of the COVID-19 pandemic. This global health crisis accelerated the transition from traditional face-to-face instruction to online education, making virtual classrooms widespread and enduring practices in higher education. This study investigates the key issues associated with video conferencing technologies in teaching and learning across three Asian countries: Malaysia, Thailand, and Bangladesh. Utilizing a design thinking approach, qualitative data was collected through interviews and focus group discussions with educators, students, and technical staff. A total of 106 participants were involved in the study. The empathize stage of the design thinking process allowed for a deeper understanding of user experiences, frustrations, and needs in the context of online teaching and learning. The define stage was then employed to categorize the recurring issues into common themes. The analysis revealed seven major themes encompassing a total of seventeen subthemes. These themes include: Infrastructure, with challenges related to internet connectivity and power reliability; Environment, which concerns the suitability of physical spaces for both teaching and learning; Competency, which covers ICT skills, pedagogical adaptability, assessment methods, and course design; Support, including the roles of institutional management, parental or family involvement, and community resources; Tools, which refer to problems encountered with software and hardware devices; Health, addressing the impact on mental and physical well-being; and Self-efficacy, related to users' confidence and the learning curve in adopting new technologies. The findings shed light on the multifaceted and interconnected nature of the issues and emphasize the need for solutions. The outcomes of this study are valuable not only for video conferencing platform developers aiming to improve functionality and usability but also for higher education administrators seeking to create more inclusive, supportive, and effective digital learning ecosystems.

Keywords: Design Thinking, Online Teaching and Learning, Virtual Classroom, Educators

1. Introduction

The COVID-19 pandemic prompted a swift shift to online education, establishing video conferencing platforms as essential tools for maintaining communication and instructional continuity. While these platforms are primarily used for communication across various sectors (Suduc, Bizoi & Filip, 2023), their application in education expanded significantly during and after the pandemic (Gladović, Deretić & Draskovic, 2020; Suduc, Bizoi & Filip, 2023). Features such as real-time interaction, virtual classrooms, and collaborative tools enabled educational institutions to continue delivering instruction across geographically dispersed regions (Camilleri & Camilleri, 2022; Parasian & Yuliati, 2020).

Research highlights the educational benefits of video conferencing, including enhanced collaboration, improved problem-solving, and more effective decision-making (Suduc, Bizoi & Filip, 2023). However, several limitations have also been identified, particularly in the context of teaching and learning (Cavus & Sekyere-Asiedu, 2021; Dumford & Miller, 2018; Ebert, Levett-Jones & Jones, 2019; Ling et al., 2024; Putri et al., 2020; Suduc, Bizoi & Filip, 2023).

Despite the benefits of these platforms, their adoption and effectiveness vary widely, especially in parts of Asia where challenges such as uneven digital infrastructure and limited digital literacy persist. This article explores the issues surrounding the use of video conferencing for education in three Asian countries: Bangladesh, Malaysia, and Thailand

2. Video Conferencing Platforms

Video Conferencing Platforms are digital tools or software applications that enable real-time communication through audio, video, and text over the internet (Camilleri & Camilleri, 2022; Purnell, 2019; Rop & Bett, 2012). In educational settings, these platforms facilitate remote teaching and learning by allowing live virtual classes, student-teacher interaction, screen sharing, and collaborative activities (Parasian & Yuliati, 2020). Some commonly used video conferencing platforms for education in Asia countries include Zoom, Google Meet, Microsoft Teams, and Cisco Webex. These platforms have become essential for online education, especially during and after the COVID-19 pandemic, offering a means to continue instruction despite physical distance. However, their effective use depends on technological access, user training, platform features, and internet connectivity, which vary across regions and institutions.

Video conferencing platforms have become central to remote education, but numerous challenges limit their effectiveness. A persistent issue is accurately evaluating student performance in virtual settings compared to traditional face-to-face classrooms (Dumford & Miller, 2018), compounded by classroom management difficulties (Dumford & Miller, 2018), technological skill gaps, and unequal access to devices and internet, particularly in under-resourced areas v. Security concerns, such as inconsistent data encryption, complicate safe and private participation (Cavus & Sekyere-Asiedu, 2021).

Physical and psychological concerns have also been reported. Extended screen time during video conferencing can result in postural issues and screen fatigue (Camilleri & Camilleri, 2019), while digital distractions such as social media or unrelated websites diminish the participants' focus and productivity (Camilleri & Camilleri, 2022; Putri et al., 2020). Many educators face challenges with unfamiliar digital tools due to limited technical skills, leading to feelings of insecurity when conducting online classes. This lack of confidence increases psychological stress and hinders their ability to effectively adapt teaching methods (Rio-Chillcce, Jara-Monge & Andrade-Arenas, 2021; Al-Samarraie, 2019).

Technical issues such as poor internet connectivity, audio/video disruptions, and software incompatibilities continue to disrupt learning (Ling et al., 2024; Al-Samarraie, 2019). Furthermore, background noise, overlapping conversations, and lack of non-verbal cues impair communication (Gillies, 2008; Lee, 2007; Suduc, Bizoi & Filip, 2023). Self-conscious behavior during video sessions (Maher, Moussa & Khalifa, 2020) and the inability to conduct hands-on or lab-based learning are additional limitations (Rahim et al., 2020)

From a pedagogical standpoint, the lack of curriculum alignment with video conferencing approaches has been noted (Ip, 2012; Ling et al., 2024), highlighting the need to adjust syllabi and adopt new teaching strategies tailored for online delivery. Teachers must also carefully plan sessions, set clear expectations, and select appropriate tools to support effective instruction (Adipat, 2021).

3. Design Thinking

Design Thinking is a customer-centered innovation approach that applies designers' methods to business processes, aiming to develop creative ideas and models for both products and services. It is an integrative and holistic process involving collaboration among various experts with a work environment designed to foster creativity through the principles of People, Process, Place, and Partnerships. The approach begins with deep customer understanding rather than technology or business goals, emphasizing empathy by closely observing users to align innovations with their real needs. Design Thinking also promotes rapid prototyping, encouraging early, simple, and functional representations of ideas to gather customer feedback and refine solutions efficiently Müller-Roterberg (2018, p.1).

The design thinking models by Gibbons (2016) and Mueller-Roterberg (2018) follow similar processes with slight variations. Gibbons' model includes six phases: empathize, define, ideate, prototype, test, and implement, while Mueller-Roterberg (2018) outlines six comparable phases: understanding, observe, point-of-view, ideate, prototype, and test. Both models begin with a user-centered approach, but they frame the initial stages in distinct ways. Gibbons (2016) began with the "Empathize" phase, which focuses on developing a deep understanding of users, their challenges, and their needs. Mueller-Roterberg (2018), on the other hand, divides this stage into two distinct phases: "Understanding" and "Observe." The "Understanding" phase emphasizes grasping the nature of the problem or requirement, while the "Observe" phase involves conducting detailed research and field observations to understand users in their actual environments.

The next stage is "Define" (Gibbsons, 2016) or "Point-of-View" (Mueller-Roterberg, 2018) to narrow down insights gathered from the earlier stage into a clear problem statement that focuses on a specific user or user group. This clarity forms the foundation for the next phase, "Ideate,". This stage encourages brainstorming a broad range of creative and unconventional ideas that might address the user's needs or problems. Next is "Prototype" phase, where initial concepts are translated into tangible forms. Gibbons (2016) emphasizes collaborative sketching, sharing, and building on one another's ideas during this phase. Mueller-Roterberg (2018) aligns closely with this view, highlighting the importance of experimentation and early visualization of potential solutions.

The "Test" phase comes next and is focused on evaluating prototypes through user feedback. This stage aims to determine which aspects of the solution are effective and which need improvement. It is also a point for assessing the feasibility and potential impact of the proposed ideas.

The study only focuses on the first three stages of Müller-Roterberg (2018) to identify issues of using video conferencing platforms in education across three Asian countries: Bangladesh, Malaysia, and Thailand.

4. Methodology

A design thinking approach was employed to explore the issues related to video conferencing platforms for teaching and learning in three Asian countries: Bangladesh, Malaysia, and Thailand. The study involved educators, students, and information technology (IT) staff with prior experience using video conferencing for educational purposes. Data was collected through focus group discussions and in-depth interviews. There were 33 participants from Bangladesh, 52 from Malaysia, and 21 from Thailand.

The study was carried out in three structured phases to explore the challenges associated with using video conferencing tools in teaching. Stage 1: Understanding the Problem aimed to establish the issues of using these platforms. This phase involved selecting participants and formulating relevant questions to guide the investigation. The participants included lecturers, students, and technical staff with over three years of experience using video conferencing for instructional purposes. This is to ensure their deep familiarity with the context. Data collection methods included observation, in-depth interviews, and focus group discussions.

In Stage 2: Observation, researchers conducted on-site visits to observe how participants used video conferencing tools within their teaching settings. These observations were supplemented with interviews to gain deeper insights into the challenges faced during teaching and learning practices.

Stage 3: Defining the Problem focused on synthesizing the data gathered from the earlier stages. Interview and discussion recordings were transcribed and analyzed using thematic analysis to uncover patterns and common themes. This process helped categorize the key issues users experience when using video conferencing platforms in their teaching and learning environments.

5. Findings and Discussions

The issues identified across three Asia countries, namely Bangladesh, Malaysia, and Thailand, are categorized into seven themes: infrastructure, environment, competency, support, tools, health, and self-efficacy.

5.1 Infrastructure

Under the Infrastructure theme, two categories were identified: connectivity and power supply. Malaysia, Thailand, and Bangladesh faced unstable internet connections, especially in rural areas, where slow speeds, weak Wi-Fi, and limited bandwidth disrupt live video sessions. Mobile data costs in rural Malaysia and Thailand further limit access for some students. The findings are consistent with Al-Samarraie (2019), Ebert, Levett-Jones, and Jones (2019), and Ling et al. (2024).

Additionally, power supply problems, including frequent outages and load shedding, affect the continuity of online classes. In Thailand, high costs for backup power solutions add to the challenge, while in Bangladesh, even brief outages during storms or maintenance cause repeated disruptions.

5.2 Environment

Teaching and learning categories were identified under the Environment theme. Educators and students in Malaysia, Thailand, and Bangladesh faced virtual environmental issues with online learning from home. A lack

of dedicated teaching and study spaces, especially in rural or crowded areas, leads to frequent distractions and reduced teaching and learning effectiveness. Background noise, poor lighting, and limited privacy are common issues that disrupt focus and communication during online sessions.

Students often struggle with motivation and engagement in informal home settings, while the absence of structure and study routines further weakens learning outcomes. In all three countries, unequal access to the internet and digital devices, particularly in remote areas, continues to widen the education gap.

5.3 Competency

The study found four categories under the Competency theme, namely Information and Communication Technology (ICT), pedagogy, assessment, and course design. In Malaysia, Thailand, and Bangladesh, the integration of video conferencing in education faces several issues. Lack of ICT proficiency and difficulty troubleshooting software issues hinder effective use of digital tools, while keeping up with evolving technology and features like breakout rooms is a struggle. Inadequate training and low confidence in digital teaching methods also impair educators' ability to adapt. These findings are in line with Gillies (2008), Lee (2007), and Suduc, Bizoi and Filip, (2023) findings.

Pedagogically, limited engagement, distractions, and insufficient online teaching training reduce effectiveness, especially in Bangladesh, where there's resistance to online teaching. Educators also face challenges in facilitating collaborative learning due to limited exposure to digital tools. Inconsistent online assessment practices, plagiarism concerns, and equity issues related to technology access further complicate learning environments. In terms of course design, many educators in Malaysia and Thailand struggle to adapt traditional content to online formats, resulting in disjointed learning experiences. Bangladesh lacks a standardized framework for online course creation, leading to inconsistency. Similar issues were shared by Ip (2021) and Ling et al. (2024).

5.4 Support

Under the Support theme, three key categories of issues were identified: management, parent/family, and community. In Malaysia, issues in managing online teaching included the absence of standardized guidelines, unrealistic expectations from management, and insufficient support for students with limited access to technology. Educators also faced high workloads and reduced personal time.

Thailand experienced similar issues with a lack of formalized policies, increased workload for adapting content, and limited institutional support for video conferencing tools. In Bangladesh, educators struggled with insufficient training on online tools, inconsistent IT support, and a lack of specific policies for video conferencing. Budget constraints also hindered technological support for online teaching. The issues supported the findings of Al-Samarraie (2019), Ling et al. (2024), Rio-Chillcce, Jara-Monge & Andrade-Arenas, (2021).

All three countries lack parental support, with students managing academic tasks independently while balancing household duties, which limits study time and focus. Cultural and societal factors also posed challenges. In Malaysia, the community prefers face-to-face education and lacks industry support for video conferencing tools, while Thailand faced societal resistance to online learning. The issues were outlined by Ling et al. (2024).

5.5 Tools

Issues concerning Tools were divided into two categories: hardware and software. In Malaysia, Thailand, and Bangladesh, there is a lack of adequate hardware, including outdated devices and insufficient facilities for online learning. This results in poor connectivity and disrupted learning experiences. In Thailand, frequent hardware failures and inadequate investment in technology infrastructure worsen the situation, while Bangladesh struggles with a lack of devices for both students and teachers.

Software-related issues also impede learning. Application crashes, audio problems, and unstable Learning Management Systems (LMS) disrupt lessons, making communication difficult and hindering access to materials. Inconsistent software use, often due to reliance on free trials or individual purchases, creates confusion and inefficiencies. In Bangladesh, a lack of training for educators on digital tools further complicates the situation. Additionally, compatibility issues between devices and software in Thailand and Malaysia limit engagement and participation, while the high cost of maintaining multiple software platforms puts a financial strain on institutions. The issues are also highlighted by Ling et al. (2024)

5.6 Health

Health-related issues identified in the study were mental and physical health. Students in Malaysia, Thailand, and Bangladesh have experienced a range of mental health challenges due to the shift to online learning. A key concern of the three countries is the loneliness and emotional distress caused by the lack of in-person interaction. The reduction in social interaction has negatively impacted students' overall mental well-being, especially in settings where group work and peer support play a critical role. Additionally, screen fatigue, which results from prolonged hours in front of digital devices, has decreased motivation and mental exhaustion, making it difficult for students to stay engaged with their studies. The issues were similar to the findings of Camilleri and Camilleri (2019) and Putri et al. (2020).

Physically, students have been affected by the extended use of digital devices during online classes. Common issues include digital eye strain, which causes discomfort such as blurred vision, dry eyes, and headaches. Poor posture from sitting for long periods in non-ergonomic home setups has also led to muscle pain and physical discomfort, which is also shared by Camilleri (2022). Furthermore, the sedentary lifestyle is associated with online learning. This issue, marked by minimal physical movement, has contributed to increased physical stress and potential long-term health risks such as obesity and poor cardiovascular health. These issues underline the need for balanced screen time and integrated physical activity during the learning day.

5.7 Self-efficacy

Confidence and learning curve are two categories identified under the Self-efficacy theme. Across Malaysia, Thailand, and Bangladesh, a lack of confidence and ICT skills remains a major barrier to effective online education. Educators in all three countries feel insecure using digital tools, with many lacking sufficient training, particularly in managing virtual classrooms and conducting online assessments. This results in reluctance to adopt innovative methods and low motivation. The same issues were revealed in the literature (Rio-Chillcce, Jara-Monge & Andrade-Arenas, 2021; Al-Samarraie, 2019).

The steep learning curve further complicates digital adoption. Teachers and students struggle with self-learning, technical troubleshooting, and mastering multiple platforms. Inadequate training and resistance to change, especially in Bangladesh, hinder adaptation to online formats. These issues are worsened by software limitations and connectivity issues, particularly in rural areas, which were mentioned by Ebert, Levett-Jones, and Jones (2019) and Ling et al. (2024).

6. Conclusion

Advancements in technologies have transformed the landscape of teaching and learning through the use of video conferencing platforms. While these technologies offer significant benefits such as real-time interaction, collaboration, and continuity of instruction, they also present a complex array of challenges, particularly in developing regions. This study, focusing on Malaysia, Thailand, and Bangladesh, identified seven major themes: Infrastructure, Environment, Competency, Support, Tools, Health, and Self-efficacy, that encapsulate the multifaceted issues faced by educators, students, and IT support staff. Using a design thinking approach, the research provided a deeper understanding of user experiences and needs, highlighting critical gaps in digital readiness, pedagogical adaptability, and technical infrastructure. These findings underline the importance of context-specific interventions and the need for collaborative efforts among educators, institutions, platform developers, and policymakers to enhance the effectiveness of virtual education.

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Ethics and AI Declaration

Ethical clearance was not required for the research.

AI tool was used for language editing of this paper.

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Virtual Reality Experience for Digital Literacy: Identifying Extremist Symbolism in Social Media

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Abstract: This paper explores the development and usability of a hand-tracking-based Virtual Reality (VR) application designed to enhance digital literacy by teaching users to recognize extremist symbolism on social media. Given the increasing prevalence of covert extremist content online, immersive educational tools are essential to equip users with critical analytical skills. A mixed-methods usability study was conducted with 15 participants (average age 30; mostly male) evaluating general usability, immersion, engagement, interaction quality (especially related to hand-tracking) and acceptance of AI-generated voices. The VR application achieved a high usability rating (System Usability Scale score: 80.17). The perceived engagement and fun using the hand-tracking was shown to have a strong correlation with the perceived control of using the hand-tracking ($r = 0.898$, $p < 0.001$, regression analysis: $\beta = 0.424$, $R^2 = 0.806$), showcasing the need for intuitive and robust controls, as well as the importance of usability considerations. A notable finding was the unexpected negative correlation ($r = -0.76$, $p = 0.00095$, regression analysis: $p = 0.001$, $\beta = -0.68$ and -0.85, $R^2 = 0.58$) between the perceived quality of Artificial Intelligence (AI)-generated voices and motion sickness, suggesting that voice naturalness might either mitigate discomfort or that motion sickness could negatively affect voice perception. Qualitative feedback emphasized the importance of intuitive interactions, clear guidance, gesture precision and richer educational content. Additionally, users identified interaction consistency and detailed tutorial elements as important factors for a positive user experience. The study concludes that well-designed VR applications using precise hand-tracking and clear instructions contribute effectively to an engaging and otherwise well received learning experience in the educational environment. Key areas for further research include the relationship between voice quality and motion sickness or general user comfort, long-term retention of digital literacy skills, as well as comparing the learning effects of a more expansive, rich environment with traditional teaching methods.

Keywords: Virtual Reality; Digital Literacy; Hand-Tracking; User Engagement; Usability; Social Media

1. Introduction

Social media platforms play a significant role in shaping the public opinion. Unfortunately, they are also used to spread hate speech and extremist ideologies, often through subtle cues and coded symbols that may not be obvious to the average user (Yesmen, Naha and Sharmin, 2023). Extremist groups take advantage of this environment by using coded language and symbols to communicate messages covertly. For example, the number *88* is a commonly used extremist symbol and acts as a shorthand for the infamous phrase *"Heil Hitler"* (with the 8 standing for the eighth letter of the alphabet, *H*). A hidden reference that can circulate on social media undetected by those unfamiliar with it (Michael, 2009). Such examples underscore the need for improved digital literacy so that individuals can recognise these signs of extremist content, before they participate in accidentally spreading such symbols.

Educational interventions are needed to raise awareness of extremist symbolism and help users critically evaluate online content. Traditional approaches to digital literacy, like lectures or text-based guides, may not fully engage learners, especially when confronting abstract concepts like covert symbols. However, recent advances in immersive VR-technology opens new possibilities by offering the potential to improve learning engagement and effectiveness in various domains (Conrad, Kablitz and Schumann, 2024). VR can simulate realistic scenarios and allow for active, experiential learning, which may be particularly useful for practicing how to identify and respond to problematic online content. By placing users inside an environment that is the embodiment of a metaphor for social media algorithms, a VR application can provide a safe, yet memorable space to encounter extremist cues and learn to spot them.

This research explores how a hand-tracking based VR application can be developed to enhance digital literacy education by increasing user engagement in the context of identifying extremist symbols on social media. The work addresses the following main question:

"How can a hand-tracking-based Virtual Reality application be developed to enhance digital literacy education by increasing user enjoyment and engagement?"

To investigate this, the VR experience “Down the Rabbit Hole” was developed and user-tested. This paper summarises the development of the VR application, the methodology of the user study, and the key findings from the evaluation. The results offer insights into the benefits and challenges of using VR as a tool to increase engagement in education, particularly involving social media literacy, and are discussed with respect to future improvements and the broader implications for digital literacy initiatives.

2. Literature Review

The existing literature underscores that VR is not only an effective educational tool, offering rich interactivity and immersive storytelling, but also a technology with inherent challenges. These include issues related to user comfort, usability, and the ethical presentation of sensitive content. Research on digital misinformation further illustrates the complexity of countering false narratives, particularly as social media continues to shape perceptions of history and contemporary events. By integrating insights from VR-based educational design, HCI principles (including hand-tracking and AI voice usage) and misinformation research, this paper seeks to offer a novel perspective on how immersive experiences can engage users while raising awareness of the impacts of misinformation.

2.1 Virtual Reality Overview

VR is a technology that creates simulated environments, enabling users to immerse themselves in digital worlds that can either replicate or radically differ from reality. Originating from early flight simulators and experimental research in the middle of the 20th century, VR has rapidly evolved due to advances in computer graphics, sensor technology, and display systems. Modern VR systems, such as the Oculus Quest series and HTC Vive, integrate Head-Mounted Displays (HMDs), motion tracking, and haptic feedback to deliver a high degree of presence and interactivity. These technological improvements have broadened VR’s application across education, training, therapy, and entertainment, making it a versatile tool for both experiential learning and immersive storytelling.

2.2 Virtual Reality in Education

VR has been widely adopted in educational contexts because of its potential for immersion, engagement, and experiential learning. Research suggests that VR learning environments promote higher retention rates and motivation compared to traditional instructional methods (Conrad, Kablitz and Schumann, 2024). Additionally, interactive roleplaying scenarios in VR have proven effective for enhancing historical understanding and empathy in learners (Yang and Boulom, 2024). Beyond interactive applications, 360-degree videos have also received attention as an immersive educational medium. A comparative study found that more immersive devices induced stronger place illusion, more positive affect, and better learning outcomes, all while minimizing simulator sickness (Rupp et al., 2019). Conversely, less immersive methods not only undermine engagement but also lead to increased simulator sickness, thereby negatively impacting user well-being and knowledge retention. Despite these benefits, integrating VR into curricula poses technical and pedagogical challenges. Many VR applications require substantial hardware resources and issues such as motion sickness could negatively affect learning outcomes. Furthermore, managing cognitive load is critical to effective VR learning experiences (Rogers and Franklin, 2021). Scholars in e-learning emphasize reducing extraneous cognitive load. That is, the burden unrelated to core learning tasks, to optimize student performance and comfort (Davids, Halperin and Chikte, 2015).

2.3 Challenges of Misinformation in Digital Media

Misinformation and extremist content have become pressing concerns in online spaces. The proliferation of social media platforms such as TikTok, Telegram, Facebook and X, facilitates rapid dissemination of unverified or polarizing information (Rogers, 2023). Research indicates that selective exposure and algorithmically reinforced echo chambers can further entrench individuals within biased viewpoints (Hameleers and Van Der Meer, 2020), (Kim, 2023). This environment could intensify the risk of historical revisionism and extremist narratives going unchallenged. While studies on misinformation typically explore algorithmic detection, user behaviour, and platform policies, relatively few have investigated how immersive media, particularly VR, could counter or inadvertently perpetuate such narratives. By transporting users into alternative virtual contexts, VR provides unique tools to encourage critical thinking and empathy (Stavroulia and Lanitis, 2019). However, designers must carefully curate content and interactions to avoid reinforcing echo chamber effects, which refer

to environments where individuals are exposed only to information that aligns with their existing beliefs, reinforcing biases and limiting diverse perspectives.

2.4 Historical Education and Collective Memory

As direct memories of major historical events fade with time, awareness of events such as the Holocaust risks the loss of details, exaggeration or reinterpretation (Bourgeois, 2020). Historical memory is a crucial component of group identity, even though it naturally evolves over time (Gvinjilia, 2023). In the context of the Holocaust and other atrocities, studies indicate that digital natives may rely on fragmented social media content for historical information, raising concerns about inaccurate or revisionist depictions (Donovan, 2022). While more research is needed, educational VR simulations have the potential to support historical education by creating immersive experiences that can help learners engage with historical content in meaningful ways. Careful design and evidence-based approaches are necessary to assess their effectiveness in preserving historical accuracy and fostering critical engagement with the past.

2.5 Hand-Tracking in VR

Hand-tracking has emerged as an intuitive and natural way to interact with virtual environments, eliminating the need for physical controllers. However, studies reveal mixed results regarding whether hand-tracking truly outperforms controllers in terms of speed and ease of use (Hameed, Möller and Perkis, 2023). For instance, some investigations have found that participants using hand-tracking did not report higher immersion or achieve better performance than those using controllers (Hameed, Möller and Perkis, 2023). (Varela-Aldás et al., 2023). Therefore, further research might be needed to investigate whether technological advancements and different hand-tracking implementations could provide benefits over controllers. Adapting guidelines from HCI literature may suggest that hand-tracking gestures need to be easily discoverable, require minimal physical strain, and map intuitively to actions. Failure to optimize these factors can contribute to extraneous cognitive load (Davids, Halperin and Chikte, 2015).

2.6 AI-Generated Voices

Voice-overs and interactive dialogue can significantly influence immersion, especially when characters or commentators guide users through educational experiences (Yang and Boulom, 2024), (Gorini et al., 2011). Although professionally recorded audio has traditionally been used, AI-generated voices are increasingly prevalent due to their cost efficiency and scalability. Research indicates that the quality and naturalness of AI voices can affect user trust, engagement, and emotional response (Choi and Zu, 2022). However, if an AI voice sounds inauthentic or robotic, it may disrupt immersion and reduce perceived credibility, thereby increasing the cognitive effort required from the listener. Moreover, studies have shown that users often cannot reliably distinguish AI-generated voices from human ones, which raises ethical and security implications (Barrington, Cooper and Farid, 2022).

3. VR Application Design

“Down the Rabbit Hole” is an interactive, story-driven experience designed to teach users about hidden extremist symbolism on social media through exploration and puzzle-solving. The application was built using the Unity game engine for the Meta Quest platform, leveraging the headset’s hand-tracking capability to allow natural interaction without physical controllers. The design draws on the metaphor of “going down the rabbit hole”, reflecting how one might unknowingly descend into extremist content online through algorithms.

Users begin the experience on an island beach, introduced by a mysterious rabbit character. The rabbit serves as a narrative guide, leading the user to an island with a cave that symbolizes the descent into the depths of extremist forums. *Figure 1 and 2* illustrate the VR environment on rabbit island, including the rabbit guide that leads the narrative.



Figure 1: Rabbit Island from above



Figure 2: Approaching Rabbit Island from the users perspective

After falling into the depths of the cave the user is confronted with a digital display showing an antisemitic meme, containing subtle references that are not immediately obvious. The user is challenged to inspect the content and identify any hidden hateful symbolism or coded messages. For example, the meme features a seemingly innocent icon of a ballpoint pen, which is a reference to a known Holocaust denial conspiracy about the usage of a ballpoint pen trying to discredit Anne Frank's diary. The immersive environment encourages the user to look closely and engage with the content, not unlike the critical observation needed in real social media browsing.

To reinforce the learning, the application includes an interactive puzzle that the user must solve after observing the social media post. For this puzzle segment, letters are scattered around interactive elements in the cave and the user must physically reach out with their hands to collect these floating letter spheres. These letter spheres only appear during interaction with educational information about the social media content and therefore make sure every piece of content is interacted with. After collecting the spheres the user assembles the letters into a word or phrase that reveals the hidden message in the extremist post. This design element turns the act of deciphering a coded message into an engaging activity. Solving the word puzzle "hidden codes" emphasizes the point of the application and what is supposed to be the key takeaway. Throughout this process, visual and audio feedback give meaning to the users' actions. A narrator voice (via an AI-generated voiceover) announces the tasks for the user, while other AI voices are used to explain the different symbolism used. The use of an AI voice allowed for easy iteration on the script in the projects scope, though care was taken to ensure the synthetic speech was clear and appropriately serious in tone.

A key design consideration was to keep interactions intuitive. Users select answers or progress through dialogue by using simple hand gestures. For example, giving a "thumbs-up" gesture in front of an option will select one answer, while a "thumbs-down" gesture would select another. A subtle gaze-based indicator (a small icon that lights-up when the user looks directly at a commenter) was implemented to help users understand what elements can be interacted with, addressing the discoverability of view-based interactions. The environment also provides continuous guidance through the rabbit character and visual as well as auditive prompts, so that even users new to VR can follow along. Figure 3 shows the educational content in the Rabbit Hole Cave, while Figure 4 shows the solving of the final code word puzzle after collecting the letter spheres.

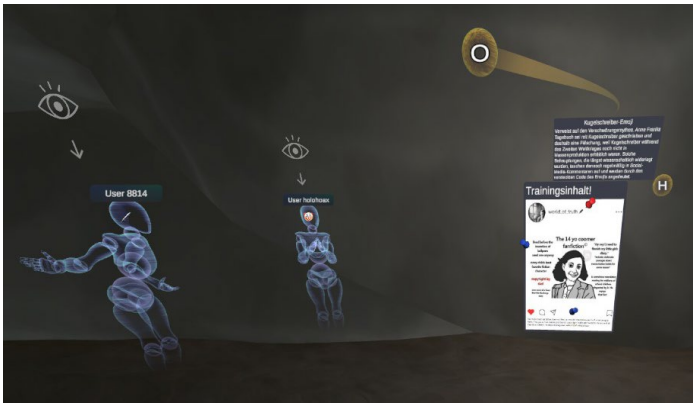


Figure 3: Interacting with social media content inside the Rabbit Hole

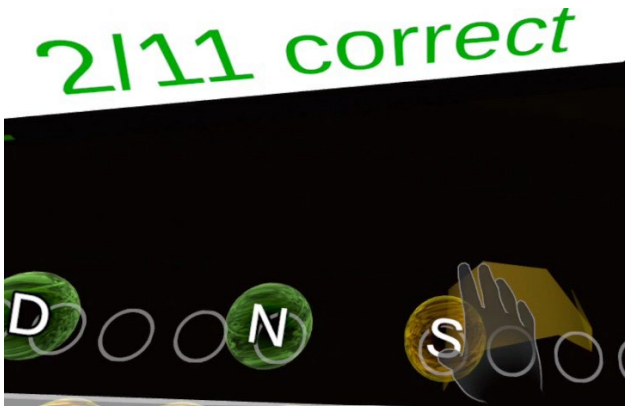


Figure 4: Solving the word puzzle

In terms of implementation, performance optimisations were applied to ensure a smooth experience on the standalone VR headset. The virtual scenes (the island shore, the cave interior, etc.) were kept relatively small and geometry was optimised, since complex graphics could reduce frame rates and possibly induce motion sickness. The overall experience was designed to last around 10–15 minutes, balancing a journey that is long enough to immerse yourself in the narrative with a duration that would not exhaust novice VR users. By the end of *the experience,* the user has interacted with a piece of extremist content, attempted to identify covert symbols, and received immediate feedback and education about those symbols. The expectation is that this immersive trial-and-error learning will help users become more alert to similar extremist cues in real online environments.

4. Methodology

An evaluation study was conducted to assess the usability and educational impact of the VR experience. A total of n=15 volunteer participants (average age of 30, 11 male and 4 female) were recruited from the university campus. Notably, about two-thirds had prior experience with VR technology (67% reported using VR more than a dozen times), while the remainder had little to no VR exposure.

Each participant took part in an individual session lasting approximately 36 minutes. Sessions began with a **pre-experience questionnaire** to collect baseline data. This questionnaire asked about demographics, prior experience with VR, and initial awareness of extremist symbolism. It also included a self-rating of confidence in identifying harmful online content. This gauged participants' baseline confidence level in spotting harmful content.

Participants were then introduced to the VR equipment (an Oculus Quest headset) and given a brief tutorial on using hand gestures for interaction. They proceeded to use the *Down the Rabbit Hole* VR application on their own, with a study facilitator observing for any technical issues and noting any commentary.

After completing the VR experience, participants filled out a **post-experience questionnaire**. This survey included quantitative measures (notably the **System Usability Scale (SUS)** for usability and Likert-scale items application and technology specific areas, like the perceived control using hand-tracking. In addition to this,

qualitative questions were collected through the questionnaire in the areas of immersion, engagement, interaction, usability and physical discomfort. To conclude the questionnaire, users had to take note of their most memorable, most enjoyable and least enjoyable moments to promote feedback on both weak and strong areas of the application.

5. Results

5.1 Pre-Study-Questionnaire

From a sample of n=15 people who completed the study, 73% or 11 out of 15 people identified as male, with an average age of 30.4. Many people had prior VR experience, with 66.7%, or 10 out of 15 people having had extensive prior experience, while 5 people had only limited or moderate experience. Most people rated themselves as somewhat knowledgeful and aware of hidden codes in social media with an average of 3.6 out of 5. In general people were confident that they could identify harmful content in social media with an average of 4.13 out of 5. Most people chose the English version of the application, while only 5 people chose to test the German version. However, every participant had to declare to be fluent in English to participate in the study.

5.2 Post-Study-Questionnaire

Overall, the VR application was well-received in terms of usability. The average SUS score from the 15 participants was **80.17** (out of 100). According to standard SUS benchmarks, a score around 80 indicates good to excellent usability, exceeding the statistical average of 70.9 as found by Bangor, Kortum and Miller (2009). Most participants navigated the experience without major issues, and no one encountered a serious technical problem that prevented completion. In terms of engagement, participants gave very high ratings. When asked to rate how engaging and fun the experience was, the mean response was **4.67 out of 5**, with 10 out of 15 participants selecting the highest agreement level. Many participants commented that they enjoyed the experience and the hand-tracking, one user noting their most enjoyable aspect as: *"Interacting with the puzzle letters. picking up the letters and watching them move to the sorting table and finally the interaction sorting the letters to form the puzzle word."* To many the experience did not feel like a lesson but more like a game, which kept their attention. A summary of key quantitative metrics from the study is provided in Table 1. In rows with a darker background the question is worded negatively. Figure 5 showing the perceived control using hand-tracking for the user, with an average result of 4.27 out of 5. Figure 6 shows the user perceived engagement and fun using the hand-tracking, with an average result of 4.67 out of 5. The sense of presence in VR was rated at an average of 4.33 out of 5. At last, the perceived quality of the AI generated voices resulted in an average rating of 4 out of 5.

Table 1: Results of the System Usability Scale Test

Question	Rating of 1	Ratings of 2	Ratings of 3	Ratings of 4	Ratings of 5	Average Ratings
Frequent use	0 (0%)	3 (20%)	2 (13.3%)	4 (26.7%)	6(40%)	3.87
Complexity	7 (46.7%)	6 (40%)	1 (6.7%)	0 (0%)	1 (6.7%)	1.8
Ease of use	0 (0%)	0 (0%)	2 (13.3%)	8 (53.3%)	5 (33.3%)	4.2
Tech support needed	4 (26.7%)	6 (40%)	2 (13.3%)	3 (20%)	0 (0%)	2.27
Function Integration	0 (0%)	0 (0%)	1 (6.7%)	4 (26.7%)	10 (66.7%)	4.6
Inconsistency	8 (53.3%)	2 (13.3%)	2 (13.3%)	2 (13.3%)	1 (6.7%)	2.07
Learnability	0 (0%)	0 (0%)	0 (0%)	9 (60%)	6 (40%)	4.4
Cumbersomeness	8 (53.3%)	3 (20%)	1 (6.7%)	3 (20%)	0 (0%)	1.93
Confidence	0 (0%)	1 (6.7%)	1 (6.7%)	3 (20%)	10 (66.7%)	4.47
Learning Required	11 (73.3%)	2 (13.3%)	2 (13.3%)	0 (0%)	0 (0%)	1.4

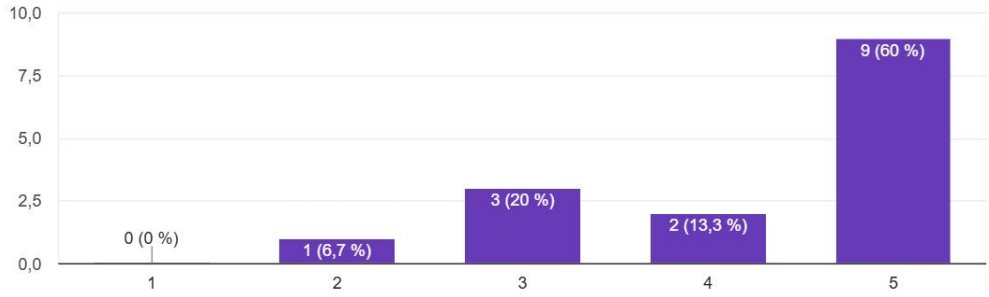


Figure 5: Perceived Control Using Hand-tracking (1 = low, 5 = high)

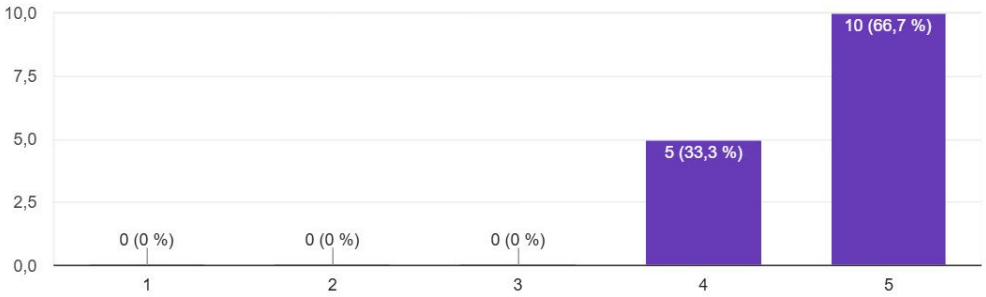


Figure 6: Engagement and Fun using Hand-tracking (1 = low, 5 = high)

5.3 Qualitative Data

In addition to the quantitative data, participants provided open-ended feedback, which was analyzed thematically to identify recurring patterns. The qualitative analysis highlighted several key themes:

5.3.1 Immersion and Engagement

Many participants described a strong sense of immersion, emphasizing how the experience felt realistic and engaging. One participant noted, “I was feeling that I am in the scene and engaging, and it is like real life." This sentiment was consistently shared in other responses.

5.3.2 Interaction and Usability

Participants expressed both appreciation and constructive feedback regarding interaction design. Many praised the intuitive nature of hand-tracking and interactive elements, as mentioned in the comment: "How easy it was to use. Really intuitive." However, some participants encountered difficulties with gesture recognition, with one stating, "Sometimes it's not clear what gestures I had to use to interact.".

5.3.3 Physical Discomfort

While the overall technical performance was well-received, specific sequences, such as the boat ride or the free-fall into the rabbit hole were mentioned by at least one participant describing a "slight nausea" in these moments. Another hinted at disliking the teleportation over long distances: "(...) movement felt a bit heavy when moving a lot.".

5.3.4 Specific Suggestions

Beyond general usability, participants provided specific feedback on interaction mechanics. One user suggested: “Hints on what object is going to be grabbed” to improve clarity.

6. Discussion

This chapter discusses the evaluation results of the interactive VR experience designed to improve digital literacy about extremist symbolism on social media. The findings offer insights into usability, hand-tracking interactions, AI-generated voices, educational impact, immersion, and overall user engagement.

The SUS score of 80.17 indicates good usability, with high ratings for system integration, ease of learning, and user confidence. However, lower scores for Frequent Use suggest the application is currently perceived as limited, highlighting areas for expanding content and improving gesture controls, guidance, and consistency.

Hand-tracking received mixed feedback. Participants appreciated its intuitiveness and immersion but noted issues with gesture accuracy. Users who experienced better gesture recognition and perceived control reported higher engagement and fun ($r = 0.898$, $p < 0.001$; $\beta = 0.424$, $p < 0.001$). This strong correlation indicates that refining gesture precision could significantly enhance user satisfaction.

AI-generated voices were generally well received, though German voices were rated slightly lower than English voices. Despite occasional unnatural pronunciations, statistical analysis showed no significant perceived quality difference between languages. An intriguing finding was a strong negative correlation between voice quality and motion sickness ($r = -0.76$, $p = 0.00095$), suggesting that voice naturalness may influence user comfort or vice versa.

While specific educational impact data was not collected, participants praised the realistic integration of hidden extremist codes. Reactions to the authenticity of the content varied greatly based on individual perspectives, which would fit the polarized self-assessments of individuals abilities to identify hidden codes in social media as seen in Figure 7.

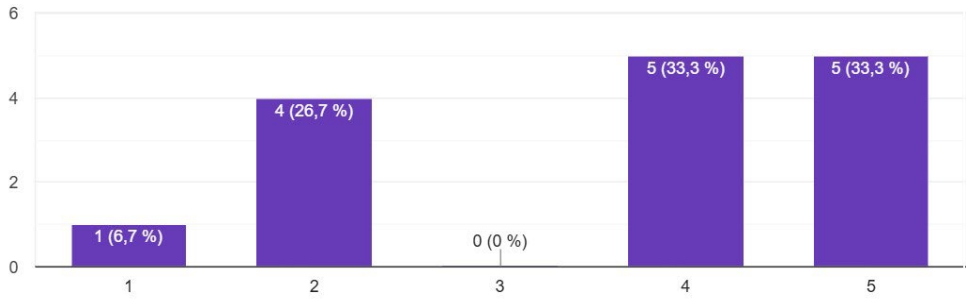


Figure 7: Self-Assessed awareness of hidden codes in social media (1 = low, 5 = high)

Immersion was generally high, although some users experienced discomfort during intensive movement sequences, such as boat rides or falls. This suggests optimizing navigation methods could further enhance comfort and presence.

Overall, the VR experience effectively engaged users through interactive elements like hand-tracking and puzzles, reinforcing the potential of VR for educational applications and engagement, as supported by qualitative feedback and existing literature.

7. Conclusion

This study investigated how a hand-tracking-based VR application could enhance engagement and enjoyment in digital literacy education. Findings showed users found the application generally engaging and intuitive, with precise and responsive hand-tracking significantly contributing to higher engagement. AI-generated voices were positively received, with no significant quality differences between languages, although a notable link between voice quality and motion sickness emerged, requiring further investigation.

Overall usability was highly rated, but participants identified challenges in gesture recognition accuracy and occasional system inconsistencies. Addressing these along with optimizing motion comfort settings would enhance accessibility and ease of use.

The research contributed to the VR education field by demonstrating that effective hand-tracking significantly boosts user engagement, highlighting AI-generated voices as efficient tools, and underscoring the need for further exploration into voice quality and motion sickness. The study also emphasized the importance of

expanding digital literacy education and offered practical insights for future misinformation awareness applications.

Limitations included the small sample size and limited content within the prototype, restricting the generalizability and depth of long-term educational impact evaluation. Future research should involve larger and more diverse participant groups, test additional interaction methods like voice commands or controllers, and investigate AI-voice quality's impact on comfort more comprehensively.

Application improvements suggested by participants include better grab interactions for precise control, reducing forced motion sequences to mitigate discomfort, clearer in-app guidance to enhance usability, refining the gaze-based interaction system used for the virtual commenters, and expanding educational content for comprehensive knowledge assessment.

After all, continued refinement of usability and interaction mechanisms is an important step not only in developing educational VR applications, but any application and can undermine the intended purpose of the application if not addressed.

Ethics Statement

No specific ethical clearance was required for this project and study. All participants were adults who provided informed consent prior to participation. All data was anonymised to protect participants' privacy.

AI Statement

Some sections such as the abstract started as the bare structure of a summarized draft of the more detailed thesis this paper is based on. Any paragraphs that are based on the structure of an AI draft have been rewritten for coherence and factuality and extensively proofread to produce a qualitative result.

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A Synthesis of e-Learning Research Topics: A Qualitative Content Analysis

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Abstract: Because of the prevalence and improvements in digital technology, e-learning is now commonly delivered in various delivery modes, including online, blended, and mobile learning. Over the years, extensive research on e-learning has explored diverse topics, ranging from instructional design to digital skills, student-centred learning, and so on. Given the ever-expanding body of literature, there is an essential need to systematically synthesise the vast research topics on e-learning. This study addresses this need by conducting a qualitative content analysis of primary empirical articles on e-learning that were published in the Electronic Journal of e-Learning (EJEL) from its first issue in 2003 to 2024. The primary objective of this study is to examine the research foci of these articles to identify key research topics, thereby providing a thorough review of e-learning research over the last two decades. The study findings suggested six main categories of research topics: (1) user experience, (2) learner attributes, (3) learning outcomes, (4) teaching and learning, (5) adoption barriers, and (6) educator preparedness. The findings also showed that the six main categories could be further divided into 21 subcategories. These topics reflect a broad range of e-learning research across pedagogical, technological, and sociocultural dimensions. By synthesising e-learning research over the past two decades in EJEL, this study adds to the cumulative body of knowledge on research topics that have shaped the research landscape in e-learning, as well as reveals potentially underexplored areas.

Keywords: Digital Technology, Educational Research, E-learning, Qualitative Content Analysis, Research Synthesis

1. Introduction

The widespread accessibility of the internet, as well as the prevalent adoption of digital technology such as computers and smartphones, has fuelled the growth of e-learning (Ghali and Amari, 2024). In contrast to face-to-face learning, e-learning provides learners the opportunity to learn outside of physical constraints, such as time and location (Chaw and Tang, 2019; Cronje, 2022). However, compared to face-to-face learning, e-learning requires different pedagogical approaches, learning designs, and assessment strategies for effective knowledge transfer and skill development (Almasri, 2022; Gasmi and Bouhadada, 2023; Rabayah and Amira, 2022).

Previous studies have investigated diverse research topics on e-learning. As the body of literature grows, some studies have attempted to synthesise e-learning research to classify themes or research topics. Some of these studies extend back to the early 2000s (e.g., Cronje, 2014; Hung, 2012; Lin and Hu, 2015; Maurer and Khan, 2010). Some of the more recent studies include Brika et al.'s (2022) bibliometric analysis of 602 e-learning articles from 2020 to 2021; Pathak and Singh's (2023) bibliometric analysis of 417 e-learning articles from 2020 to 2023; and Peters et al.'s (2022) scoping review of 291 articles from 2015 to early 2020 by authors affiliated with the Universitat Oberta de Catalunya. However, relying solely on bibliometric analysis that primarily focuses on publication metadata or only articles published by authors affiliated with a single university limits the breadth and depth of the analysis.

To address this research gap, this study conducted a qualitative content analysis of primary empirical articles published in the Electronic Journal of e-Learning (EJEL) from its first issue in 2003 to 2024. The objective of this study is to address the research gap by providing a more extensive and up-to-date synthesis of research topics on e-learning. This study adds the recent findings to the cumulative body of knowledge in e-learning research and provides educators, researchers, and policymakers with useful insights into the current state and future directions of e-learning research. Furthermore, this study supports the assertions by Brika et al. (2022), Pathak and Singh (2023), and Peters et al. (2022) that such a study can help identify research synergies and gaps for future e-learning research.

The remainder of this paper provides a background to the research, explains the research design and method, presents the study findings, and concludes with a discussion of the study findings.

2. Research Background

2.1 E-Learning

Unlike face-to-face learning, e-learning provides learners with the flexibility and accessibility to learn at their own pace and from anywhere (Gashi et al., 2024). The wide availability of internet connectivity and developments in technology have contributed to the increasing growth of e-learning (Paiva et al., 2016). Although technology is an integral part of e-learning (Paiva et al., 2016), Andrews and Haythornthwaite (2007) posit that e-learning is more than just using technology to deliver content; it also involves social elements such as interaction and collaboration. They further explain that these elements highlight the sociotechnical characteristics of e-learning, particularly what and how people use technology for teaching and learning.

E-learning evolves with time, as do technology and how learners, educators, and educational institutions use them in teaching and learning (Andrews and Haythornthwaite, 2007). Today's e-learning technology includes such examples as learning management systems (LMS) (e.g., Blackboard, Moodle), video conferencing tools (e.g., Zoom, Microsoft Teams), online collaboration tools (e.g., Google Docs, Padlet), multimedia tools (e.g., YouTube, Canva), and so on.

E-learning can be delivered through various modes, including online, blended, and mobile learning. Online learning delivers learning through the internet. Learners access learning materials, including learning activities and assessments, through digital platforms like LMS. However, learners need strong self-regulation and proficiency in digital skills to be comfortable in this type of online learning environment (Kwiatkowska and Wiśniewska-Nogaj, 2022; Wolverton et al., 2020). Blended learning integrates both face-to-face and online learning, supplementing face-to-face learning with the flexibility and accessibility of online learning. This mixed mode of learning promotes student-lecturer and student-student interactions, especially for social learning or hands-on activities (Najjemba and Cronjé, 2020; Suriagiri et al., 2022). Mobile learning engages learners through mobile apps using devices such as smartphones or tablets and often supports microlearning and gamification to enhance learner engagement (Kohnke, 2021; Mohtar et al., 2023).

2.2 Research Topics in E-learning

E-learning research covers a wide range of topics because it is cross-disciplinary, linking such fields as social science, cognitive science, and technology (Brika et al., 2022; Hung, 2012; Peters et al., 2022), as well as heterogeneous, investigating largely issues that are context-dependent and multifaceted (Rüth and Kaspar, 2017; Sarsa and Escudero, 2016).

Conole and Oliver (2007) identify four main themes in e-learning research: pedagogical, technical, organisational, and sociocultural issues. Pedagogical issues refer to the pedagogy of e-learning, such as learning designs, digital skills, online communities, including communication and collaboration, etc. Technical issues concern the technology in e-learning, such as technical architectures, e-learning platforms, technological developments, etc. Organisational issues relate to factors that arise at the organisational level, such as strategies for integration, organisational processes, roles and functions, etc. Sociocultural issues include the broader context that influences pedagogical, technical, and organisational issues, such as legislative requirements, policy drivers, institutional approaches and cultures, etc.

Previous studies have attempted to classify themes or research topics in e-learning. Some of the recent studies include those by Brika et al. (2022), Pathak and Singh (2023), and Peters et al. (2022). Brika et al. (2022) indicated nine clusters: motivation and students' attitudes to e-learning systems; comparison between blended learning and virtual learning; online assessment versus formative assessment; stress, anxiety, and mental health of students; education strategies to develop students' skills; quality and performance of higher education strategies of e-learning; challenges of medical education and distance learning; changing higher education curricula using technology; and using artificial intelligence to transform e-learning. Pathak and Singh (2023) highlighted five clusters: research methods; self-serving technological features; user interactivity in an online environment; COVID-19 and challenges; and collaborative learning. Peters et al. (2022) reported seven themes: design and evaluation of learning resources; learning analytics and automatisation; e-learning adoption; innovative pedagogies and technologies; student or teacher learning practices or performances; assessment and feedback; and collaboration and interaction.

3. Research Design and Method

3.1 Qualitative Content Analysis

This study conducted a qualitative content analysis (QCA) to identify the research topics in the article texts by categories and subcategories (Mayring, 2014; Schreier, 2012). QCA systematically reduces large volumes of textual data by employing a coding frame for coding and categorisation (Schreier, 2012). QCA is well-suited to this study, as it is useful for the examination of patterns in the research topics.

3.2 Database and Article Screening

This study downloaded articles published from Vol. 1, No. 1, in 2003 to Vol. 22, No. 10, in 2024 from the online archive of the EJEL. The search resulted in a total of 640 articles. The initial screening and the subsequent full paper screening filtered out 356 articles and 26 articles that did not meet the inclusion criteria, respectively. Therefore, this study included 258 articles in the final analysis. Figure 1 depicts the flow diagram of the article screening process and the exclusion criteria.

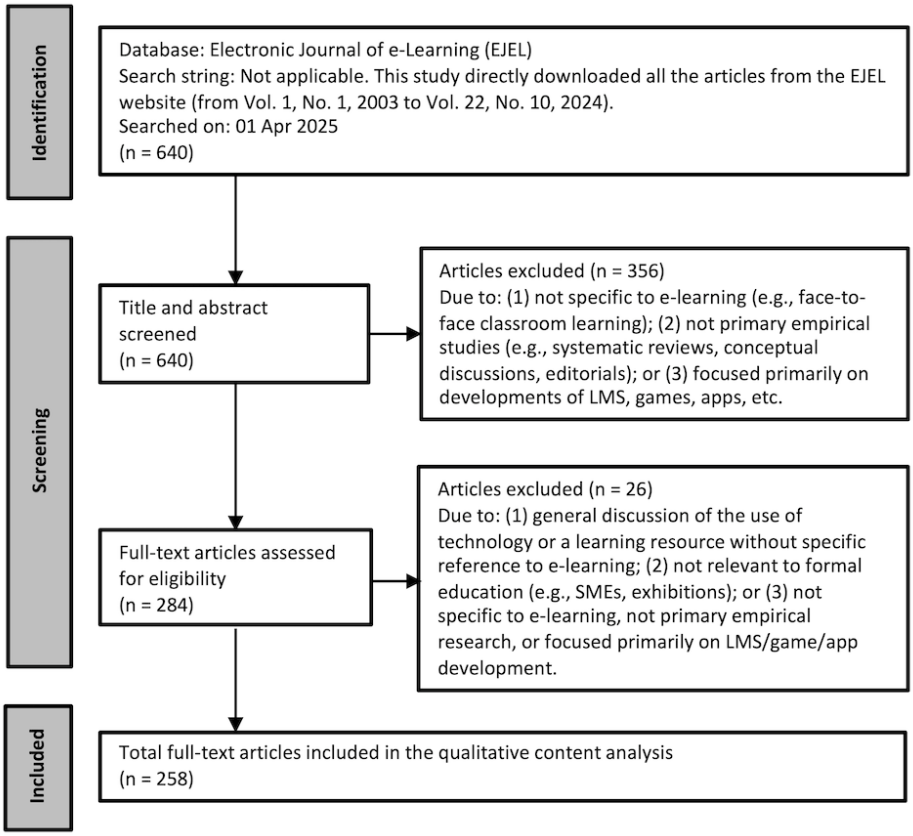


Figure 1: Flow diagram of the screening process (adopted from the PRISMA 2020 statement, Page et al., 2021)

3.3 Data Analysis

This study followed Schreier's (2012) recommended steps for QCA: (1) created a preliminary two-level coding frame from a random sample of 40 articles (about 15% of the 258 articles) using a data-driven approach; (2) segmented the article texts that were relevant to the articles' research scope into coding units; (3) conducted two rounds of trial coding in a pilot phase to evaluate the reliability of the coding frame; and (4) carried out the main analysis.

Each of the two rounds of trial coding included a random sample of 40 articles. To maintain coding consistency, the coding was done by a single coder with a two-week gap in between, as recommended by Schreier (2012). After the two rounds of trial coding, some revisions were made to the coding frame, including merging, removing, or renaming some subcategories. Between the two rounds, the percentage of agreement was 88.51%

(i.e., the number of coding units on which the coder agreed divided by the total number of coded units). Thus, the intra-coder reliability was satisfactory.

Figure 2 depicts the final coding frame that was used in the main analysis, which consisted of six level-one categories and 21 level-two subcategories. The level-one categories represent the main dimensions, and the level-two subcategories represent the subdimensions. The coding frame satisfied four methodological requirements: unidimensionality, mutual exclusiveness, exhaustiveness, and saturation (Schreier, 2012). In QCA, a coding unit can be coded into more than one subcategory. However, a coding unit cannot be coded to more than one subcategory within the same category.

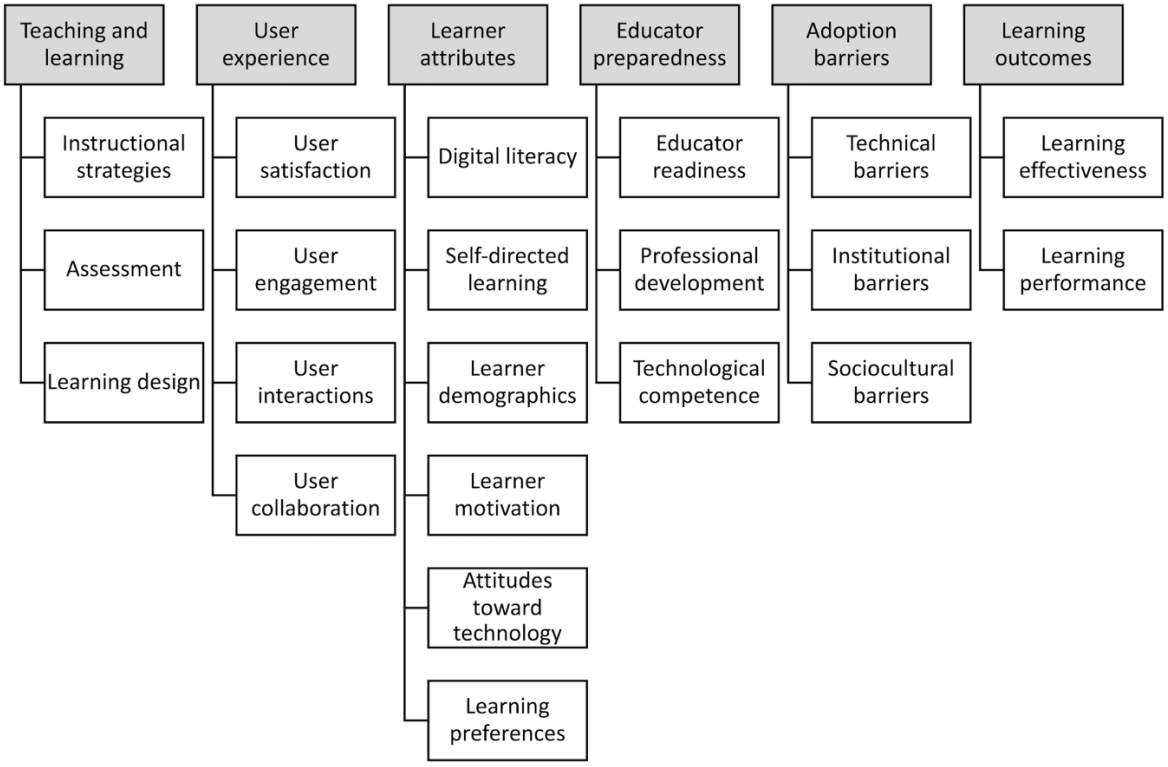


Figure 2: Coding frame

4. Study Findings

Table 1 shows the frequency and percentage of coding units coded into subcategories. The top five subcategories in order of frequency are user engagement (10.1%), learning effectiveness (10%), learning design (8.9%), learning performance (8.9%), and attitudes toward technology (5.6%). The bottom five subcategories are digital literacy (2.7%), learning preferences (2.7%), sociocultural barriers (2.7%), technological competence (2.5%), and professional development (1.9%).

Table 1: Frequency and percentage of coding units coded into a subcategory

Subcategory	Frequency	Percentage (%)
User engagement	74	10.1%
Learning effectiveness	73	10.0%
Learning design	65	8.9%
Learning performance	65	8.9%
Attitudes toward technology	41	5.6%
Learner demographics	35	4.8%
User satisfaction	33	4.5%
User collaboration	33	4.5%

Subcategory	Frequency	Percentage (%)
User Interactions	32	4.4%
Educator readiness	31	4.2%
Learner motivation	29	4.0%
Technical barriers	29	4.0%
Instructional strategies	28	3.8%
Assessment	27	3.7%
Institutional barriers	24	3.3%
Self-directed learning	21	2.9%
Digital literacy	20	2.7%
Learning preferences	20	2.7%
Sociocultural barriers	20	2.7%
Technological competence	18	2.5%
Professional development	14	1.9%
Total	*732*	*100.0%*

Table 2 shows the frequency and percentage of coding units coded into a subcategory both within and across categories. Across categories, user experience is the largest category (23.5%), followed by learner attributes (22.7%), learning outcomes (18.9%), teaching and learning (16.4%), adoption barriers (10%), and educator preparedness (8.6%). Within individual categories, user engagement (43%), attitudes toward technology (24.7%), learning effectiveness (52.9%), learning design (54.2%), technical barriers (39.7%), and educator readiness (49.2%) were the top subcategories in the user experience, learner attributes, learning outcomes, teaching and learning, adoption barriers, and educator preparedness categories, respectively.

Table 2: Frequency and percentage within and across categories

Category	Subcategory	Frequency	Within Category Percentage (%)	Across Category Percentage (%)
User experience	User engagement	74	43.0%	
	User satisfaction	33	19.2%	
	User collaboration	33	19.2%	
	User Interactions	32	18.6%	
	Subtotal	*172*	*100.0%*	*23.5%*
Learner attributes	Attitudes toward technology	41	24.7%	
	Learner demographics	35	21.1%	
	Learner motivation	29	17.5%	
	Self-directed learning	21	12.7%	
	Digital literacy	20	12.0%	
	Learning preferences	20	12.0%	
	Subtotal	*166*	*100.0%*	*22.7%*
Learning outcomes	Learning effectiveness	73	52.9%	
	Learning performance	65	47.1%	
	Subtotal	*138*	*100.0%*	*18.9%*
Teaching and learning	Learning design	65	54.2%	
	Instructional strategies	28	23.3%	
	Assessment	27	22.5%	

Category	Subcategory	Frequency	Within Category Percentage (%)	Across Category Percentage (%)
	Subtotal	*120*	*100.0%*	*16.4%*
Adoption barriers	Technical barriers	29	39.7%	
	Institutional barriers	24	32.9%	
	Sociocultural barriers	20	27.4%	
	Subtotal	73	100.0%	10.0%
Educator preparedness	Educator readiness	31	49.2%	
	Technological competence	18	28.6%	
	Professional development	14	22.2%	
	Subtotal	*63*	*100.0%*	*8.6%*

5. Discussion and Conclusions

The study findings reflect nearly two decades of research topics on e-learning in EJEL, with six main categories emerging: (1) user experience, (2) learner attributes, (3) learning outcomes, (4) teaching and learning, (5) adoption barriers, and (6) educator preparedness. Within the main dimensions, there are 21 subdimensions.

The largest main dimension is user experience, accounting for nearly a quarter of all coded units. This dimension encompasses learners' and educators' interactions with technology and learning environments across four subdimensions: (1) user engagement (such as behavioural and cognitive involvement in e-learning activities) (e.g., Cui and Coleman, 2020; Sadeck et al., 2023); (2) user satisfaction (such as subjective evaluation of e-learning experience) (e.g., Cação, 2017; Wolverton et al., 2020); (3) user collaboration (such as group-based collaborative learning) (e.g., Barber and King, 2016; Cronje and van Zyl, 2022; Straková and Cimermanová, 2018); and (4) user interactions (such as learner-learner and learner-instructor interactions) (e.g., Elizondo-Garcia and Gallardo, 2020; Xiu and Thompson, 2020). Among these, user engagement is the largest subdimension.

The second largest main dimension is learner attributes, accounting for just under a quarter of all coded units. This dimension captures learners' characteristics across six subdimensions: (1) attitudes toward technology (such as beliefs or feelings about digital tools) (e.g., Al Arif et al., 2024; Chan et al., 2015; Fauzi et al., 2021); (2) learner demographics (such contextual factors as cultural background and prior experience) (e.g., Chaw and Tang, 2023; Kurtz et al., 2022; Luef et al., 2019); (3) learner motivation (such as intrinsic or extrinsic drivers for engagement) (Berestova et al., 2022; Eltahir and Babiker, 2024; Valdez and Maderal, 2021); (4) self-directed learning (such as initiative and responsibility for one's own learning) (e.g., Adinda and Mohib, 2020; Akinyi et al., 2024; Sadeck et al., 2023); (5) digital literacy (such as competence and proficiency in technology) (e.g., Hall et al., 2013; Kwiatkowska and Wiśniewska-Nogaj, 2022; Tang and Chaw, 2016); and (6) learning preferences (such as preferred modes of learning) (e.g., Al-Azawei and Lundqvist, 2015; Chaw and Tang, 2023; Garthwait, 2014). Among these, attitudes toward technology is the largest subdimension.

The third largest main dimension is learning outcomes, accounting for nearly one-fifth of all coded units. This dimension evaluates results from the learning process across two subdimensions: (1) learning effectiveness (such as perceived quality and goal attainment of the learning process) (e.g., Bentley et al., 2012; Oluwadele et al., 2024; Tang and Chaw, 2016) and (2) learning performance (such quantifiable achievements as test scores and completion rates) (e.g., Cui and Coleman, 2020; Eltahir and Babiker, 2024; Kurtz et al., 2022). Both subdimensions are largely comparable in size.

The fourth largest main dimension is teaching and learning, accounting for just over one-sixth of all coded units. This dimension examines the planning, execution, and evaluation of learning delivery across three subdimensions: (1) learning design (such as learning outcomes, activities, and resources) (e.g. Adinda and Mohib, 2020; Elizondo-Garcia and Gallardo, 2020; Oluwadele et al., 2024); (2) instructional strategies (such as pedagogical approaches for learning delivery) (e.g., Barber and King, 2016; Charbonneau-Gowdy and Galdames, 2024; Cui and Coleman, 2020); and (3) assessment (such as formative and summative evaluation methods) (e.g., Dominguez-Figaredo et al., 2022; Nakayama et al., 2010; Valdez and Maderal, 2021). Among these, learning design is the largest subdimension.

The fifth largest main dimension is adoption barriers, accounting for about one-tenth of all coded units. This dimension highlights the challenges and obstacles that can hinder e-learning adoption across three subdimensions: (1) technical barriers (such as technology infrastructure and internet access) (e.g., Ahmed et al., 2018; Berestova et al., 2022; Weber et al., 2014); (2) institutional barriers (such as organisational policies and resource allocation) (e.g., Delgaty, 2017; MacKeogh and Fox, 2009; Roushan et al., 2016); and (3) sociocultural barriers (such as cultural or societal norms) (e.g., Ahmed et al., 2018; Charbonneau-Gowdy, 2018; Eppard et al., 2021). Among these, technical barriers is the largest subdimension.

The sixth largest main dimension is educator preparedness, accounting for just under one-tenth of all coded units. This dimension examines the capacities needed for effective e-learning adoption across three subdimensions: (1) educator readiness (such as willingness, confidence, and openness to adopt technology) (e.g., Greener and Wakefield, 2015; Kyalo and Hopkins, 2013; MacKeogh and Fox, 2009); (2) technological competence (such as proficiency with digital tools) (e.g., Almpanis, 2015; Greener and Wakefield, 2015; Kyalo and Hopkins, 2013); and (3) professional development (such as training programmes and continuous learning opportunities) (e.g., Almpanis, 2015; Greener and Wakefield, 2015; Kyalo and Hopkins, 2013). Among these, educator readiness is the largest subdimension.

In conclusion, the study findings help meet the research objective and fill in the research gap with a more extensive and up-to-date synthesis of research topics on e-learning. These findings indicate the areas that have received greater attention and those that may be further explored for a deeper understanding of the digital transformation of learning, from its design, planning, and implementation to continuous improvement. In addition, as technology advances and learners' digital literacy improves, it may be necessary to revisit some well-researched areas for updates in today's educational, technological, and sociocultural context.

Ethics and AI Declaration

This study did not require ethics approval as it involved only a literature review of articles published in EJEL, and the use of AI was mainly for preliminary searches and grammatical checks.

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From Nervous to Noteworthy: Evaluating SPEAKS, An Educational Software for Speech Content

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Abstract: Public speaking is a critical competency for professionals, yet many higher education graduates lack sufficient training in this area. While educational institutions offer public speaking courses, these often cannot provide the level of individualized support students need as this would be too resource-intensive. Although various software tools exist to bridge this gap by supporting students with aspects such as non-verbal communication and slide design, there is a notable lack of tools that assist with the preparation of speech content—a key component of effective public speaking. To address this gap, we developed SPEAKS (Speech content Preparation for Effective and Authentic Knowledge Sharing), an educational application that guides students through preparing speech content while teaching them how to do so effectively. SPEAKS uses a scripted, chat-based interaction with a humorous and empathetic cockatoo character, who leads users step by step through seven stages of speech preparation. These include defining audience knowledge, setting learning goals for the audience, crafting engaging introductions, and ensuring coherence between the introduction and conclusion. The tool is grounded in public speaking pedagogy and expert interviews with 13 public speaking instructors, which informed both the instructional content and the design principles. We conducted a user study with 17 participants to evaluate SPEAKS in terms of perceived usability, perceived usefulness, perceived learning, and its impact on public speaking-related confidence. The results show that SPEAKS is easy to learn and use, and participants found its guidance-based support helpful for preparing speech content. Importantly, users reported a significant increase in their confidence to deliver a good speech after using the tool. Qualitative feedback further confirmed the tool's usability and highlighted its strengths in supporting structured content development. Participants also identified areas for improvement, which can inform future iterations of the application. Overall, the findings suggest that guidance-based software like SPEAKS can effectively supplement traditional public speaking training by addressing the often-overlooked aspect of content preparation, especially in contexts where in-person resources are limited.

Keywords: Public Speaking Competencies, Speech Content Preparation, Educational Technology

1. Introduction

Communication competencies are considered one of the core competencies that higher education graduates should acquire (Morreale, 2015). However, many graduates lack communication competencies (Chan, 2011). To address this issue, higher education institutions mainly provide courses focused on public speaking (LeFebvre and LeFebvre, 2020). However, for courses to be successful at teaching public speaking competencies, students need to practice a lot while receiving guidance and feedback. This is quite time- and resource demanding, which is why students do not receive as much support as they would need (Barrett et al., 2022).

Software supporting students to increase their public speaking competencies could help. There has been a significant amount of research on such software systems. Many of these systems video- and audio-record the user while they train their speech and provide feedback on their non-verbal communication (Roque et al., 2019; Ochoa et al., 2018; Schneider et al., 2016). Some systems also give feedback on the design of slides, e.g. on the font size, amount of text or graphics (Echeverria et al., 2015; Luzardo et al., 2014). Additionally, some systems aim to audio-record the presentation and give feedback on verbal communication, e.g. on the used syntax or whether all topics the user planned to present have been mentioned (Chen et al., 2014; Trinh et al., 2017).

Another important aspect in public speaking is speech content. However, to the best of our knowledge, research on software supporting the preparation of the content is limited. Therefore, we developed SPEAKS (``Speech content Preparation for Effective and Authentic Knowledge Sharing''), an educational application with the aim to guide users through the process of preparing the content of a speech. SPEAKS was informed by expert interviews, public speaking literature, and prior work on software support. In this paper, we present the user

evaluation of the first version of SPEAKS. This paper presents a user evaluation with 17 participants, focusing on usability, perceived usefulness, confidence gains, and qualitative feedback on their experience and usage.

The contribution of this paper is to present how users use and perceive SPEAKS, a new tool that guides students through the preparation of speech content while educating them.

2. SPEAKS "Speech Content Preparation for Effective and Authentic Knowledge Sharing"

SPEAKS is an educational app for speech content preparation. It follows a guidance-based approach with a scripted chat-based interaction where a cockatoo takes users by the hand and leads them step by step through the process of preparing the content of their speech. The key objectives of SPEAKS are to help users structure their speeches effectively, to teach them important lessons related to speech content preparation and to mitigate public speaking anxiety (PSA) in this context. Screenshots of SPEAKS can be found in Figure 1.

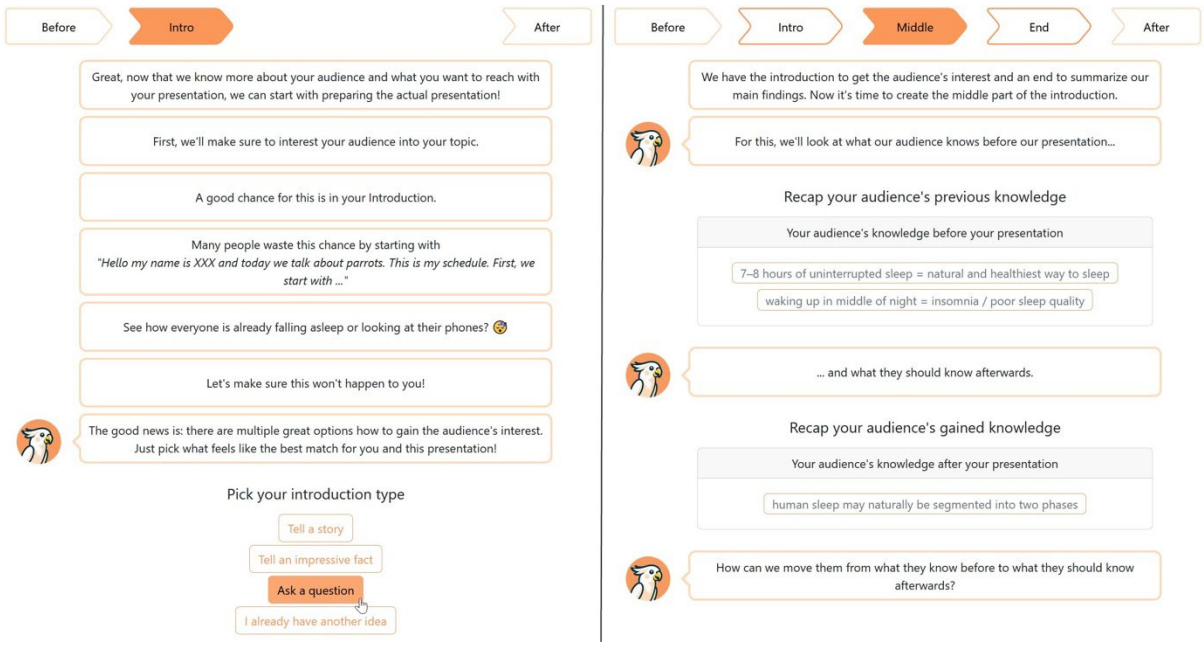


Figure 1: Screenshots of the software SPEAKS: steps *4) Introduction* and *6) Middle*.

2.1 Design Principles and Pedagogical Approach

SPEAKS is designed based on existing research in public speaking education, as well as a preliminary research in which we interviewed 13 public speaking teachers. In these interviews, we extracted information on speech preparation, public speaking best practices, and teachers' ideas and concerns regarding software intended to support students to become better at public speaking. The interviews allowed us to extract lessons SPEAKS should teach, and design principles to foster effective learning in the unique context of public speaking. Those will be explained in the following.

2.1.1 Speech Content Preparation Lessons Taught

While SPEAKS guides the user through the preparation of the presentation content, its objective is to teach the following three aspects. First, an effective speech should be adapted to the audience's previous knowledge, allowing the speaker to connect with what they already know and guide them toward new insights. Second speakers should use the introduction to gain the audience's attention. SPEAKS offers strategies on how to do that effectively. Finally, SPEAKS aims to teach that the conclusion of the presentation should match the introduction and reinforce the main points of the speech. These lessons are based on expert interviews as well as on common elements of public speaking evaluation rubrics (Van Ginkel et al., 2017; Schreiber et al., 2012; Morreale et al., 2007).

2.1.2 Observational Learning

Experts emphasized the importance of observational learning in public speaking education, expressing concerns that it might be lost in software-based approaches. Therefore, the whole interaction with the cockatoo is designed to follow the principles of effective presentations drawn from expert interviews and public speaking rubrics (Schreiber et al., 2012; Van Ginkel et al., 2017; Morreale et al., 2007; Broeckelman-Post et al., 2020). A running example in which the cockatoo appears to plan a speech alongside the user further supports observational learning

2.1.3 Encouraging Authenticity and Individuality

Beyond observational learning, interviews with public speaking teachers highlighted the importance of authenticity and individuality. Teachers were concerned that software supporting students during the speech preparation might lead to all students having a similar "robot-like" speaking style. To counter this, SPEAKS explicitly encourages authenticity and individuality by offering varied introduction options and encouraging users to choose what best suits their style and context. The cockatoo's running example is then also adapted based on the user's choice.

2.1.4 Mitigating Public Speaking Anxiety

Public speaking anxiety (PSA) is common (Richmond et al., 2013; Barrett et al., 2022). While some applications focus on PSA reduction (Valls-Ratés et al., 2023; Wang et al., 2020; Schneider et al., 2018; Bubel et al., 2016), and research offers elaborate procedures for its mitigation (Richmond et al., 2013; Bodie, 2010), SPEAKS is not specifically designed for PSA reduction. However, given its significance, we integrated subtle elements that may help alleviate PSA during speech preparation. To counter negative self-focused thoughts which are key contributors to PSA (Schulz et al., 2008; Vîslă et al., 2013), SPEAKS utilizes humour, praise and positive reinforcement. It also emphasizes that public speaking skills are learnable, which is linked to lower PSA and better performance (Nordin and Broeckelman-Post, 2019). Lastly, the cockatoo's humorous, empathetic personality aims to increase user comfort, reflecting findings that sociable virtual coaches improve user satisfaction (Wang et al., 2020).

2.1.5 Cognitive Load Management

As multiple experts described speech preparation as cognitively demanding, SPEAKS aims to reduce cognitive load by breaking speech preparation down into a step-by-step process. At each stage, only the information relevant to that step is shown to prevent overload.

2.2 Technical Implementation

SPEAKS was built using Vue.js and deployed via GitLab Pages, allowing participants to access it through their browsers on personal devices. The chatbot interaction was fully scripted, users could only enter their presentation topic, select an introduction type, and provide bullet-point plans for each section of their presentation and for the initial reflection on their audience and presentation goals.

We intentionally kept the technical design simple, as the interviewed presentation teachers preferred straightforward, interactive guidance over technically complex solutions. This study also aimed to test whether users would find such a technically simple yet carefully designed tool useful.

SPEAKS stores all data only locally on the user's device. This approach was chosen both for ease of implementation and to support a privacy-first design philosophy, where users retain full control over their data. In this study, participants were asked to download their presentation and usage data and upload it during the survey. However, in general use, SPEAKS can function without an internet connection, and no data is collected unless users choose to share it.

2.3 Speech Preparation Steps in SPEAKS

Overall, SPEAKS consists of seven different steps: *1) Welcome, 2) Audience Before, 3) Audience Afterwards, 4) Introduction, 5) End, 6) Middle, 7) Summary*. These steps will be explained in more detail in the following.

In *1) Welcome*, the cockatoo starts the interaction with a question, explains the source of the app's knowledge to build credibility, and asks for the user's topic. In *2) Audience Before* users reflect on their audience's prior

knowledge and record it. Afterwards, in *3) Audience Afterwards*, they define what their audience should learn. By this, the user is setting the goals for their presentation in a practical way. Next, users begin content planning. In *4) Introduction*, the purpose of the introduction (getting the audience's attention) is explained in an interesting way. Multiple ways to start the speech (e.g. telling a story, starting with an impressive fact, or asking a question) are offered, each with examples and guidance. Users are encouraged to choose the one that best matches them and their presentation and then outline their introduction in bullet points. In *5) End*, users plan their conclusion. The purpose of this order is to ensure that the introduction and end of the speech are connected and to ensure coherence. SPEAKS displays the introduction the user created previously and asks them to close the loop to their introduction. It also shows the intended audience takeaways from *3) Audience Afterwards*, emphasizing these as the main points of the speech to be briefly repeated in the conclusion. In *6) Middle,* users prepare the middle part of their presentation. In this step, the user is asked to recap what they previously wrote about the audiences' previous knowledge and the knowledge gained through the speech. Then, they should design the middle part as a bridge between both. Finally, in *7) Summary* SPEAKS presents a overview of the whole presentation the user created (the bullet points entered in *4) Introduction*, *6) Middle* and *5) End*).

3. Method

3.1 Purpose

The purpose of this study is to evaluate how users use and perceive SPEAKS, an educational tool designed to support students in preparing more efficient content for their speeches. By guiding users through the content preparation process, the tool aims to enhance the effectiveness of students' speeches and their public speaking competencies. To evaluate SPEAKS, we defined the following research questions:

RQ1: What is the perceived general user experience of SPEAKS?

RQ1a: What is the perceived usability of SPEAKS?

RQ1b: What is the perceived usefulness of SPEAKS?

RQ1c: What is the perceived learning when using SPEAKS?

RQ2: How does using SPEAKS affect users' confidence in delivering an elevator pitch?

For RQ1, the intention is to look at user experience as a key factor to create a good technological intervention which at one point can support presentation competencies training. Additionally, as confidence is crucial for public speaking but at the same time public speaking anxiety is a common problem, RQ2 focuses on the effects of SPEAKS on users' confidence.

3.2 Participants

The study involved 17 participants who were attending a summer school for researchers in the field of educational technology. All participants voluntarily chose to participate in a workshop on presentation competencies during which the newly developed educational tool was introduced and evaluated. The participants ranged in age from 26 to 54 years (M = 34.2, SD = 8.4) with self-reported gender distribution of 3 male and 14 female.

3.3 Procedure

The study took place during a workshop on presentation competencies. Participants were welcomed, introduced to the research project behind SPEAKS, and informed about the study procedure. Participants could ask questions and signed an informed consent. Afterwards, they filled out the pre-test questionnaire (see Section Apparatus and Material). Next, participants used SPEAKS to create a three to five minute elevator pitch about their research topic with other participants of the summer school as their target audience. After completing preparing their speech content with SPEAKS, the participants filled out the post-test questionnaire. An overview of this procedure can be found in Figure 2.



Figure 2: Overview of the procedure of the experiment

3.4 Apparatus and Material

Participants accessed SPEAKS via a website on their own laptops.

In the pre-test questionnaire, we collected demographic information (age, gender) and asked them to rate their agreement with the statement "I feel confident that I can do a great elevator pitch" on a scale from 0 (extremely disagree) to 100 (extremely agree).

In the post-test questionnaire, we again asked about their confidence in doing a great elevator pitch. Additionally, we used the Technology Acceptance Model (TAM) (Davis, 1989) questionnaire with a 7-point Likert scale to assess the perceived usefulness and the perceived ease of use of SPEAKS. To gain deeper insights, participants answered four open-ended questions about three things they liked, three things they would improve, what they learned, and where they needed more support.

Researchers also took notes on participant questions and issues during the session, and usage data was logged to analyse how users interacted with SPEAKS.

4. Results

To analyse how a guidance-based approach to support students with preparing the content of a speech is used and perceived by users, we used a mixed-methods approach to test SPEAKS by collecting insights via a TAM questionnaire, log data and results from open-ended qualitative questions, as well as observations by the researchers during the experiment.

4.1 TAM

We used the post-test questionnaire to assess the perceived ease of use and the perceived usefulness of SPEAKS.

Regarding the perceived ease of use, most participants agreed at least slightly that SPEAKS was easy to learn, easy to become skilful at and easy to use. However, regarding "easy to do what I want", "clear and understandable" and "flexible" the responses were slightly less positive. The overall ease of use mean was 5.23 (SD = 1.41).

Regarding perceived usefulness, most users rated SPEAKS positively, with a mean of 5.46 (SD = 1.04).

The combined mean across all TAM items (ease of use and usefulness) was 5.34 (SD = 1.25). The detailed results can be found in Figure 3.

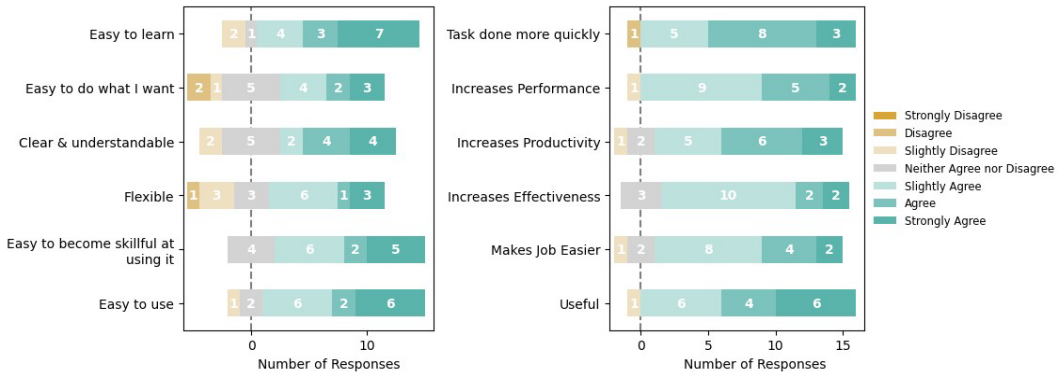


Figure 3: Reported results regarding perceived ease of use (left) and perceived usefulness (right)

4.2 Usage of SPEAKS

To analyse participants' usage of SPEAKS, we tracked participants' interactions with SPEAKS. One participant who entered no data was excluded from the analysis.

On average, participants spent 30.5 min (SD: 16.5 min, median: 27.2 min) preparing their speech. Completion times ranged from 10.4 to 71.9 minutes. Most participants (13) completed the process without revisiting previous steps. Two returned to *5) End*, and one to *6) Middle*. An overview of how much time participants spent per step can be found in Figure 4.

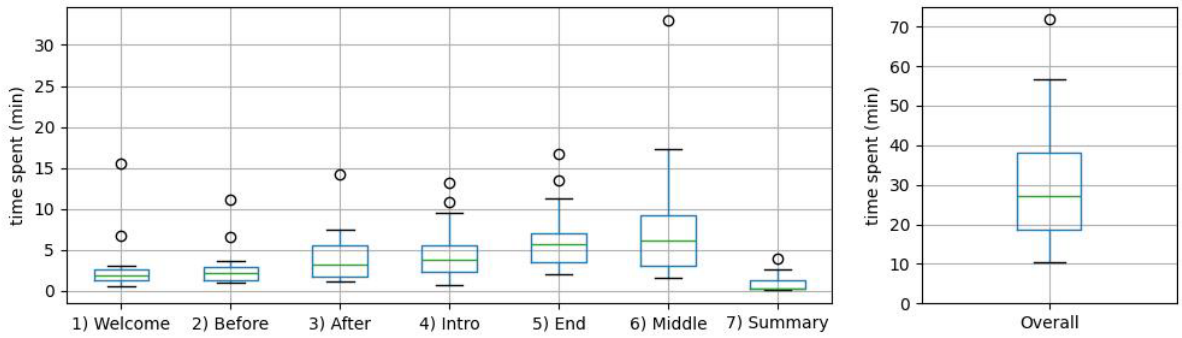


Figure 4: Overview of the time participants spent per step of SPEAKS and overall. *"2) Before"* stands for step *"2) Audience Before"*, *"3) After"* for *"3) Audience Afterwards"* and *"4) Intro"* for *"4) Introduction"*.

SPEAKS offers users to choose from different introduction types ("story", "question", "fact" and "other"). Eleven users decided to start with a question, five chose to start with a story, one with a fact and none came up with another idea.

4.3 Qualitative Feedback

To gain more insights beyond pure number-ratings, we asked participants about three things they would improve, where they needed more support, three things they liked and what they learned.

The main critical points were the navigation, the lack of editing options for the entered bullet points and some specific instructions being unclear to some participants. For the navigation, eight participants reported aspects to improve. Four would have needed an explanation in the beginning on how to go to the next message from the cockatoo (via clicking or using the right arrow). Additionally, four people criticized that it was not possible to jump between sections directly (e.g. from *7) Summary* to *4) Introduction*), but users had to navigate back step by step through each message. Three participants wished for a start screen explaining the task and/or SPEAKS further. Additionally, eight participants wanted to edit their content in *7) Summary* instead of being only able to view it. Last, three participants found some instructions unclear, mainly the one about "closing open brackets from the introduction."

When asked about where they would have needed more support, most participants (8) said none, while two mentioned the "closing open brackets" instruction. The rest of the wishes for more support were only mentioned by one participant each, with no common themes.

The most reported learnings were about creating an engaging introduction and creating the intro and the end of the presentation before creating the middle of the presentation, each mentioned by four participants. Other learnings were mentioned only once with no shared patterns.

Regarding what participants liked, the most mentioned aspect was the guidance (10 mentions), directly followed by SPEAKS being easy and intuitive to use (9). Other frequently mentioned aspects were the UI (6), the running example (6), interactivity (2) and the summary of their presentation plan in step *7) Summary* (2).

4.4 Observations During the Experiment

During the experiment, we documented participant questions and issues. Some software-related issues were observed, where content occasionally disappeared following page reloads or backward navigation. F participants asked about the instruction to "close open brackets" as the analogy was unclear to them, two were confused by the navigation, and one expected AI-generated pitch content and was surprised it wasn't provided.

4.5 Confidence Changes

Users rated their agreement with the statement “I feel confident that I can do a great elevator pitch.” before and after using SPEAKS. After using SPEAKS, all participants reported confidence levels equal to or higher than before. At the start, the average confidence was 50.12 (SD: 22.32), at the end it increased to 63.65 (SD: 18.63).

To test for statistical significance, we used a Wilcoxon signed-rank test due to non-normal data (verified via Shapiro-Wilk test). The resulting p-value was below 0.01, indicating a statistically significant increase in self-reported confidence at the 1% level.

5. Discussion

To evaluate the usage and users' perception of SPEAKS, a software designed to support users in preparing effective speech content by guiding them through the content preparation process, we conducted a user test.

RQ1 focused on the general user experience of SPEAKS. Participants used SPEAKS for an average of 30.5 minutes, indicating substantial engagement. However, the wide range in usage time (10.4 to 71.9 minutes) indicates considerable variation in user behaviour. This may be related to differences in how much information users looked up, how much detail they included in their pitch plans, and whether they used bullet points or full sentences.

Most users chose “question” as their introduction type though other options were also selected. This suggests that the approach to increase diversity in introductions was partially successful.

RQ 1a explored the perceived usability of SPEAKS. Three main patterns emerged from both the TAM and qualitative data. First, SPEAKS was described as easy to use in the TAM (items: “Easy to learn”, “Easy to become skilful at using it”, “Easy to use”). This was also reflected in the qualitative data: the second most liked aspect was that SPEAKS was easy and intuitive to use, while the third most liked aspect was the UI (together with the running example). Additionally, most users reported not needing additional support and those who did typically mentioned a single unclear phrase.

Second, minor issues regarding clarity and understandability have been reported. The TAM item “clear and understandable” received slightly lower ratings, even though most users still at least slightly agreed that SPEAKS was clear and easy to use. When looking at the qualitative data, this seems to mainly have been due to unclear instructions, namely the missing explanation on how to go to the next speech bubble and the term “closing open brackets”.

Third, issues regarding flexibility were reported. In the TAM questionnaire, multiple people disagreed that SPEAKS is “Flexible” and makes it “Easy to do what I want”, even though the majority still at least slightly agreed with these statements. In the qualitative data, nearly half of the users wished for the option to edit their input later or move more freely between preparation steps (e.g. from *7) Summary* directly to *3) Introduction*).

RQ1b addressed the perceived usefulness of SPEAKS. Results indicate that SPEAKS has been perceived as useful for supporting users to prepare the content of a speech. The TAM results were positive and additionally the most liked feature was the guidance-based approach. Therefore, we can conclude that a guidance-based approach can be useful for supporting users to prepare the content of their speeches. Additionally, the usefulness of SPEAKS specifically might be increased even more when adding the possibility to edit the content entered by the user.

RQ 1c explored perceived learning. SPEAKS aimed to teach the following lessons: to think about your audience's previous knowledge and your goals (“what your audience should learn”) before starting to create the speech, that the introduction should be used to gain the audience's attention and that the end of the speech should be connected to the introduction and summarize the main point(s) of the speech. While SPEAKS was able to transfer the lesson on the introduction catching the audience's attention, the other lessons have not been reported as learnings. This might be due to either SPEAKS not teaching these lessons well, users not being aware that they learned these lessons, or them already knowing them before using SPEAKS.

In this study, SPEAKS was used as an example of a software with a guidance-based approach intended to support students with the preparation of content for their speeches as well as teaching them relevant aspects related to speech content preparation. We can see that in general, such an approach is useful for and appreciated by the users and succeeded in teaching them new lessons about speech content preparation. The current

implementation is easy to use, but could benefit from improvements in flexibility, navigation, and clarity in specific areas.

RQ2 examined the impact of SPEAKS on users' confidence in delivering an elevator pitch. We observed a significant increase in this confidence, which can be understood as an increase in skill execution confidence. Given the established link between skill execution confidence and actual skill development (Hays et al., 2007) this increase may point to skill improvement supported by SPEAKS.

5.1 Limitations and Future Work

The main limitation of the study concerns the participant sample, which consisted of only 17 individuals, mainly female, all researchers in educational technologies and voluntarily attending a workshop on presentation competencies. These characteristics make it difficult to generalize our findings due to the small sample size and the population being skewed towards participants interested in learning about presentations and using educational technologies. However, we consider that the results obtained are good enough to provide a general positive outlook about SPEAKS together with important insights on how to improve it.

This study did not aim to rigorously test for learning effects, as its primary goal was to explore initial perceptions and usage patterns of SPEAKS. To evaluate whether SPEAKS effectively teaches audience adaptation, creating engaging introductions, and coherent conclusions, future research should conduct a randomized controlled trial. A full description of the proposed randomized controlled trial can be found in Mouhammad (2023).

While this approach offers strong internal validity, it is resource-intensive and may be challenging to implement at scale. As a more feasible alternative, future studies could assess students' conceptual understanding of the targeted skills through pre- and post-tests before and after using SPEAKS.

6. Conclusion

This paper presented and evaluated SPEAKS, an educational application designed to teach and support students in preparing effective speech content.

The main findings of the presented study were:

- *Usefulness:* Participants found the guidance-based support useful for speech content preparation
- *Confidence gains*: Using SPEAKS significantly increased users' confidence in their ability to give a good speech
- *Usability:* Participants found SPEAKS easy to learn and use, with positive feedback on its usability and interface design

Moreover, the study identified several areas for improvement which can further enhance the user experience of SPEAKS.

Importantly, SPEAKS illustrates that a technically simple yet thoughtfully designed tool can be perceived by learners as a valuable aid in preparing presentation content, suggesting potential for supporting public speaking skill development

Overall, guidance-based software support for speech content preparation, as provided by SPEAKS, shows great promise in bridging the gap between the need for more support in public speaking training regarding the aspect of speech content preparation and the limited availability of in-person training resources.

Ethics Declaration

An application for ethical approval was submitted to the "Ethikkommission" of DIPF | Leibniz Institute for Research and Information in Education, and approval was granted under number DIPF_EK_2024_08.

AI Declaration

Microsoft Copilot was used to assist with text refinement, structural improvements, and clarity throughout the manuscript. All content was reviewed and finalized by the author.

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Artificial Intelligence in Education as Lifelong Learning: What Should be Learnt?

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Abstract: The rapid development of tools and techniques in the field of Generative AI (GenAI) has affected many sectors. One of these sectors is definitely education, where teaching, learning, assessment, curricula and policy document need to be revised and updated. Many research studies also highlight the necessity for teacher professional development regarding Artificial Intelligence in Education (AIED), as AIED is also a field under constant development and will need continuous upskilling during the coming years. There are now teacher training courses in fundamental AIED available, and more are under development. There seems to be a consensus regarding what an introduction course in AIED should comprise, but not regarding which topics continuation courses should follow-up related to continuous lifelong learning. With the heutagogical idea of asking the learners about what to learn, this question was posted to participants in a course on fundamental AIED. In a discussion forum, course participants gave their suggestions and commented on other course participants' postings. Moreover, the forum postings were supplemented with suggestions and comments from email conversations between the authors and course participants. According to the concept of Open Coding, forum postings and email conversations were analysed and divided into the categories of: AI didactics, GenAI tools for teaching, Prompt engineering, Audio generation and Voice cloning, Customisation of AI models, AI and disinformation, Applicable takeaways and AI sustainability and ethics. All of the categories were found to be relevant in a second Axial coding reanalysis. The category Applicable takeaways was found to be the axial category that ties all of the categories together for a meaningful course design. The conclusion is that a continuation course, as in introductory courses on AIED, must contain both theoretical parts with themes such as AI sustainability and ethics, but also concrete applications such as AI didactics to fulfil the aim of Applicable takeaways. Finally, it could be difficult to involve all the categories in just one or two continuation courses. However, as mentioned earlier, AIED should to be seen as continuous lifelong learning.

Keywords: Artificial Intelligence in Education, AIED, AI, Lifelong Learning, Teacher Professional Development

1. Introduction

The current Artificial Intelligence (AI) spring, with a rapid development of Generative AI (GenAI) tools affects different areas to different extents. The same is true for professional development in AI and GenAI. In more technical areas, there is a need for specialised training with a specific focus on AI tools and techniques. This paper has a focus on general teacher professional development in Artificial Intelligence in Education (AIED). Several research studies have highlighted the need for broader professional development that involves subject matter experts, teachers and instructional designers (Kumar et al. 2024; Meli et al. 2024). There are also research studies pointing out the necessity for continuous professional development in AIED (Meli et al. 2024; El Din 2025; McGury et al. 2025), and that professional development is best provided on an institutional level (Bannister & Carver 2024). In recent years, the advancements of AI have had direct impact on all levels of education (Tyson & Sauers 2021). Fullan et al. (2024) point out the strong potential of AI, involving “enormous potential to improve learning, teaching, pedagogical innovations, assessment, and educational administration through intelligent tutoring systems, chatbots, robots, learning analytics dashboards, adaptive learning systems and automated assessment” (p 340). However, Neumann et al. (2023), see challenges and opportunities in AIED. Challenges involve the limited knowledge of how students utilize AI, uncertainties in evaluating AI in school, varying perceptions of acceptable use, increased time demands for assessments, and the unknown potential of AI. Conversely, opportunities lie in enhanced student support, fostering creativity, and potential for driving and advancing educational innovation. This means that AI introduces a wide range of ethical, moral, and practical challenges for all actors in education (Strzelecki 2023).

Many universities have been rapid to respond to these calls for professional development in the past few years and have launched teacher training courses on fundamental AIED as a form of professional development. These courses have been implemented and are now more under development. There seems to be a consensus on the need for introductory courses and a fundamental content in AIED for educators on all levels. However, which

topics the continuation courses should provide in follow-up courses is unclear. According to the heutagogical idea of asking the learners about what to learn, the question was posted in a course on fundamental AIED at one university, which is described in the next section. What course participants found to be important topics for further learning was also discussed in webinars at the end of the course, in order to capture the need for new content in a continuation course.

The main research question to answer in the study was: "What topics are important to involve in continuing courses on artificial intelligence in education?". Moreover, this paper also presents ideas for how this learning should be structured, employing Communities of Inquiry (CoI) and the ideas of shifting professional development to institutional development.

2. The Introductory Course

The introductory course was designed and developed to be run as a 7,5 ECTS standalone distance course open for all persons with general entry requirements for higher education. In the first two course iterations, the majority of participants were working in different educational contexts, and many of them were working full-time. A course that is given at a department of education should have a focus on pedagogical and didactical aspects of education or AIED. However, to better understand the more general aspects of AIED, the course was also outlined to involve technical, administrative and ethical aspects of AI. Early in the course development process, the course was divided into four main sections:

1. Introduction and tool testing
2. AI in Education
3. Multimodal AI
4. Discussion webinars as knowledge cafés

To support the course sections above, the course was designed to involve a mix of teacher-led synchronous activities, online workshops, group discussions, and asynchronous self-studies. Moreover, these activities and six mandatory assignments were created to meet the learning objectives that are listed in the section below.

The overall aim of the course was to present, discuss and apply fundamental tools and theories in the field of AIED. After course completion, the participant should be able to:

- Understand and explain the history and development of AI and AIED
- Analyse and discuss the main opportunities and challenges of AIED
- Evaluate and discuss different tools for detection of AI generated texts
- Explore and apply different GenAI modalities such as text, images, sound and music
- Compare, discuss and reflect over how GenAI could affect and enhance teaching and learning activities and assessment in various educational contexts

A course that was built around the overall objective of combining practical and theoretical aspects of AI for a deeper understanding of AIED was expected to be useful even after course ended (Mozelius 2025).

3. FAITH – Institutional Development

In the Swedish context, the case presented in this paper is an institutional development project called Frontline application of Artificial Intelligence and Technology-enhanced Learning in Higher education (FAITH) (Mozelius et al. 2024). This project is located at the Department of Education, Mid Sweden University and runs for three years. The project focuses on developing new teaching practices and courses by implementing AI tools in the department's educational operations. Teachers at the department are involved in several activities to support the defined goals of the project. The main activities in the institutional development plan include participating in a professional development course held by AIED experts; creating a development plan, including a design that implements AIED; implementing the plan in courses; learning from try-outs and reiterating lessons learnt the next try-out. The results of the try-outs are also discussed and disseminated at institutional development seminars. In the project, the teachers involved develop new courses and revise existing courses.

FAITH is also a professional development project running between 2024-2026 with the aim of stimulating the further development of institutional teaching and education programs. In the project, teachers and department staff are expected to work and develop educational operations to adapt to the emerging field of AI. The integration of AI and technology-enhanced learning is a main objective, and the FAITH project will take advantage of ongoing higher education pedagogical development initiatives with collaborating universities. Thus, the

project strives to increase the understanding and competence in AI and technology-enhanced learning (Jaldemark et al. 2024). In professional development efforts, design-based research is a key methodology which involves iterative and cumulative development processes (Jaldemark, Håkansson Lindqvist, & Mozelius 2019). The project consists of three phases: preparation, implementation and evaluation. Preparation included detailed planning, forming a steering group, and recruiting key competencies for the group team. The project team involves a mix of AI and technology-enhanced learning experts and program managers. All of the members of the project team will implement and evaluate the project to achieve both educational and institutional development.

4. Teaching AI in Education Through the Lens of a Critical Community of Inquiry

In the evolving landscape of post-secondary education, the rise of generative AI brings both promise and complexity. For graduate students in education—experienced, pedagogically grounded, and future-focused—this moment offers a unique opportunity: to shape not only how AI is used in the classroom, but also how it is understood, critiqued, and ethically applied across disciplines.

As AI becomes increasingly embedded in educational systems, the need for pedagogically grounded frameworks to guide its development and application is more urgent than ever. The Community of Inquiry (CoI) framework provides a shared model of pedagogical leadership that supports directed and peer teaching, deliberative dialogue, and the development of metacognition and critical reflection. This framework offers a rigorous foundation for evaluating and applying AI tools through processes that foster deep and meaningful learning.

In Canada, the FAITH for-credit graduate seminar was offered at a Canadian post-secondary institution. To orient students to the course and its activities, they were introduced to the CoI conceptual framework and its applications. Norms for participation, along with agreements on practices and timelines, were collaboratively established.

Students were informed that the course was designed around the CoI framework developed by Garrison, et al. (2000). In this temporary learning community, each member was expected to actively support the learning and teaching of others. Weekly asynchronous discussion forums were hosted on the learning management system, complemented by bi-weekly synchronous web meetings to foster real-time engagement across social, cognitive, and teaching domains. Participation contributed to course grading. Originally developed in the context of early text-based online learning in the late 1990s, the CoI framework integrates quality educational practices, the practical inquiry model, and distance education theory. It remains the most widely referenced and applied model for online learning due to its simplicity and versatility (Bozkurt 2019).

The CoI is a socially collaborative, constructivist framework that outlines the core elements of meaningful online learning. It dynamically supports the development of community and the pursuit of intellectual inquiry in any educational setting. The framework comprises three essential elements, or presences:

1. Social Presence (SP): The ability of participants to identify with the community, communicate purposefully in a trusting environment, and build interpersonal relationships by projecting their individual personalities.
2. Cognitive Presence (CP): The extent to which learners construct and confirm meaning through sustained reflection and discourse within a critical community of inquiry.
1. 3.Teaching Presence (TP): The design, facilitation, and direction of cognitive and social processes to achieve personally meaningful and educationally valuable learning outcomes.

Subsequent research introduced a fourth element, Emotional Presence, which underpins the original three. Defined as “the outward expression of emotion, affect, and feeling by individuals and among individuals in a community of inquiry, as they relate to and interact with the learning technology, course content, students, and the instructor” (Cleveland-Innes & Campbell 2012), emotional presence is especially relevant in the context of AI’s disruptive impact. Emotional presence enables authentic reactions and discussions.

Throughout the course, discussion forums and synchronous meetings were guided by the principles of deliberative dialogue to support all four presences: social, cognitive, teaching, and emotional. AI can be taught through the lens of the Community of Inquiry, but equally important is aligning AI tools with the goals of deep and meaningful learning.

Recent research has explored how generative AI (GenAI) can be designed to support the CoI model. For example, AI can enhance cognitive presence by prompting learners to reflect, integrate, and resolve complex ideas through

adaptive feedback and inquiry-based scaffolding (Melisa et al. 2025). Similarly, social presence can be supported by AI-driven conversational agents that foster respectful discourse and peer engagement. Teaching presence is amplified when AI assists educators in designing and facilitating learning experiences, offering real-time analytics and personalized interventions.

However, as Holmes et al. (2021) argue, ethical intentions alone are insufficient. The integration of AI into education must be guided by a commitment to fairness, transparency, and learner agency. The CoI framework provides a pedagogical and ethical compass, ensuring that AI tools may be effective content providers and aligned with the values of collaborative inquiry and critical thinking.

A practical example of this integration is the use of AI chatbots designed with CoI principles to support informal and formal learning through structured dialogue and reflection. These tools demonstrate how AI can be used not just to deliver content, but to co-construct knowledge in a community of learners. The CoI framework challenges developers and educators to move beyond efficiency and automation. It invites a reimagining of AI as a partner in the learning process; one that supports the human dimensions of education: dialogue, reflection, and shared meaning-making.

5. Method

The study presented in this paper was carried out with an action research approach with the idea of a concrete and systematic approach "that enables teachers to investigate their own teaching and their student's learning" (Nolen & Putten 2007, p 401). There are various types of action research, where this study belongs in the British tradition of action research described by Norton (2009 p 71), as an approach "that links research to improvement of practice and is education orientated". The authors' overall objective was that the conducted research should have a positive impact on the future design of the involved courses. Moreover, educational action research is an approach where researchers can have the dual roles of being not only researchers, but who are also involved in the educational context that is researched. In this study, one of the authors was the main teacher in the introductory course that data were collected from, and two of the authors were involved in the creation of the syllabi for both the introductory course and the planned continuation course.

5.1 Data Collection

Data were collected from forum postings in discussion fora in two versions of the introductory course described above. Participants gave suggestions and commented on other course participants' postings where they gave their opinion on the importance of creating continuation courses on AIED. The data from forum postings have been supplemented with suggestions and comments from email conversations between the author and course participants in both course iterations, and in the second iteration this topic was discussed in groups in one of the course webinars.

5.2 Data Analysis

The described mix of collected data have been analysed according to the Grounded theory analysis method of data being 1) fractured and labelled, and 2) conceptualised around a central category (Moghaddam, 2006). In the first analysis phase, well-known under the term of Open coding, data were broken down into units of meaning and later aggregated to categories as outlined by Khandkar (2009). The Open coding was conducted by the first author, but was also discussed with the other authors to find relevant preliminary categories based on the identified codes and subcodes that were identified in the interview answers. The next phase of the Axial coding was guided by the Grounded theory idea of "coding that treats a category as an axis around which the analyst delineates relationships and specifies the dimensions of the category" (Bryant & Charmaz 2007 p 603). In the Axial coding, the preliminary categories from the Open coding were reassembled into more abstract conceptual categories around the central axis of 'Higher education transformation for lifelong learning'.

Larger Grounded theory analysis often involves a third phase. This third phase is sometimes referred to as Confirmatory coding (Cleveland-Innes & Campbell 2012), and sometimes as Selective coding (Walker & Myrick 2006). In this third phase, where the identified categories in the second phase are revised and integrated with a description of their interrelationship is not a part of this study, and rather a potential for future work.

5.3 Ethical Considerations

In almost all types of action research, authors must consider the dual roles of being researchers as well as part of the studied context. A duality that was relatively easy to handle in this limited study, but the risk for bias is always present. As pointed out by Nolen and Putten (2007, p 403): "*When the researcher is a member of and plays a role in the system under investigation, issues surrounding role definition, role ambiguity, and role conflict are often significantly greater than when a researcher enters the school as an objective outsider".*

According to the principle of informed consent, all course participants were informed at the very start of the courses that selected parts of the course activities would be part of research studies. With the general respect of informant integrity, all course participants were kept as anonymous as possible and data have been collected without saving any personal information.

6. Findings and Discussions

As reported in Mozelius (2025), the first evaluation of the introductory course was mainly positive considering the university standard questions that are presented in Table 1.

Table 1: Answers in the standard questionnaire.

Question	1.Very poor	2.Poor	3.Sufficient	4.Good	5.Very good
1. What is your overall impression of the course?				75%	25%
2. Have the course aim and the learning objectives been clear and relevant?			12.5 %	50%	37.5%
3. To what degree have the learning objectives been aligned to the content?			12.5 %	62.5%	25%
4. How to you estimate your pre-knowledge at the course start?		25%	12.5 %	12.5 %	50%
5. How was the support and help from the teachers (when needed)?				50%	50%
6. How do you see the course regarding structure, assessment, communication standard, teachers use of language, and accessibility (based on the aspects of gender, ethnicity, sexual orientation, age and disability)?				50%	50%

Regarding Question 2. and 3., there have been minor updates for course iteration 2 and 3, and regarding Question 4, the pre-knowledge level was clearly higher in course iteration 2. At present, the university standard evaluation for course iteration 2 is not yet, but participants have given their opinions in forum postings and in webinar discussions.

A main challenge brought up by several course participants, is the time shortage for full-time working professionals, and how to combine the scheduled course activities and group work with schedules in workplaces. Both first course iterations had a high percentage of full-time working teachers. A suggestion from some of those teachers was a summer course, which has now been realised in iteration 3 of the introductory course.

Regarding the research question on important topics to involve in continuing courses, the suggestions from participants in the two first iterations were quite similar. The result from the initial Open coding analysis gave the categories of AI didactics, GenAI tools for teaching, Prompt engineering, Audio generation and Voice cloning, Customisation of AI models, AI and disinformation, and AI sustainability and ethics. Many participants stressed the need for concrete AI-aligned teaching and learning activities that could be used in their daily work after the course duration. In the Axial coding, this was included as the central axial category 'Applicable takeaways'. The outcome from the analyses could also work as a guiding blueprint for the development of the first continuation course that is sketched in the next section is illustrated in Figure 1. All the aligned categories could be seen as takeaways that course participants after a completed course could apply in their everyday work-life or study-life.

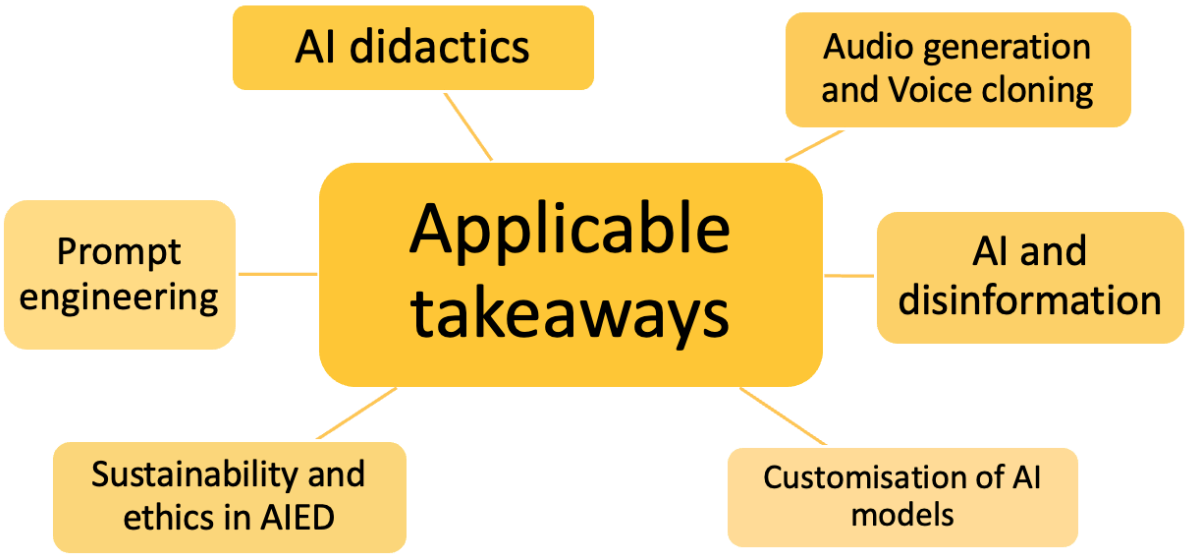


Figure 1: Suggested applicable takeaways for continuation courses.

It has been argued that prompt engineering will be of less importance for the future improved versions of AI-bots, however, the selected course literature has sections on prompt engineering. The course assignments on 'AI didactics' could also involve prompt engineering in the construction of lesson plans and assignments. 'Audio generation and Voice cloning' could preferably be combined with activities on ' AI and disinformation', but also used in the course activities on 'AI supported accessibility'. Moreover, the category of 'AI and disinformation' could be an important aspect of 'Sustainability and ethics in AIED'. Regarding the remaining category of 'Customisation of AI models' two interesting concepts to present and discuss would be Socratic dialogues (Orynbassarova & Porta 2024), and the Study Buddy idea (Durgungoz & Kharrufa 2025). Finally, several participants have brought up that AIED should be multimodal and not only about generating text.

7. A First Sketch for a Continuation Course

Similar to the introductory course, the first continuation course should stimulate active learning with a mix of lectures, workshops, seminars and individual work combined with group work. The overall course aim should be to present, apply and discuss how artificial intelligence techniques could be sustainably implemented in different educational contexts. Course content should be built around the concepts of prompt engineering, AI supported construction of multimodal teaching and learning activities, construction of assignments with clear instructions for the allowed use of AI, and social, financial, environmental and ethical aspects of generative AI. After a completed course the participants should be able to:

- Apply and reflect over different prompting strategies for multimodal generative AI
- Create and critically review a series of lessons in a chosen educational context with AI generated teaching and learning activities
- Create assignments that assess these teaching and learning activities, and to clearly describe how and when AI is allowed in the student solutions of the assignments
- Explore and describe how different AI techniques could increase inclusion and accessibility in technology enhanced learning
- Analyse and discuss social, financial, environmental and ethical aspects sustainability aspects of generative AI

Finally, course development should be conducted as a part of the described FAITH project, and build upon the theoretical framework of Communities of Inquiry.

8. Conclusion

In conclusion, it can be noted that the introductory course has worked out relatively well, although there are, as always, parts to redesign and improve. The continuation course should, in the same way as introductory courses in AIED, contain both theoretical parts on themes such as AI sustainability and ethics, but also concrete hands-

on activities AI to fulfil the aim of Applicable takeaways. AIED is a rapidly emerging field where it is difficult to involve all the categories in just one or two continuation courses. Thus, AIED should definitely be seen as continuous lifelong learning, with applicable takeaways as an important main concept in the course design. Part of the redesign could be to move the more theoretical parts of the introductory course to the continuation course, and to have more hands-on activities first and theory later. However, considering lesson planning and assessment it seems to make sense to start with theory, and to later apply the theory.

Beyond answering the research question about what topics are important to involve in continuing courses on artificial intelligence in education, the study also provided two ideas on how this should be carried out. Firstly, this is conducted on the staff level, in collaboration with the project team in the FAITH initiative, where we also will compare how AIED has been implemented at our Canadian partner university. Secondly, on the teacher and student level, as a Community of Inquiry, it will be important to further discuss and refine the cognitive, social and teaching presences in the courses.

9. Future Work

Both the involved courses will be given in several iterations during the coming year with the same types of evaluations and follow-up activities as presented in this paper. It is the authors' intention is to attend next year's ECEL conference as well, to further discuss the complex and shifting field of AIED. What we see as an important part of the iterative redesign is to have a continuous dialogue with other teachers and researchers in this field.

Ethics and AI Declaration

Data were collected with informed consent, and no AI tools have been used in any part of this paper.

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Enhancing Social Work Education Through E-Portfolios: Pedagogical Practices and Praxis at the University of Fort Hare

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Abstract: The integration of digital tools in higher education has transformed pedagogical practices, particularly in professional disciplines such as social work. This study explores the use of e-portfolios in social work education at the University of Fort Hare, emphasizing their role in enhancing student learning, reflection, and professional identity formation. By adopting a praxis-oriented approach, the study examines how e-portfolios facilitate experiential learning, critical engagement, and competency development. The findings highlight best practices in implementing e-portfolios, including student support, and assessment strategies. Furthermore, the study discusses challenges such as digital accessibility and the need for faculty capacity-building. Ultimately, the research examines the potential of e-portfolios to bridge theoretical knowledge and practical application, equipping students with essential skills for professional social work practice.

Keywords: E-portfolios, Social Work Education, Pedagogy, Praxis.

1. Background

In 2019, the Teaching and Learning Centre at the University of Fort Hare introduced e-Portfolios to address the persistent challenges associated with managing large volumes of hardcopy portfolios submitted by students for work integrated learning. Within the Faculty of Social Sciences and Humanities, and specifically in the Social Work programme, the move to e-Portfolios was driven by a need to streamline submission processes, reduce physical storage burdens, and align assessment practices with the growing emphasis on digital literacy in higher education. Initially piloted in professional education programmes, the e-Portfolio initiative was progressively extended to include students in social work, especially as part of their fieldwork and practice learning requirements. By 2020, in response to the disruptions caused by the COVID-19 pandemic, the University shifted to online modalities, and e-Portfolio training was integrated into the institutional Learning Management System called Blackboard. Using Blackboard Collaborate, students were introduced to digital tools on Blackboard for their e-portfolios to document their learning, reflections, and professional growth. The transition to digital portfolios represents a significant pedagogical shift. It enables students to curate evidence of their theoretical grounding and applied competencies in a dynamic and accessible format. E-Portfolios have since become a central component of the teaching and learning strategy in social work education at the University of Fort Hare, supporting critical reflection, experiential learning, and professional identity formation. This paper explores how e-Portfolios are enhancing pedagogical practices and shaping a praxis-oriented approach to learning in social work, contributing to more holistic and student-centred education.

2. Literature Review

2.1 E-Portfolios in Higher Education

The integration of e-portfolios into social work education at the University of Fort Hare reflects a broader pedagogical shift in higher education aimed at promoting reflective, experiential, and student-centered learning. E-portfolios are digital collections of student work that showcase evidence of learning, growth, and competency development over time. In social work education, they serve as dynamic platforms for integrating academic knowledge with field-based practice, fostering a praxis-oriented approach essential for developing ethical and competent practitioners (Panke, 2014).

2.2 Role of Digital Tools

The integration of digital tools in higher education has significantly transformed pedagogical approaches, shifting from traditional, teacher-centred methods to more student-centred and technology-enhanced learning environments (Redecker & Punie, 2017). Among these innovations, e-portfolios have emerged as dynamic platforms that support the documentation, reflection, and assessment of student learning over time. E-portfolios are defined as digital collections of students' work that showcase academic development, critical reflections, and professional skills (Barrett, 2010). They also serve as integrative learning tools, enabling students

to connect disparate learning experiences into a cohesive professional narrative (Batson, Chen, Watson, & Zubizarreta, 2007). Over the past decade, scholarship has highlighted both their successes and the need for continued exploration into their pedagogical potential (Yancey, 2009). In the context of social work education, e-portfolios are widely recognised for fostering critical reflection, ethical awareness, and the integration of theory with practice (Ajandi, Chan, & Daniels, 2019).

They also provide structured frameworks for evaluating both student learning and curriculum effectiveness, ensuring assessment processes capture the breadth of professional competencies (Alvarez & Moxley, 2004). In addition, they serve multiple functions, including demonstrating competency, facilitating feedback, and supporting both formative and summative assessment (Stefani, Mason, & Pegler, 2007). Within competency-based and outcomes-driven education, e-portfolios are particularly valuable as they provide tangible evidence of learning, integrate theoretical knowledge with practical application, and monitor progress across various learning outcomes (Garrett, 2011). Furthermore, they have proven effective in evaluating curriculum design and student learning outcomes, ensuring that programme objectives are met while capturing the complexity of professional development (Fitch, Peet, Glover Reed, & Tolman, 2013). However, their adoption particularly in African higher education contexts is closely linked to broader issues of digital access and inclusivity, with structural inequalities in ICT infrastructure shaping the extent to which students can engage effectively with such tools (Asongu, Orim, & Nting, 2019). This makes e-portfolios an essential tool for disciplines such as social work, where reflective practice, evidence-based learning, and demonstrable competency are central to professional training.

2.3 E- Portfolios in Social Work Education

The integration of digital tools in higher education has significantly transformed pedagogical approaches, driving a shift from traditional, teacher-centred methods to more student-centred and technology-enhanced learning environments (Redecker & Punie, 2017). Among these innovations, e-portfolios have emerged as dynamic platforms for the documentation, reflection, and assessment of student learning over time. Defined as digital collections of students' work that demonstrate academic development, critical reflections, and professional skills (Barrett, 2010), e-portfolios also function as integrative learning tools, enabling students to connect diverse learning experiences into a cohesive professional narrative (Batson, Chen, Watson, & Zubizarreta, 2007). Over the past decade, research has highlighted both the successes of e-portfolio implementation and the need for continued exploration of their full pedagogical potential (Yancey, 2009). In social work education specifically, e-portfolios are recognised for fostering critical reflection, ethical practice, and the integration of theory with field-based learning (Ajandi, Chan, & Daniels, 2019). They have also been used as structured frameworks for evaluating both student learning and programme effectiveness, ensuring that assessment captures the full scope of professional competencies (Alvarez & Moxley, 2004). Beyond these pedagogical benefits, e-portfolios perform multiple functions, including demonstrating competency, facilitating feedback, and supporting both formative and summative assessment (Stefani, Mason, & Pegler, 2007). Within competency-based and outcomes-driven education, they are particularly valuable for providing tangible evidence of learning, linking theoretical knowledge with practical application, and tracking progress across diverse learning outcomes (Garrett, 2011). Furthermore, they have proven effective in evaluating curriculum design and student learning outcomes, ensuring alignment between programme objectives and professional development goals (Fitch, Peet, Glover Reed, & Tolman, 2013). However, their adoption especially within African higher education contexts remains closely tied to broader issues of digital access and inclusivity, with structural inequalities in ICT infrastructure influencing students' ability to fully engage with such tools (Asongu, Orim, & Nting, 2019). Collectively, these qualities make e-portfolios an essential resource in disciplines such as social work, where reflective practice, evidence-based learning, and demonstrable competency are central to professional training.

2.4 Empirical Evidence on the use of E-portfolios Effectiveness

Empirical evidence on the effectiveness of e-portfolios highlights their significant role in enhancing learning outcomes across diverse educational contexts. Studies consistently show that e-portfolios serve as powerful tools for self-reflection, skill development, and career preparation, offering multifaceted benefits to students and professionals alike. In higher education, research conducted at West Visayas State University found that e-portfolios significantly improved students' academic performance, creativity, and self-reflection skills, with no differences observed across gender or grade levels (Siosan, 2023). Similarly, at Ritsumeikan University, e-portfolios were shown to enhance career advising by fostering student independence and proactive engagement, leading to improved career planning strategies (Higuchi & Takekawa, 2011).

In the context of job market preparation, research on IT job seekers revealed that e-portfolios facilitated the hiring process by enabling employers to evaluate candidates more comprehensively than through traditional curriculum vitae, resulting in higher acceptance rates (Tasji & Turani, 2023). Furthermore, in clinical education, a study on practitioner nurses demonstrated that e-portfolios significantly improved clinical competence, with participants in the e-portfolio group achieving higher post-test scores in both knowledge and performance compared to a control group (Najaffard et al., 2024).

These findings complement previous studies in social work education that have shown how e-portfolios support competency-based assessment, facilitate feedback, and encourage integration of theory with practice (Garrett, 2011; McGuire, Lay, & Peters, 2009). Through structured reflection, students develop critical thinking skills and strengthen links between theoretical frameworks and field-based practice, in line with **Kolb's (1984) experiential learning model** and **Schön's (1983) reflective practice approach.**

While the benefits are evident, scholars caution that the effectiveness of e-portfolios is influenced by user engagement, digital literacy, and institutional support. This suggests the need for sustained training, curriculum integration, and alignment with professional standards to maximise their impact and ensure sustainable adoption in higher education contexts.

2.5 Pedagogical Theories Underpinning E-Portfolio Use

The use of e-portfolios in social work education at the University of Fort Hare is grounded in several key pedagogical theories that emphasize active, reflective, and socially situated learning. Kolb's (1984) theory of experiential learning underlines the importance of learning through experience, where students engage in a cyclical process of concrete experience, reflective observation, abstract conceptualization, and active experimentation. E-portfolios facilitate this process by allowing students to document and reflect on their fieldwork and classroom learning. Complementing this, Schön's (1983) concept of reflective practice positions students as reflective practitioners who learn by thinking critically about their actions and experiences in real-world contexts. E-portfolios serve as a space for this critical reflection, fostering deeper understanding and professional growth. Additionally, Wenger's (1998) theory of communities of practice highlights the value of collaborative learning and identity formation within professional communities. Through peer feedback, shared digital artifacts, and collaborative reflection, e-portfolios help students participate in a learning community, supporting their integration into the professional culture of social work.

3. Theoretical Framework and its Application

This study is anchored in Kolb's Experiential Learning Theory (1984) and Schön's Reflective Practice Model (1983). These frameworks emphasize the cyclical nature of learning through experience, reflection, conceptualization, and application principles that are foundational in professional education, particularly in social work. Kolb's model supports the development of competencies through active engagement with real-world experiences, while Schön's work emphasises the importance of reflective practice in forming professional identity and integrating theory with practice. The e-portfolio, as both a pedagogical and assessment tool, enables students to document, reflect on, and assess their learning journey in alignment with these theories.

Kolb (1984) conceptualizes learning as a continuous process involving four stages:

- ***Concrete experience*** through students starting with a practical or real-world experience example: community placement or case study.
- ***Reflective observation*** involves reflect on what happened, how they felt, what worked, and what did not.
- ***Abstract conceptualization*** involves linking their reflections to theories, frameworks, or professional knowledge (example social justice theory, ethical guidelines).
- *A**ctive experimentation*** is when they use these insights to inform future practice or decision-making.

According to this model, students gain knowledge by engaging in experiences, reflecting on
them, forming theoretical insights, and applying those insights in new situations. In the context of social work education, this cycle facilitates the development of professional competencies through active engagement with real-world scenarios such as field placements, service-learning projects, and applied case studies. These experiences form the basis for reflective learning and theoretical synthesis, which are critical for developing practical skills and professional judgment.

Complementing Kolb's framework is Schön's (1983) concept of the **reflective practitioner**, which highlights the importance of reflective thinking in professional learning. Schön distinguishes between **reflection-in-action** (thinking during the activity) and **reflection-on-action** (thinking after the activity), both of which are integral to the formation of professional identity and the capacity to navigate complex, uncertain practice environments. This is especially relevant in social work, where students must continuously analyze their decisions and experiences to align with ethical standards, social justice values, and client-centered approaches.

The integration of e-portfolios into the social work curriculum aligns with these theories by providing a structured space for students to **document their experiences, critically reflect on their learning,** and **demonstrate their professional growth over time.** As both a pedagogical and assessment tool, the e-portfolio supports experiential and reflective learning, enabling students to make meaningful connections between academic knowledge and field-based practice. Through the iterative process of capturing experiences, articulating insights, and planning for future action, students engage in a cycle of learning that embodies the principles articulated by both Kolb and Schön. In this way, e-portfolios serve as a platform for **praxis,** the synthesis of theory and practice which is foundational to the preparation of competent and reflective social work professionals.

4. Methodology

4.1 Research Design

This study adopted a mixed-methods research design grounded in Kolb's Experiential Learning Theory (1984) and Schön's Reflective Practice Model (1983), both of which emphasize the cyclical nature of learning through experience, reflection, conceptualization, and active experimentation. Data were collected using a structured evaluation form administered to second year social work students who participated in an e-portfolio training session. The instrument included both closed-ended questions (e.g., Likert-scale responses on confidence, usability, and perceived support) and open-ended prompts that encouraged students to articulate their reflections on the training experience, expectations, and learning needs. Quantitative data was analyzed descriptively to identify patterns in digital confidence and usability, while qualitative responses were thematically coded to surface insights into students' engagement with experiential and reflective learning processes. This design allowed the study to examine how students moved through the stages of experiential learning from concrete experience during the training to reflective observation and conceptual understanding and how they began to internalize the reflective practices necessary for professional social work. The alignment of the research design with these pedagogical frameworks ensured that data collection and analysis captured not only cognitive outcomes but also the reflective and affective dimensions critical to competency development and professional identity formation in social work education.

4.2 Sampling

The study employed a purposive sampling strategy to select participants who were directly involved in the e-portfolio training initiative within the Department of Social Work at the University of Fort Hare. Participants included undergraduate social work students who attended the structured training session on e-portfolio usage, as they were best positioned to provide informed feedback on the pedagogical value and practical implementation of e-portfolios in their field work experience. This sampling method ensured that data was gathered from individuals who had firsthand experience with the intervention, aligning with the study's focus on experiential and reflective learning. A total of 98 students completed the evaluation form, offering both quantitative and qualitative data relevant to the research objectives. The purposive nature of the sample supports the study's interpretive approach, which seeks in depth of understanding, particularly in relation to how students engage with digital tools to enhance professional learning and identity development.

4.3 Data Collection

The data collection process was integrated into the conclusion of the e-portfolio training session to ensure high response rates and capture immediate student feedback. Participants were provided with digital versions of the evaluation form to accommodate different levels of digital accessibility. The instrument was developed to align with the study's theoretical framework, particularly emphasizing reflective learning and user engagement with digital tools. Instructions were clearly communicated, and participants were given adequate time to complete the form independently. The collection process also ensured anonymity to encourage candid reflections,

particularly on challenges related to platform use, confidence levels, and expectations for applying e-portfolios in their academic and fieldwork contexts.

4.4 Data Analysis

According to Udah et al. (2024), data analytics entails the systematic examination of large and complex datasets to uncover hidden patterns, correlations, and valuable insights. In this study, students' narratives were subjected to content analysis, focusing on phrases, meaning units, sentences, and keywords. These were color-coded in alignment with the predetermined thematic framework, and the extracted datasets were subsequently categorized into thematic groups.

A mixed-methods approach was employed, integrating thematic analysis with descriptive statistics. Quantitative responses from Likert-scale items were analyzed using basic statistical techniques to identify trends in student confidence, usability perceptions, and support needs (Creswell & Creswell, 2018). These descriptive findings offered a concise overview of students' engagement with the e-portfolio platform following the training.

Qualitative data from open-ended responses were analyzed by looking at recurring phrases and concepts grouped into broader categories (Braun & Clarke, 2006). This process yielded key themes such as digital preparedness, reflective practice, and the integration of theory with practice.

The thematic analysis was grounded in Kolb's (1984) Experiential Learning Theory and Schön's (1983) Reflective Practice Model, both of which conceptualize learning as a dynamic, cyclical process involving active participation, reflection, and conceptualization. These frameworks provided a pedagogical lens through which the qualitative findings could be coherently interpreted within the context of social work education.

5. Results

In line with Schon's Reflective Practice Model and Kolb's (1984) Experiential Learning Theory, descriptive statistics and thematic coding were used to evaluate the data from 98 second-year social work students. This framework gave educators a way to analyze how students developed during and after the e-portfolio training by tracking their progress through the experiential learning cycle.

5.1 Concrete Experience

The training session functioned as the immediate, hands-on learning experience within **Kolb's (1984) Experiential Learning Model**. Before the session, 83 students (84.7%) reported having no prior exposure to e-portfolios, indicating that the training introduced a completely new learning environment for most of the students. Despite this initial unfamiliarity, post-training results demonstrated a notable improvement in confidence levels, with 59.2% of students stating that they felt *slightly confident*, 35.7% reporting that they were *very confident*, and only 5.1% indicating that they remained *not confident*. In addition, students identified hands-on demonstrations as the most beneficial aspect of the training. Activities such as live submission practice and navigation walkthroughs gave them direct, tangible engagement with the platform. Many responses referenced "submission," "final upload," and "practical steps," reinforcing the value of experiential exposure.

Qualitative feedback from open-ended responses revealed that students found the **practical demonstrations** particularly beneficial. Activities such as *submitting the portfolio*, *completing the final submission process*, and *navigating the platform* were consistently mentioned as the most helpful elements of the session. These findings directly align with the **hands-on engagement** principle central to the *concrete experience* stage of Kolb's learning cycle, where students benefit from direct participation in realistic, practice-based activities.

5.2 Reflective Observation

Within Kolb's (1984) Experiential Learning Cycle, the reflective observation stage requires students to look back on their experiences and evaluate them critically. When students were asked whether the e-portfolio would assist them in reflecting on their learning journey, 56.1% explicitly responded "Yes," while an additional proportion offered qualified agreement, indicating responses such as *"I think so."*

Qualitative feedback revealed recurring themes of self-assessment, tracking progress, and identifying strengths and weaknesses. Students expressed that the e-portfolio could help them monitor their academic and professional development in a structured manner. One student articulated this sentiment by stating: "*By looking*

at my challenges and experiences and achievements, I can better understand how I am developing both professionally and personally in the field of social work."

This response reflects a recognition of the e-portfolio's potential as a deliberate and structured tool for reflection-on-action, as conceptualized by Schön (1983). Through this process, students demonstrated an ability to integrate self-awareness into their ongoing professional growth, linking personal experiences to their development as emerging social work practitioners.

5.3 Abstract Conceptualization

In the abstract conceptualization stage of Kolb's (1984) Experiential Learning Cycle, students move beyond reflection to connect their experiences with theoretical frameworks and structured knowledge. The students' expectations of the e-portfolio revealed evidence of emerging theoretical integration, with many responses highlighting its value in linking theory to practice and in deepening their understanding of social work frameworks.

The analysis also revealed specific areas where students felt they required additional support to effectively use the e-portfolio. The most frequently mentioned needs included uploading and organizing content (36.7%), navigating the platform (24.5%), and linking theory to practice (14.3%). These skill gaps suggest that while students were beginning to make connections between their learning experiences and professional theory, further conceptual scaffolding is necessary to consolidate these insights.

This stage highlights the importance of ongoing academic support to ensure that students are able to situate their practice within recognized professional standards and the broader values of social justice that underpin social work education. Providing targeted guidance in both the technical and conceptual aspects of e-portfolio use will be critical in supporting students to fully integrate their experiential learning with disciplinary theory.

5.4 Active Experimentation

The final stage of Kolb's (1984) Experiential Learning Cycle, active experimentation, involves applying newly acquired knowledge and skills to future contexts. When students were asked whether they felt ready to work independently on their e-portfolios, 40.8% responded "Yes," 39.8% answered "Maybe," and 19.4% indicated "No." These mixed responses suggest varying levels of readiness to transfer the training experience into independent application, with a strong correlation observed between readiness and reported confidence levels. Students who felt prepared to work independently often outlined clear plans for using the e-portfolio to prepare for field placements, monitor their academic progression, and document professional competencies for future employment or practice requirements.

However, several challenges emerged that may hinder effective active experimentation. Digital literacy gaps and difficulties in platform navigation were notable barriers, with 11.2% of respondents rating the platform as "difficult" to use and 3.1% describing it as "very difficult." These findings indicate that while a proportion of students are ready to independently apply their learning, ongoing technical support and targeted skills training will be necessary to ensure that all students can fully engage with the e-portfolio as a tool for professional development and lifelong learning.

6. Discussion

The findings indicate that the e-portfolio training effectively initiated the stages of **Kolb's (1984) Experiential Learning Cycle** while incorporating the principles of **Schön's (1983) Reflective Practice Model**. Together, these frameworks offer a comprehensive pedagogical foundation for understanding how students engage with, internalize, and apply learning in professional education (Kolb, 1984; Schön, 1983). In the **concrete experience** stage, most students, without prior exposure to e-portfolios, gained direct, hands-on experience through activities such as submitting assignments and navigating the platform. This aligns with Kolb's assertion that direct engagement forms the basis for deeper learning and subsequent conceptualization.

The **reflective observation** stage was demonstrated in students' recognition of the e-portfolio as a tool for self-assessment, progress monitoring, and identifying strengths and weaknesses. Here, Schön's (1983) concepts of **reflection-on-action** (evaluating after the event) and **reflection-in-action** (thinking during the process) were evident, as students engaged with the tool both retrospectively and in real time to enhance their practice.

During **abstract conceptualization**, students began connecting their reflections to broader professional theories, recognising the e-portfolio as a bridge between academic learning and field practice. Schön's model reinforces this process by highlighting reflection as essential for integrating experiential insights with professional standards and ethical frameworks.

In **active experimentation**, students expressed intentions to apply e-portfolio skills in field placements and professional development. However, readiness varied, with digital literacy gaps and platform navigation challenges impeding some students' capacity for independent use. This aligns with existing literature emphasising the need for sustained technical support and scaffolding in digital learning environments (Creswell & Creswell, 2018; Redecker & Punie, 2017). Overall, integrating Kolb's experiential stages with Schön's reflective practice principles created a structured pathway from experience to application. The e- portfolio thus emerged not only as a repository for their field work experience but also as a dynamic tool for ongoing reflection, professional identity formation, and lifelong learning in social work education (Braun & Clarke, 2006; Garrett, 2011).

7. Conclusion

This study explored the integration of e-portfolios in social work education at the University of Fort Hare, framed within **Kolb's (1984) Experiential Learning Cycle** and **Schön's (1983) Reflective Practice Model.** The findings demonstrate that the e-portfolio training effectively initiated the experiential learning cycle for most students, moving them from first-hand engagement to reflection, conceptualisation, and, in some cases, active application.

The e-portfolio emerged as more than a digital repository but it served as a pedagogical tool that facilitated **self-assessment, the integration of theory and practice**, and **professional identity formation**. However, the variation in student readiness, alongside identified challenges in digital literacy and platform navigation, shows the importance of sustained support structures. By aligning experiential and reflective learning processes, the e-portfolio holds significant potential to enhance the development of competent, reflective social work practitioners prepared for the complexities of professional practice.

8. Recommendations

Ongoing technical training should be provided to strengthen students' digital literacy, navigation skills, and content management. Structured reflective activities must be embedded in the curriculum to promote **reflection-on-action** and **reflection-in-action** (Schön, 1983). E-portfolios should be integrated across modules to create a continuous record linking theory and practice. Mentorship and peer support systems can enhance collaboration, feedback, and problem-solving. Assessment criteria should align with e-portfolio tasks, and institutional support must address digital literacy gaps while providing staff development. Ongoing research is needed to assess long-term impacts on employability, professional readiness, and lifelong learning.

Ethics Declaration

The author confirms that this study was conducted in accordance with relevant ethical standards and institutional guidelines for research involving human participants. Ethical clearance was obtained from the Inter-Faculty Kuman Research Ethics Committee: IFHREC-25/08-0299. All participants were fully informed about the purpose and procedures of the study, and their voluntary participation was secured through written informed consent. The privacy, confidentiality, and anonymity of participants have been strictly maintained, and all data were handled in compliance with applicable data protection regulations.

AI Declaration

This paper was prepared with the assistance of artificial intelligence tools, specifically ChatGPT (OpenAI), which was used to enhance language clarity and to support the development and refinement of ideas throughout the writing process. The author retains full responsibility for all critical analysis, content decisions, and the overall structure of the work. The use of AI adhered to relevant ethical and institutional guidelines.

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AI Intelligent Tutoring System Tailored to the Students' Personality and Neurodiversity

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Abstract: Over the past few years, several Universities and Educational Institutes have introduced e-learning platforms to support robust alternatives to face-to-face teaching, where students can benefit from them by revisiting topics covered in class without the constraints of time and space. However, despite this considerable flexibility, the role of the instructor as a facilitator is crucial to support learners when they have doubts on their learning or get stuck, by encouraging them to consider suitable strategies to approach the problem, or by providing clarification on some organisational aspects of the module. Providing quality feedback that is tailored to the individual needs of each learner, including personality and neurodiversity, is a challenging task for educators. Developing different methods of learner-specific feedback increases the workload and often fails to fully address learning gaps. The lecturer's empathy, which consists of a deep understanding of students' personal and social situations, care and concern for students' emotions, and compassionate responses, also poses a critical role in student success. Several intelligent tutoring systems have been implemented in e-learning platforms to try to provide immediate feedback to support students, but they focus more on providing feedback on content and often don't tailor feedback with adaptive empathy based on different students' personalities or neurodiversity. In this paper, an AI intelligent tutoring system based on LLM has been implemented within an e-learning platform, fine-tuned to the content and organisational aspects of the final year project module in the IT programme, with the aim of providing immediate feedback based on students' requests. The software can tailor comments to each student's personality and, where appropriate, neurodiversity, for example, showing genuine interest in responses from introverts or paraphrasing content to improve written comprehension for dyslexics. The neurodiversity information was taken from the user's profile, while personality was extracted using the MBTI (Myers-Briggs Type Indicator). Finally, the software was tested using a bespoke algorithm consisting in a matchmaking process able to detect the level of communication strategies (empathy, creativity, sensitivity) by cross matching the responses received with open online dictionaries to evaluate the effectiveness of the tailored responses.

Keywords: Generative AI, LLM, Intelligent Tutoring System, Immediate Feedback, Personality, Neurodiversity.

1. Introduction and Background

The advantages of online education, thanks to the flexibility and interoperability that make it easier access to learning resources, have led several universities and institutions to intensify the use of e-learning for on-line learning (Bigiotti, 2024) or developed as an integration of face-to-face lectures. (Nortvig, 2018). In the e-learning courses, the online tutor plays a crucial role for the success of the e-learning courses, acting as a facilitator able to guide students in the learning process by maintaining their involvement (McPherson, 2004) and providing feedback on their activities (Klimova et al., 2011) to clarify their doubts and allow them to increase their knowledge and skills. However, providing feedback is a challenging task for teachers and often students perceive the feedback provided not always effective because it is unclear, untimely, without a focus on improvement and without strategies for uptake. (Paris, 2022) In particular, if the feedback is not timely in an online environment, it could also be disadvantageous for a student who, despite the flexibility offered by the e-learning course, must interrupt his online study and wait for the 1to1 or face-to-face meetings with the teacher to clarify the doubts. Delayed feedback can indeed have a negative impact on learners' engagement (Boudin et al., 2024), which can affect their motivation and performance. In contrast, evidence confirm that immediate feedback is more effective than delayed feedback (Shute, 2008) and has the advantage of promoting active learning and contributing to improved cognitive outcomes. (Nalli, 2023)

The need to provide immediate support to students following online courses has led several institutions to develop Intelligent Tutoring Systems (ITS). The ITS is a computer-based learning software that can provide individual and adaptive feedback to students and act as an e-tutor able to provide personalised support to meet their needs without the intervention of the instructor (Bouchard, 2008) (Lin, 2023). Recent studies raised concerned about the efficacy of ITS with minimal intervention of the instructor (Son,2024), argued that it can

works properly only with specific topics (Shih, 2023), or because it doesn't always recognise their own mistakes and provided incorrect feedback. (Matsuda, 2013)

The recent development of GenAi with the spread of several LLM tools, accessible to everyone with chatbots (Clark et al., 2025) has contributed to increase the reliability and accuracy of the ITS (Wang, 2025). However, the IT solutions integrated into e-learning platforms do not effectively consider the different needs of students in terms of personality and neurodiversity, as they are often generic and lack the necessary customisation to meet the needs of individual users. (Mukherjee, 2025)

Personalised learning is an educational strategy that consist of a tailored education to the individuals, enabling them to enhance their understanding, abilities, perspectives and knowledge. (Shemshack et al., 2020). Neurodiverse learners can benefit significantly from a personalised learning because, unlike common learners who can organise their learning methods autonomously, they often require individual support to structure their own learning pathways, especially in a self-paced online course usually based on the student-centre approach.(Clouder et al., 2020) For example, students with ADHD prefer active and creative environments (Boot, 2020), introverts feel more comfortable quiet, reflective, and controlled settings (Touvinen, 2020).

The paper proposes a novel approach of an e-learning Intelligent tutoring system based on LLM, fine-tuned to the students' characteristics to maximise their learning experience by providing immediate feedback and recommendations (Polatidis et al., 2022) tailored to their personality and neurodiversity. This should contribute to bridge the gaps of the students and help them to enhance their motivation in the study and improve their academic performance.

2. Design Based Research

This work considers the characteristics of the individual learner as its primary and most important input.

The characteristics of the learners are characterised by the personality and neurodiversity that have a crucial impact for the effectiveness of the intelligent tutoring system. Indeed the intelligent tutoring system need to tailor the responses to meet the needs of the learners by providing the answer with the correct style and tone based on the different characteristics able to maximise the learning experience.

While neurodiversity information was taken from the user's profile, the personality was extracted by using Myers-Briggs Type Indicator (MBTI) by providing the related questionnaire which returns one of the 16 personalities. The MBTI is a psychometric questionnaire that measures users' preferences in terms of perception and decision-making, considering the following dimensions: Extroversion/Introversion, Sensing/Intuition, Thinking/Feeling. Feeling and Judging/Perceiving. (Ahmad, 2020) Recent studies have highlighted the effectiveness of the MBTI test in the educational field such as helping teachers to understand the needs of students and design instruction properly (Rodriguez, 2013) or as framework for categorising personality preferences and providing valuable insights (Vaughans, 2024)

Feedback should be prioritising these characteristics to be effective and as such the followed methodology is divided into 4 distinct phases:

- Phase 1: Capture the individual learner characteristics
- Phase 2: Create an individual Learning Diagnosis Profile (LDP)
- Phase 3: Interact with the learner to determine the context and motivation behind a learning request
- Phase 4: Fulfill the request and enhance it based on the LDP
- Phase 5: Evaluate the learner's interaction based on the learner's satisfaction as measured by the provided results as well as correlate satisfaction with the LLM's tuning against the individual LDP.

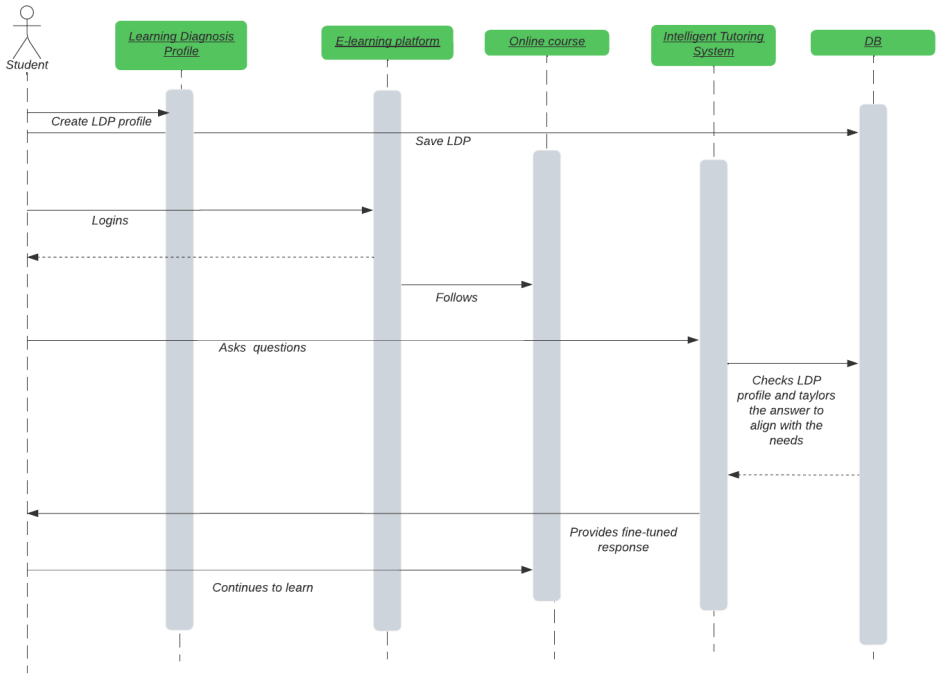


Figure 1: Sequence diagram which describes the flow of a student's interactions with the Intelligent Tutoring System when following an online course.

Phase 1 is designed to interact with the learner providing some sample questions to quantify the background, potential disability and learning method preference of each individual learner. This phase comprised 17 short questions that could be answered via multiple choice and some concise free response questions. Phase 1 is a prerequisite to mitigate the cold start problem and the only way of identifying the learner's background.

In the phase 2 an LDP is created based on the prerequisites of Phase 1. For this design 22 different profiles of MBTI personality and neurodiversity were considered, as seen in Table 3. LDPs are also considered in the tuning and pre-programming of any text requests to the LLM ITS to account for accurate responses against each individual learning case.

Regarding the phase 3 the learners are called to interact with the system while following on-line courses, providing relevant learning requests without disclosing any learning bias - requests were funnelled to ITS as genuine learning requests and the ITS did not identify any individual learning characteristics at this phase.

In the phase 4 the ITS provides answers to any learning request using a combination of the user input from Phase 3 as well as knowledge from Phase 2. The ITS considers each individual case base and attempts to tailor the output to the learner's needs that allow them to obtain an early clarification about the doubts they can encounter.

Finally, the phase 5 evaluates the effectiveness and quality of the learner's interaction with the system. For this phase a custom research component evaluates the ITS by matchmaking the fine-tuned responses against its LDP, accounting for unique personality traits or neurodiversity with different word categories. Phase 5 is designed to identify features such as empathy, Creativity and Tone Sensitivity.

3. Implementation

The Intelligent Tutoring System has been implemented using the Flask web framework and a database and is run in a virtual machine based on Ubuntu 20.04.

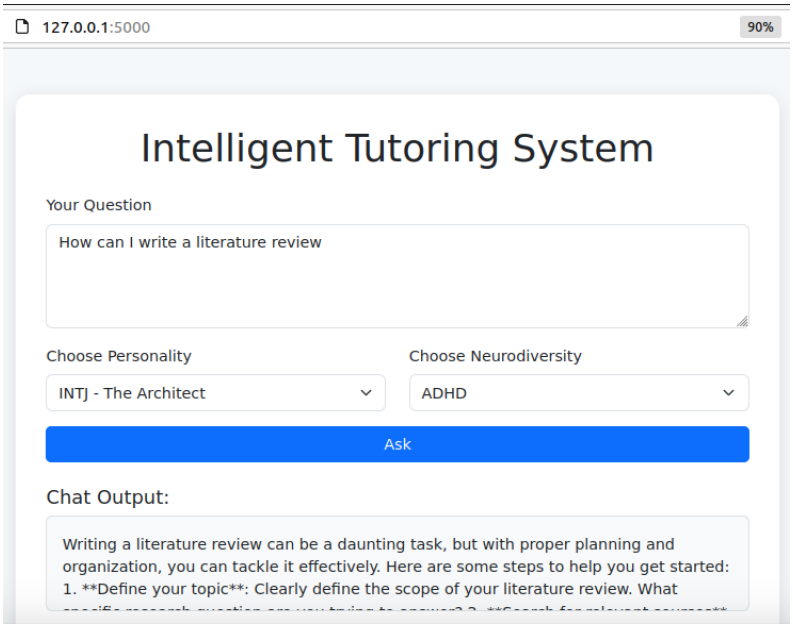


Figure 2: Example of responses tailored based different MBTI personality

The ITS currently operates as standalone software within an online environment, enabling users to easily access it for testing purposes. Although the design includes integration with the database, the software interface currently comprises a text box in which users can write questions and select their personality or neurodiversity from two drop-down menus. The software has been written in Python and developed by integrating the OpenAI API using the GPT-3.5 Turbo model. The model has been fine-tuned by mapping the personality and neurodiversity options selected by the student, offering tailored prompts to guide the ITS's responses.

```
    'Autism': "You are an assistant that is precise, logical, and
focused. Your responses may be very detail-oriented and structured, with
a preference for clear, direct communication and no ambiguity.",

    'Dyslexia': "You are an assistant that provides clear, simple, and
straightforward responses. You may sometimes use concise language,
making sure the information is easy to follow and not overwhelming.",
```

Figure 3: Example of fine-tuned prompt related to neurodiversity.

The responses are shown in the chat output and are also collected in a CSV log file on the server. This includes the user ID, personality, neurodiversity, user input and assistance response. This helps evaluate the responses provided and understand the reliability of the LLM. To evaluate the ITS, new software has been developed that can match the fine-tuned responses generated for each personality or neurodiversity with different word categories extracted using online lexicons, which identify features such as empathy (Empathy Lexicon, n.d.), creativity (Creative Writing Vocabulary, n.d.) and tone sensitivity (NRC Emotion Lexicon, n.d.). The software then returns the percentage of features in each ITS response based on the occurrences found. The software, which was developed using Python, utilises an input tokenization process to break the text into shorter tokens, making it ready to be processed by software that can analyse word frequency using the Python “collections” library. The software counts trait-relevant keywords and checks their occurrence in the provided dictionaries, returning the percentage for each feature. Finally, the software generates a CSV file that creates a table containing the question asked of the ITS, the personality type, the response and the percentage achieved for each specific trait.

4. Testing and Evaluation

The ITS has been tested by asking the question 'How can I write a literature review?' with different settings in terms of personality and neurodiversity. Specifically, 23 responses were collected by the ITS and then grouped in a CSV file generated directly by the platform and uploaded to a dedicated repository (Github repository, n.d.).

Table 1: Example of responses tailored based different MBTI personality

Question	Personality	Example of Response
How can I write a Literature Review?	ISFP - Adventurer	Writing a literature review can be a wonderful experience of exploration and synthesis. Here are some gentle steps to guide you through the process: 1. **Define Your Purpose:** Clarify the focus and scope of your literature review. What are you trying to achieve? What specific research question are you addressing? 2. **Gather Sources:** Begin by collecting a wide range of relevant sources such as academic articles, books, and other materials. Make sure to keep detailed notes as you read through them. 3. **Organize Your Thoughts:** Create an outline to structure your literature review. Think about different ways to categorize and group the sources based on themes, methodologies, or other relevant factors. 4. **Start Writing:** Begin by introducing the topic and providing context for your literature review. Then, summarize and analyze the key findings and arguments from your sources. Remember to connect the information in a coherent and logical way. 5. **Create a Narrative:** Weave together the different sources to create a narrative that flows smoothly and engages the reader. Highlight connections, disagreements, and gaps in the existing literature. 6. **Critical Analysis:** Be sure to critically evaluate the strengths and weaknesses of each source. Consider the methodology used, the credibility of the authors, and the relevance of the findings to your research question. 7. **Synthesize and Conclude:** Finally, synthesize the information you have gathered and conclude by summarizing the main findings, discussing the implications of the research, and suggesting potential avenues for future study. Remember, writing a literature review is a creative process that allows you to engage with the existing scholarship in a meaningful way. Embrace the opportunity to contribute your unique perspective and insights to the conversation.
How can I write a Literature Review?	ESTP - Persuader	To write a literature review: 1. **Define your topic**: Clearly define the scope and focus of your literature review. 2. **Gather sources**: Collect relevant academic papers, articles, books, and other sources related to your topic. 3. **Organize your sources**: Create a system to keep track of the sources you find, such as using citation management tools. 4. **Read and take notes**: Summarize the key points, methodologies, findings, and arguments of each source as you read. 5. **Identify themes and gaps**: Look for common themes, patterns, and gaps in the existing literature. 6. **Outline your review**: Create an outline that organizes your sources and key points in a logical order. 7. **Write your review**: Start writing your literature review, making sure to include an introduction, body paragraphs, and a conclusion. 8. **Cite your sources**: Properly cite all the sources you use in your review using the appropriate citation style (e.g., APA, MLA). 9. **Edit and revise**: Proofread your review for clarity, coherence, and accuracy. Make sure it flows well and addresses your research question. 10. **Seek feedback**: Consider sharing your draft with peers or professors for feedback and suggestions for improvement. Remember, a literature review should not just summarize existing research but also analyze, evaluate, and synthesize the information to contribute new insights to the field. Good luck!

As can be seen, the ITS offers different responses depending on a student's personality or neurodiversity. The aim is to suggest the most suitable option to empower learning and fill in skill gaps. Table 1 shows an example of different outputs. First, for the ISFP (Adventurer), the ITS provided a response that used decorative language, such as “wonderful experience”, and engaging sentences that reflect the student's personality and enjoyment of socialising. In contrast, the response for the ESTP (Persuader) is shorter, encouraging the student to view it as a challenge. It provides clear, brief instructions and uses the phrase 'good luck', which is more suited to students who are practical, skilled at problem solving, and drawn to challenging experiences.

Table 2: Example of responses tailored based different neurodiversity

Question	Neurodiversity	Example of response
How can I write a Literature Review?	Autism	Writing a literature review involves the following steps: 1. **Define your topic**: Clearly define the research question or area of focus for your literature review. 2. **Search for relevant sources**: Use academic databases, libraries, and other resources to find scholarly articles, books, and other sources related to your topic. 3. **Evaluate the sources**: Assess the credibility, relevance, and quality of the sources you find. Consider the date of publication, the author's credentials, and the methodology used in the research. 4. **Organize your sources**: Create an outline or a concept map to organize the sources you've gathered. Group them based on themes, theories, or key concepts. 5. **Summarize the key findings**: Write a brief summary of each source, focusing on the main arguments, methodologies, and results. 6. **Identify gaps in the research**: Highlight any areas where there is a lack of research or conflicting findings. This can help you identify the contribution your literature review will make. 7. **Synthesize the sources**: Analyze the similarities and differences between the sources you've reviewed. Look for patterns, trends, and contradictions. 8. **Write the literature review**: Start with an introduction that provides an overview of the topic and explains the purpose of the review. Then, organize the body of the review based on your outline or concept map. Make sure to include in-text citations for all sources. 9. **Conclusion**: Summarize the key findings of your literature review and discuss their implications. You can also suggest areas for future research. 10. **Edit and revise**: Review your literature review for clarity, coherence, and accuracy. Make sure your writing is well-structured and free of errors. By following these steps, you can create a comprehensive and well-organized literature review.
How can I write a Literature Review?	Dyslexia	Writing a literature review involves: 1. Selecting a topic 2. Searching for relevant sources 3. Reading and analyzing the sources 4. Organizing your review (e.g., by themes, chronologically) 5. Writing the review (introduction, body, conclusion) 6. Citing sources properly (APA, MLA, etc.) You should aim to summarize, analyze, and synthesize existing research on your topic. Be sure to include critical evaluation of the sources and discuss their relevance to your own research or argument.

Table 2 shows the responses generated for neurodiversity profiles, particularly those relating to autism and dyslexia. The response for the autism spectrum uses simple, direct language, such as 'define the research question' or 'write a brief summary of each source', avoiding metaphors or ambiguity that could limit comprehension of the profile. In contrast, the dyslexic profile yields a shorter answer characterised by structured sentences to improve readability and understanding by reducing the cognitive load that longer texts can cause.

Table 3: Evaluation of the ITS responses in terms of empathy, creativity and tone sensitivity.

Personality/Neurodiversity	Description	Empathy	Creativity	Tone Sensitivity
INTJ	Architect	4.4%	0.4%	4.4%
INTP	Logician	**13.7%**	3.4%	6.8%
ENTJ	Commander	0.0%	5.4%	0.0%
ENTP	Debater	**14.8%**	3.7%	3.7%
INFJ	Counselor	7.4%	7.4%	3.7%

Personality/Neurodiversity	Description	Empathy	Creativity	Tone Sensitivity
INFP	Mediator	3.4%	**13.6%**	3.4%
ENFJ	Giver	8.8%	0.0%	**8.8%**
ENFP	Champion	**19.0%**	3.2%	6.3%
ISTJ	Inspector	**9.5%**	0.0%	3.2%
ISFJ	Protector	**25.2%**	3.2%	**9.5%**
ESTJ	Director	4.2%	4.2%	4.2%
ESFJ	Caregiver	**9.5%**	6.3%	**9.5%**
ISTP	Crafter	4.0%	4.0%	0.0%
ISFP	Artist	**14.0%**	**18.0%**	7.2%
ESTP	Persuader	0.0%	**13.8%**	4.6%
ESFP	Performer	**10.6%**	3.5%	3.5%
ADHD	Attention Deficit	7.1%	**10.7%**	0.0%
Autism	Social communication difficulty	3.5%	**14.0%**	3.5%
Dyslexia	learning difficulty	5.0%	**12.0%**	0.0%
Dysgraphia	difficulty to write legibly	6.8%	3.4%	6.8%
Dyspraxia	coordination difficulties	5.0%	4.3%	0.0%
Dyscalculia	process numbering difficulty	6.5%	3.3%	6.5%

Table 3 illustrates the results obtained by performing the matchmaking software achieved for each selected personality type or neurodiversity. Despite the percentages not being particularly high, there are some interesting results which demonstrate how the LLM tailors its responses to meet students' needs. Empathy achieves the highest scores, demonstrating its importance in formative feedback. It creates a safe place where students don't feel judged and are open to learning from mistakes, which increases their motivation and engagement (Johnson, 2020). In individuals with certain personality types, such as ISFJ (Protector), ENFP (Champion) and ENTP (Debater), empathy scores exceed 14%. In contrast, scores for neurodiverse individuals decreased significantly. This is because neurodiverse individuals usually struggle to understand social awareness, which limits their ability to develop empathic understanding (Chapman, 2022). Instead, creativity seems to achieve higher scores in neurodiversity than in different personality profiles (except for the Artist, Mediator and Persuader, for whom creativity is one of the main features). This is because creative interventions in neurodiverse individuals generate ruptures and new forms of understanding and action that differ from traditional ones (Elisondo, 2025).

Tone sensitivity is lower in neurodiverse individuals due to their impaired understanding of emotions (Dawson, 2025), so the LLM responses seem to reduce this feature to avoid misinterpretation of concepts. However, it is interesting that higher scores are returned for personalities such as ENFJ (Giver), ESFJ (Caregiver) and ISFJ (Protector) due to their ability to be highly emotionally attuned to others, understanding their needs and concerns.

5. Conclusion

The paper demonstrated preliminary results on formative feedback tailored to students' personalities, as well as offering neurodiverse students suitable responses to help bridge their skill gaps. This work can be expanded substantially to provide students with alternative learning strategies and thus having an effective assistive tool to support their continued learning in the future.

The results demonstrate the effectiveness of the implementation of the Intelligent Tutoring System developed using the OpenAI API, specifically the ChatGPT 3.5 model. The ITS provides clear and accurate responses that can guide students on how to write a literature review by offering the formative feedback necessary for

structuring a strong review. This offering has to expanded and quantified further but so far the results seem promising.

The ITS also demonstrated its effectiveness in tailoring answers based on personality type and neurodiversity, achieving scores of 25% empathy, 18% creativity, and 9.5% tone sensitivity, increasing or decreasing features to meet learners' needs. However, concerns may arise when requests need online searches or deeper information and this could be provided by new models, such as ChatGPT 4.0. In addition, as this work only evaluated the feasibility of creating the ITS platform, a thorough investigation is required to adequately evaluate its performance. A future extension of this work could involve conducting a case study where the students can access the ITS during their self-pace online courses and collect their feedback about the responses provided . This would evaluate the effectiveness by considering the user perception and the reliability as an assistive tool for neurodiverse students during the learning.

Ethics Declaration

This is not applicable as the study only consists of a stand-alone software implementation, and doesn't involve human participants, personal data or interaction with users.

AI Declaration

The AI hasn't been adopted for the content development. A translator tool was used to refine some sentences in the paper. The OpenAI API the has been linked to the software developed in the paper.

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Enhancing Student Learning and Creativity Through LLM-based PBL Semester Projects

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Abstract: With the advent of Large Language Models (LLMs), there are becoming a larger part of people's everyday lives – in their work, personal life or learning. Especially for programmers and software developers, learning how to best utilize LLMs as part of their work is becoming a crucial skill. This is especially important to students and educators have duty to prepare them to best tackle all obstacles and best utilize AI as a tool in their programming arsenal. Research into this normally focuses on the use of LLMs as tools for teaching and evaluation. This research takes another approach presenting the results from integrating LLMs as a central concept of project-based learning (PBL) semester projects for students from multiple grades from 5th semester bachelor's to 10th semester masters. All projects develop interactive systems both traditional and virtual reality and encompass a wide variety of contexts that utilize AI as a central mechanic. We show the attitude of the participating students towards utilizing LLMs, their understanding before and after the projects of AI systems and their overall satisfaction with utilizing relatively new and open technology like LLMs. To our knowledge, this is one of the first such meta-analyses of long-term effects of utilizing LLMs in students' work. We demonstrate the positive impact of utilizing LLMs on students' motivation and learning and propose several best practices to avoid some of the pitfalls associated with using these tools.

Keywords: Large Language Models (LLMs), Interactive Systems, Project-based Learning (PBL), Student Education, Programming

1. Introduction

Students increasingly use LLMs for brainstorming, writing, editing, design, development, and programming. Educators must guide their use to prevent shallow learning and over-reliance while maximizing their potential to enhance STEM education, creativity, and project development (Wu, Duan & Ni, 2024). LLMs are also much versatile tools that can be employed as parts of interactive applications for making them more robust, reliable, and boosting the possible visualization, interaction and generational possibilities with traditional procedural algorithms (Kapania et al., 2024). Harnessing their power requires creative and outside-of-the-box thinking, as literature on human-computer interactions with LLMs is still being developed and refined (Pang et al., 2025). The best way for developing such skills is by building applications that utilize AI and facing all the decisions, problems and skills needed. Again, educators should be the ones to facilitate this process by providing projects that tackle real-world problems using LLMs.

Like other emerging technologies such as extended reality (XR), the internet of things (IoT), and personal robotics, integrating LLMs into university curricula helps students engage with them in a safe and natural environment (Ferreira & Qureshi, 2020; Maenpaa et al., 2017; Jung, 2012). Understanding LLMs requires knowledge of mathematics, statistics, machine learning, and deep learning. While not all students receive the full theoretical background needed to develop such models, they should still be able to "look inside the black box," adjust them, and apply them effectively. Project-based learning (PBL) offers a strong framework for this, linking core subjects with modern technologies like LLMs through real-world projects (Park & Ertmer, 2007; Zhang & Zhang, 2024; Nikolov, 2024). Such projects not only strengthen learning but also enhance student portfolios. Since LLMs are expected to become integral to many future jobs, this approach prepares students for the evolving workforce (Eloundou et al., 2024).

LLMs have been successfully integrated as parts of games (Gallotta et al., 2024), learning applications (Pang et al., 2025), visualization tools (Khan et al., 2025), accounting, medical systems (Qiu et al., 2024), historical preservation and museum work (Zhang et al., 2024), personal assistants, among others. Looking at all the possibilities we initialized a call for students willing to select LLM-focused projects between autumn 2023 and spring of 2025. The project call was done both for bachelor and master students and was intentionally left open for interpretation, with the possibility for working with external partners. In that period 6 projects with groups of 2 to 5 students were initialized with topics ranging from LLMs as guides and storytellers, to non-playable characters and audience. Five of the projects were concluded successfully, with one still ongoing. A meta-analysis of the projects showed that as part of 4 of them an in-depth investigation of deep learning and LLM-technologies was made, 4 projects were made multimodal using additional speech-to-text and text-to-speech modules and 4 projects combined LLM technology with virtual reality. After completing their projects, students

were surveyed about their experiences and their learning goals. An overwhelming majority of them specified that they would utilize LLMs and deep learning as a main building block in their projects in the future. Students felt inspired to explore deep learning further, with many reported improved programming and game development skills. The main challenges cited were prompt engineering difficulties, hardware-related latency, and the unpredictable nature of LLM interactions.

The main contributions of this work are:

- A report and meta-analysis of the integration of LLM-based student semester projects in a project-based learning context.
- Overview of the experiences and learnings of the students involved in the projects.
- A set of recommendations and best practices that can be useful to other researchers and educators planning to propose LLM-centered projects.

2. State of the Art

2.1 LLMs in Higher Education

Large language models (LLMs) are increasingly used as teaching tools, supporting programming, writing, research, and mathematics (Ta et al., 2023). This is particularly valuable given limited teacher resources, growing class sizes, and expanding demands for higher education (Bennedsen & Caspersen, 2008). LLM-based educational agents can generate customized exercises and feedback (Estévez-Ayres et al., 2024). While they provide specific feedback, repetition and prompt refinement are often needed for more natural explanations (Letteri & Vittorini, 2024). As exercise providers, LLMs show promise by tailoring tasks to student levels and combining multiple agents for more complete learning experiences (Jury et al., 2024; Song, Zhang & Xiao, 2024). However, challenges remain, including hallucinations, lack of transparency, and limited reasoning, which hinder broader adoption. Most research focuses on LLMs as tutors, helpers, or exercise designers (Yan, Nakajima & Sawada, 2024), while fewer studies examine their role as core components in student projects. Yet, integrating new technologies and programming concepts in projects has been shown to enhance learning outcomes and accelerate the transition from novice to experienced learners (Iftikhar, Guerrero-Roldán & Mor, 2022; Wekerle, Daumiller & Kollar, 2022).

2.2 Integrating LLMs in Human-Computer Interaction Projects

More and more fields utilize LLMs as a core building block, leveraging the possibilities of generating dynamic content on the fly (Kapania et al., 2024), the greater immersive properties that come with it (Cite), and the new interactions that become possible with it (Yang et al., 2024). The LLM-ification of the human-computer interaction space has been rapid and expanding (Pang et al., 2025), encompassing different roles, use cases, and depths of integration, opening even more possibilities of for closer interactions (Wan et al., 2024). Some examples of these are shown next. LLMs are being used in medical interactive applications for communication with patients (Yang et al., 2024), dynamic decision systems (Rajashekar et al., 2024), and personalized health care helpers (Cardenas et al., 2024). They are also used in game development as collaborative game assistants (Sidji, Smith, & Rogerson, 2024), social VR game agents (Wan et al., 2024), or interactive game storytellers (Yong & Mitchell, 2023). In cultural preservation and museums LLMs are used as tour guides (Wang et al., 2024), for personalizing exhibitions (Constantinides et al., 2024), and for enhancing cultural representation (Hutson, 2024). These examples demonstrate the versatility of the technology, but also the need for a deeper understanding of LLMs correct and ethical usage, as well as the many hurdles in integrating them into applications from user comfort, problems with interactions, the need for larger hardware resources, among others. Novice programmers need to be able to orient themselves with these new requirements, so they can more easily step into the job market.

We see that current pedagogy and HCI research into the use of LLMs focuses on their use as educational tools, and not in a more meta-analysis way – how utilizing them in exercise and project assignments can push students to more organically understand the technology. Even with their complexity generative models and LLMs are still tools, and the best way to learn a tool is to use it to build projects. In this paper we look at exactly that – how project-based learning assignments that were specifically directed towards understanding and utilizing LLMs have in the long run influenced students. To our knowledge currently there is a very low amount of such research, due to the relatively small amount of time that LLMs have become widely spread.

3. Projects Overview

To get a better understanding of how utilizing LLMs in project-based learning semester projects can affect students learning and interest in machine learning we conducted a pilot study. Between autumn of 2023 and spring 2025, as part of the bachelor's and master's education of STEM students we proposed several LLM-centric semester projects that students could choose to work on as part of their PBL education. As students are free to choose from a pool of projects or propose their own variants of projects, the LLM-based project proposals were put in a larger pool with other non-LLM ones. The proposed LLM projects were made on purpose vaguer, as to give the possibility of students pushing them in an interesting and stimulating direction. If interest was expressed by the students the projects could also be connected to external collaborators like companies, municipalities and such. Student groups were formed based on the project and can be between two and five people. As part of their curriculum students have two courses – one in bachelor's and one in the master's where they learn about machine learning and AI, and to a smaller extend about deep learning. Development and training of LLMs is not formally taught as part of the curriculum, making all learning around it based on project development. Figure 1 shows the idea of the semester project with LLMs as a core concept, together with other core technologies required by the curriculum shown as blue circles and additional concepts that students can focus on if they align with their interests in green.

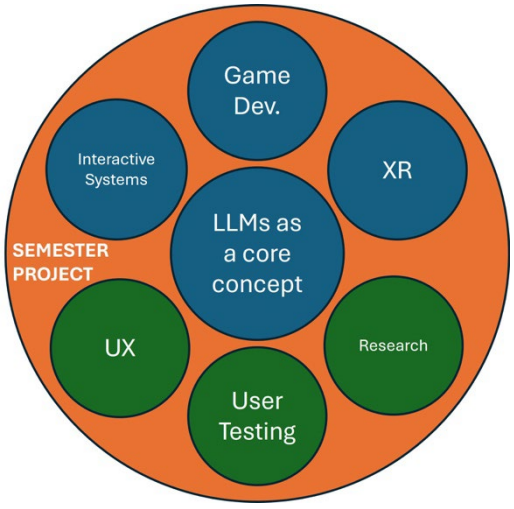


Figure 1: Idea of the proposed semester projects, with blue circles signifying required concepts and green circles representing concepts that students are free to chose to focus on.

3.1 Used Technologies

Over four semesters, six student groups pursued LLM-centric projects: two fifth-semester bachelor groups in autumn 2023, one sixth-semester bachelor, one eighth-semester master, and one tenth-semester master group in spring 2024, and one sixth-semester bachelor group in spring 2025. All projects focused on human-computer interaction and were built in Unity. Four combined LLMs with VR to enhance immersion and dynamic interactions. Another four integrated multimodal communication, using speech-to-text and text-to-speech libraries such as Whisper and Polly. Two addressed challenges of text generation speed and its effect on interaction, while three explored extending conversations with facial expressions and gestures for richer context. Finally, four projects conducted in-depth analyses of LLM models and architectures, including head-to-head comparisons, literature reviews, and preliminary user testing. Table 1 summarizes the technologies and evaluations.

Table 1: Analysis of the technologies and modalities used in the projects

Project	Used LLM	Multimodal Interaction	Connecting LLM with the Application	Additional Technology
Project 1	ChatGPT 3.5, 4.0	Text, Speech, Virtual Position	OpenAI API	VR, Whisper AI
Project 2	ChatGPT 3.5	Text, Speech, and Gaze	OpenAI API	VR, Amazon Poly
Project 3	ChatGPT 4.0	Text, Speech, Gestures, Facial Expressions	OpenAI API	VR, Whisper AI

Project	Used LLM	Multimodal Interaction	Connecting LLM with the Application	Additional Technology
Project 4	Mistral 7B	Text and Speech	LLMUnity (undreamai ,2025)	VR
Project 5	Nvidia Convai	Text and Speech	Convai API	N/A
Project 6	DeepSeek	Text	LLMUnity (undreamai ,2025)	N/A

3.2 Project Themes

Two of the projects were developed with external partners in mind. The first one was a collaborative work with a museum for building an immersive experience where LLMs were used as guides to the users, which played roles in the historical period. The immersion and the sense of being there of users was tested between using scripted answers and fully dynamic LLM-power answers from the digital guides. This project was later extended to a second project looking at the possibility of LLMs also used for gestures and facial expressions on non-playable characters (NPCs). There user interactions and sense of realism were compared between LLM-powered museum guides which could and could not provide facial expressions and gestures. The third project investigated the difference between spoken and menu interface interactions with LLM NPCs in a murder mystery game and how immersed and present users tended to be. The fourth project was directed towards LLMs as story tellers, providing commentary towards the actions of players. The students looked at requirements for time between actions and LLM commentary, the perceived importance of the interaction and the difference between tonality of what the LLM has said. All four projects were made as VR experiences. The fifth project took an even more structured approach to how can the longer wait time between people speaking and an LLM processing the answer and replying to them be addressed. User interface additions like loading bars and indicators were compared to the addition of spoken words indicating thinking. The sixth project took the idea of utilizing LLMs as spectators of digital boardgames, where user performance and interest in the game was tested when a commentary from the spectators was present or not. Example visuals of the projects are given in Figure 2 and a thematic analysis of the projects in given in Table 2.

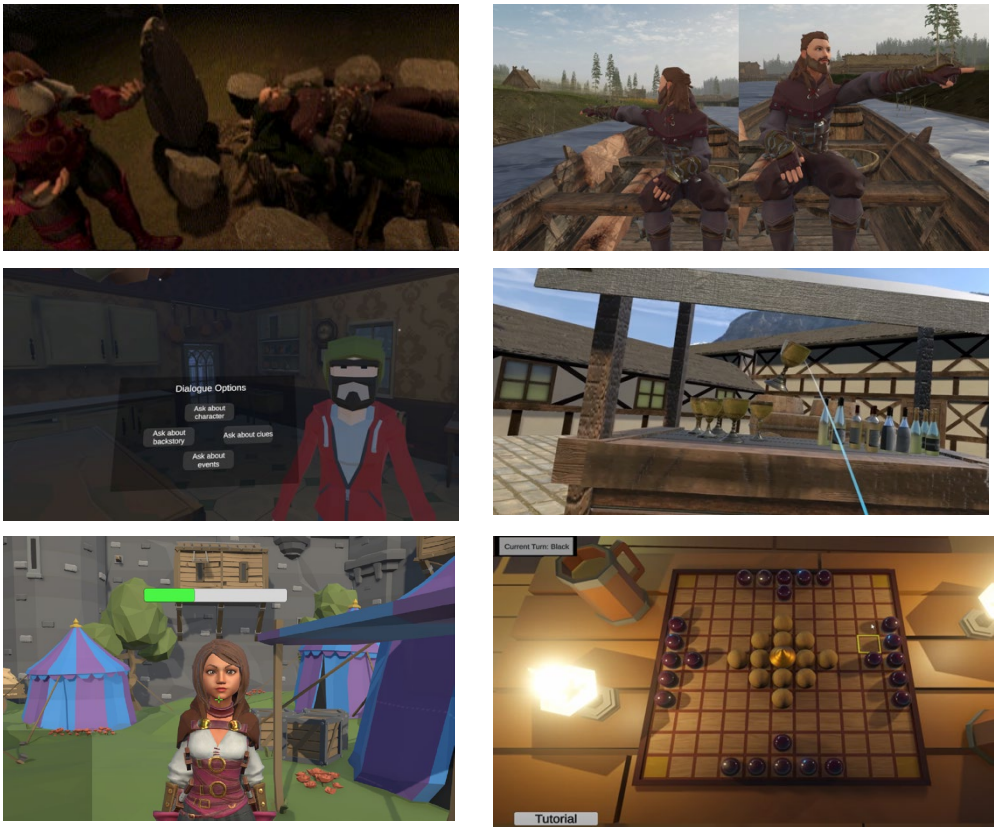


Figure 2: Visuals from the 6 projects discussed in the paper build in Unity. Projects utilized different gameplay mechanics and multimodal interactions.

Table 2:

Project	LLM Role	Tested Parameters	Focused Literature Review	Amount of Test Participants
Project 1	Historical Museum Guide	Difference in the sense of being there in users when interacting with an LLM and scripted virtual guides	Yes	28
Project 2	Historical Museum Conversational Agent	Do facial expression and gestures on a LLM agent help with user presence	Yes	26
Project 3	Murder Mystery NPCs	Presence and ease of interaction with LLMs – speech versus menus	Yes	24
Project 4	Storyteller	How users react to different tonality of commentary and importance of interactions	Yes	17
Project 5	Conversational Agent	How can the "dead air" while LLMs generate answers be filled	No	24
Project 6	Game Audience	Can the presence of an LLM-powered audience boost interest in boardgames and willingness to learn	No	14

4. Post Project Questionnaires

After the projects a questionnaire was provided to all student participants in the groups, from those students 10 students provided feedback. We wanted to provide a self-reported overview of the learning goals and overall feedback from utilizing LLMs in the projects. The questionnaire consists of twelve 7-point Likert scale statements, to which students can agree or disagree and two open ended feedback questions. The questionnaire is given below.

Q1. Developing projects connected to LLMs has given us a better outlook on modern technology.

Q2. I have used the gained knowledge from the LLM projects into the next projects or my current work.

Q3. I see the use of LLMs in interactive systems and human-computer interaction as the next step of modern software design.

Q4. It took me a long time to understand LLM technology and how to best utilize it for the project.

Q5. I think LLMs and deep learning needs to be studied more as part of the curriculum.

Q6. I have more ideas of projects connected to LLMs.

Q7. I am interested in Machine Learning and Deep Learning after working on the LLM project.

Q8. The university is equipped for projects containing strong deep learning and LLM parts for interactive applications - provided software, hardware, infrastructure.

Q9. I use LLMs more in my work (ChatGPT, Gemini, Grok, etc.) after working on the project.

Q10. Using game engines like Unity or Unreal with LLMs is straightforward.

Q11. I feel that I am a better programmer after working on the project.

Q12. I better see all the possible problems with utilizing LLMs as part of interactive applications.

Q13. If you have other ideas for using LLMs for interactive applications, games, VR/AR, etc. please give a short overview or examples.

Q14. Feedback from the project/projects you did containing LLMs.

The results from the Likert scale questions of the questionnaire are given in Figure 3 as a column diagram. In addition, looking at specific questions connected to learning, we can see that with some exceptions most students felt positive for how working with LLM-centered projects have helped and motivated them (Figure 4).

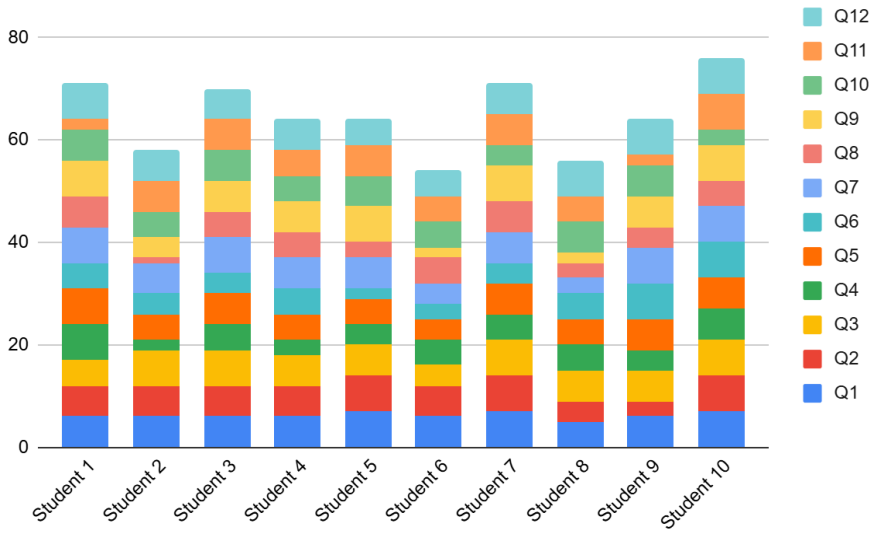


Figure 3: Stacked bar chart representing the results from all 12 questions from the students. We can see that overall students felt positive in their feedback with overall Likert scores.

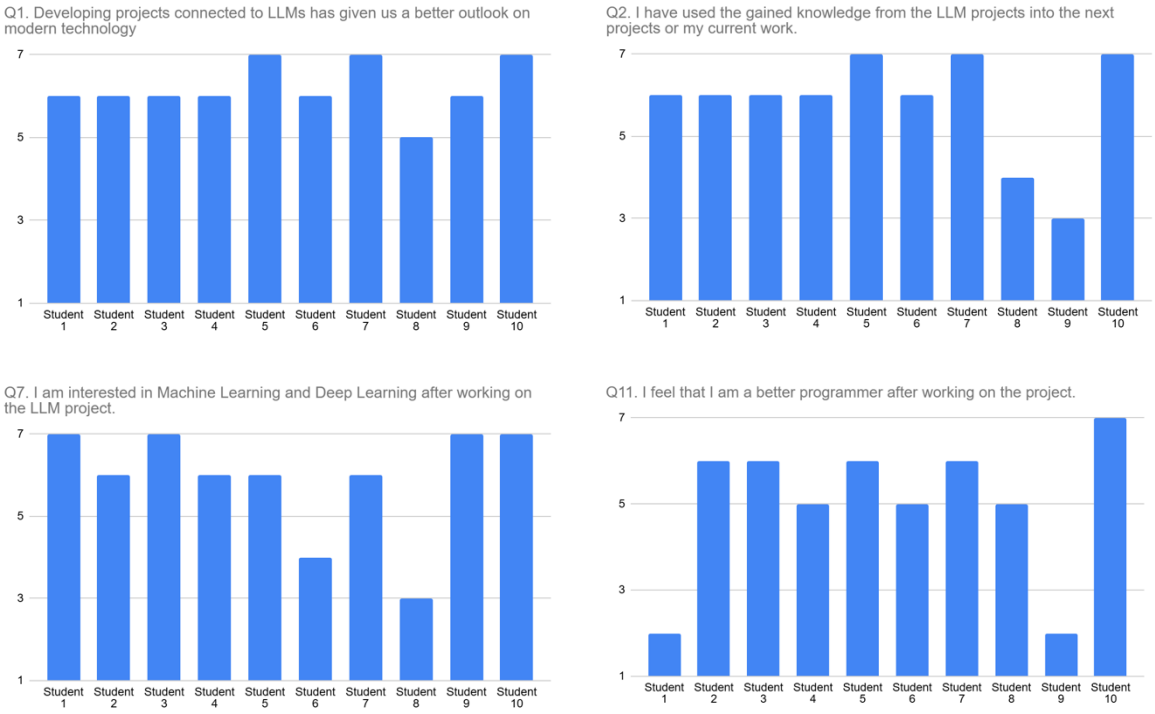


Figure 4: Examples of individual Likert question results, connected to students' self-perceived skill and motivation connected to working with the LLM-centered projects.

5. Lessons Learned and Best Practices

The feedback from students on their projects demonstrated that they enjoyed working with this new technology and had the opportunity to delve deep into how it can be best compared, implemented and tested. It also shows the need for deeper education of students into not only using LLMs in their education, but how to best utilize them as part of larger projects. Multiple students expressed the opinion that that they were missing ground knowledge on how LLMs are constructed and how they work, leading them to a lot of trial and error and frustration. This was especially present with frustrations towards the prompt engineering required to make the LLM behave as needed. Answers such as the ones below shows the need for better LLM literacy as part of the curriculum, as students end up relying on online sources with conflicting or outright incorrect information.

- "Prompt engineering requires a lot more work than you may initially think. You can try to account for as many situations as possible, but during tests you will always be made aware of something you hadn't considered."
- "A lot of time spent prompt engineering, which might not lead to as much learning. (However, it clearly shows the weaknesses of the model)."
- "I really liked working with it for the murder mystery we did, but prompt engineering was quite an issue because there were no guidelines for how to create good prompts. We had to change the system prompt a lot in order to minimize hallucinations, but often it was random…"

Another problem pointed out by students is the need for more hardware resources. Four of the projects had to utilize online API services from OpenAI, Amazon and Google for their projects, because their own hardware was not sufficient to run both the interactive application and a local version of the LLM. This opens up problems with external expenses and the data privacy of users of the interactive applications, as these online LLM providers have been shown to utilize user data as part of training their models (Yao et al, 2024). Universities should extend the services that they provide for training of deep learning model, to providing easy access to installation and calling of LLM models in a secure way, until small enough models become good enough to satisfy different use cases.

The way current LLM integration in interactive applications is done is also a point of contention. Students expressed their frustration with the state-of-the-art where most projects implement LLMs as an afterthought or as a direct replacement of existing techniques and technologies. This makes it hard to explore truly innovative uses and makes projects feel redundant or overcomplicated. This shows from answers such as the ones presented below. This shows that LLM integration should be pushed to not just substitute traditional toolchains but open up new ones.

- "…LLM integration can feel like more of an afterthought to the overall experience. (like a separate chatbot within a normal game instead of a completely new experience where the LLM is more integral)".
- "LLMs are able to enhance understanding and provide quick feedback to users, how could this compare to traditional methods in interactive systems. what holes can an LLM fill and which are better left alone."
- "…I feel that some aspects of projects should consider if LLMs really are the best option, as I feel like it should not replace every type of handcrafted experiences or be used to replace more traditional ways of doing stuff."

The findings show that the work with LLMs can be beneficial to the development and interests of students, which aligns with the broader view on the technology as a development and design tool for exercises and projects in education (Kharrufa et al. 2024). Most research in pedagogy focus on LLMs as part of the exercise and course designing, evaluation or as helpers and teaching assistance to students (French et al., 2023), but we show that generative models can be even more powerful as development tools in the hands of students. This gives them a first-hand experience in the strengths and weaknesses of the technology.

6. Conclusion

In this paper, we presented the findings from proposing tightly integrated LLM semester projects in a PBL curriculum. In the span of four semesters 6 projects were undertaken spanning different use cases for LLMs from guides and conversational agents to story tellers and audience. All projects were completed, and prototypes were tested with users. As part of the projects research and development different local and online LLMs were tested, as well as integration with multimodal interactions like speech, gaze, body positioning, and gestures. After the completion of the projects, students were given a self-reporting questionnaire to better gage their perceived levels of understanding of programming, LLMs, deep learning and interest in the subjects. It was shown that overall students were very positive for their experience and felt that it resulted in learning new and useful skills. The negative sentiments from students were directed towards not enough teaching of deep learning and LLM in the curriculum, lack of appropriate hardware and better implementation tools. The findings from this research point at a growing need for better integration of statistics, deep learning and LLMs into curriculums that have not traditionally offered these disciplines, for students to better take advantage of the modern technology.

Ethics Declaration

The paper does not require an ethics clearance. No privacy breaching data has been gathered from participants.

AI Declaration

AI tools have been used only for spellchecking, punctuation and shortening/clarification of sentences. No fully AI generated text or images are used in this paper.

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A Digital Tool to Support Self-Regulated Learning in Academic Writing

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The capacity to plan, manage, monitor and reflect on one's learning—i.e. to engage in self-regulated learning (SRL)—is vital to academic success; seminal research identified fourteen SRL strategies and showed that learners' achievement was strongly predicted by their use of SRL strategies (Zimmerman and Martinez-Pons, 1986); this difference in achievement can be accounted for by strategy presence, frequency and consistency (Nandagopal and Ericsson, 2012). Empirical evaluations indicate that most SRL tools do not demonstrably improve actual SRL behaviour—most studies did not directly measure changes in students' SRL strategies (Edisherashvili et al., 2022), highlighting a gap in understanding of whether these tools are truly helping students internalise better self-regulatory practices or just providing short-term performance boosts. This paper describes STARS, a co-designed digital tool to help bridge this gap, in particular by helping learners to (i) identify specific learning goals (ii) select and use appropriate SRL strategies (iii) monitor their progress over time. Needfinding has been conducted using surveys, focus groups, and interviews with first-year bachelor students (N=63). We present the results to date. Firstly, the highest priority needs that emerged - goal setting, emotional overwhelm, and time management - are in line with wider evidence showing that most digital-SRL interventions still lack robust goal-setting scaffolds (e.g. van Jaarsveld et al., 2024), that writing-specific anxiety drives avoidance and procrastination in undergraduate writers (e.g. Fritzsche et al., 2003), and that time-management planning is a key behavioural mediator between SRL processes and achievement (e.g. Claessens et al., 2007). Secondly, the first version of STARS has been developed to address these priority needs, and this has been piloted with a small group of learners and tutors (N=10). We report on the promising pilot results, and finally, we describe how STARS will be deployed in September 2025 in 10+ modules in three EU countries (Ireland, Estonia, and Finland).

1. Introduction

Self-regulation refers to "self-generated thoughts, feelings, and behaviours that are oriented to attaining goals" (Zimmerman, 2002). Foundational studies have demonstrated that students who actively use SRL strategies tend to perform better, and their success is linked to the presence, frequency, and consistency of these strategies (Zimmerman & Martinez-Pons, 1986; Nandagopal & Ericsson, 2012). Yet, despite increasing interest in digital tools designed to support SRL, many of these interventions have shown limited impact on students' actual self-regulatory behaviour. Indeed, a recent systematic review found that most SRL tools fail to directly measure changes in learners' SRL strategy use, raising concerns that these tools may only yield short-term performance improvements without fostering genuine skill development (Edisherashvili et al., 2022).

This paper introduces STARS, a digital tool designed to address this gap. STARS aims to do this by combining measurement and support for specific SRL strategies, the so-called "third wave" of SRL support (Panadero, 2017). Using a participatory action research approach, co-designed with learners and tutors, STARS focuses on helping students (i) define clear learning goals, (ii) adopt and practice SRL strategies, and (iii) monitor their progress over time. Section 2 describes the aims of the research, the approach used (action research), followed by Section 3, which details the method and the results of the first needfinding phase with needfinding activities such as surveys, interviews, and focus groups involving first-year bachelor's students (N=63). The needs identified through these activities were used to inform the design of the digital prototypes given in Section 4. Section 5 concludes and outlines the next steps.

2. Research Approach

2.1 Aim

The effectiveness of SRL strategies on their learning achievement is well established, e.g., (Harris & Graham, 2016; Junaštíková, 2024; Lim et al., 2023). The work aims to enable learners to measure and reflect on their current use of SRL strategies and to facilitate the selection and deployment of new or enhanced SRL strategies to improve their learning achievement. The main research questions are: (i) How do learners' reported and

observed use of SRL strategies evolve over time? (ii) How well do specific tool features (e.g. scheduler, writing analytics, reflection journal) meet the identified learner needs in goal-setting, emotional regulation, and time management? (iii) What barriers and enablers do learners experience when attempting to deploy SRL strategies?

2.2 Approach

This study adopts an action research methodology, which is particularly suited to the development of educational interventions in real-world contexts. Action research involves a cyclical process of planning, acting, observing, and reflecting, which aims to improve practice and generate knowledge. It has different variations, but "what unites different conceptions of action research is the desire for improvement to practice, based on a rigorous evidential trail of data" (Cohen et al., 2017). In this case, the objective is to iteratively design, test, and refine a digital tool—STARS—that supports learners in deploying and reflecting on self-regulated learning (SRL) strategies in academic writing.

A core principle underpinning STARS is co-creation: learners and teachers are not treated as passive end-users, but as active partners in the design and refinement of the tool. By involving learners and teachers at multiple stages—through surveys, focus groups, usability testing, and ongoing feedback cycles—we ensure the tool is grounded in its intended users' lived experiences and authentic needs. This participatory approach surfaces the real barriers learners and teachers face and enables the development of usable and meaningful solutions in practice.

The action research process has been structured around successive design-test-reflect cycles. Each cycle contributes to the dual goals of improving the STARS tool and deepening our understanding of how digital interventions can support SRL in academic writing contexts. This methodological approach allows for the continuous alignment between learner needs, theoretical insights, and practical implementation.

The overall plan is for action research iterations to take place over three semesters. Needfinding informs prototype design, and as prototypes are used in authentic environments (embedded in modules) and evaluated with data captured by the tool, surveys, and focus groups, we can find barriers and enablers, determine how well the needs are met, and explore how learners' reported and observed use of SRL strategies evolves over time.

3. Needs Analysis

3.1 Method

A needfinding questionnaire was made available to three cohorts: nine MSc students, twenty-eight first-year Psychology undergraduates, and thirty-seven first-year Computing undergraduates. The questionnaire was designed to be relatively broad and flexible, and to realistically capture learners' everyday strategies (or their absence). The questionnaire was structured around Zimmerman's three phases of SRL (forethought, performance and reflection) and asked students to describe and evaluate their current practices with regard to: (i) goal setting and planning, (2) time management, (3) self evaluation, (4) managing emotions, (5) help seeking, (6) task strategies and (7) reflection. It combined both open and closed questions, and afforded students space to upload photographs of any specific tools (e.g. time management or planning tools) that they currently use when completing their assignments. The questionnaire was administered in class and was followed by focus-group discussions where learners were free to discuss the questions in more depth.

3.2 Results

Some key observations from the learner data were:

(i) Learners often don't set goals; 28% do not set any goals, and only 10% record their goals in a structured way. The majority rely on mental checklists or vague intentions. Nearly identical results were found from planning.

(ii) Learners often experience negative emotions, especially overwhelm; for example, students were asked to identify which emotion(s) they typically feel when doing an assignment (54% - overwhelmed, 32% - nervous, 19% - curious, 19% - excited).

(iii) Some learners have difficulty managing time; 16% reported poor time management or heavy reliance on procrastination and stress as motivators. The rest rely on fixed schedules or time blocks (42%) or break tasks into smaller components to manage workload (30%), but only 6% reported using external tools (e.g., diaries, calendars, or mind maps).

Across all three cohorts, students often described intentions to manage time effectively, but lacked consistency or formalisation in their methods. MSc students most frequently attempted to plan in advance using diaries or

timetables. However, some Psychology and Computing students adopt reactive or last-minute approaches, with time management described as "poor", “stress-inducing”, or subject to procrastination cycles. Despite this, all groups strongly desired more structure, acknowledging that clear plans reduced anxiety and improved productivity. Barriers to effective goal setting and time management included emotional volatility (e.g., anxiety, overwhelm), lack of confidence in self-discipline, or difficulty translating abstract intentions into actionable steps.

3.3 Identified needs

Table 1 maps the principal learner needs to Zimmerman’s SRL phases derived from participant data analysis. Another key need is minimising effort expectancy, which is “the degree of ease associated with the use of the system” (Venkatesh et al., 2003). This is significant regardless of whether usage is voluntary or mandatory but only in the initial phase of usage; it becomes insignificant after “extended and sustained usage” (Venkatesh et al., 2003). This is vital for those participants in our cohorts with low digital skills. It is vital that they feel they use STARS to help them deploy SRL, rather than STARS becoming yet another barrier to their learning.

Table 1: The top needs identified by analysing the participant data

SRL Phase (Zimmerman)	Participant data	Sample quote from focus group	Need
Forethought	Learners often don't set goals;	*“I don't, they pile up and then I complete them all last minute”*	Learners need a way to easily set goals and track their progress
Forethought/ Performance	The majority of learners feel overwhelmed/nervous about what they need to do;	*“Typically get stressed and overwhelmed and spend a lot of time panicking.”*	Learners need a way to manage these emotions.
Forethought	Learners struggle with managing their time;	*““I don't manage my time much... I'm constantly procrastinating and… thinking that 'Stress is the ultimate motivator.'”*	Learners need flexible tools to plan their writing around real-life routines and energy levels.
Reflection	Learners do not use feedback to improve future work;	*“Aside from looking at feedback when it comes, I don't really engage in reflection, except maybe when I submit.”*	Learners need a way to store, revisit, and act on their reflections.

4. Prototype Design

The previous section described the highest-priority needs that were identified. This section starts by showing why existing tools cannot meet these needs and then briefly describes current prototypes. It then provides a needs-features matrix indicating how features meet the needs using available evidence.

4.1 Shortcomings of existing tools to meet these needs

While participants were familiar with popular organisational tools (e.g., Google Calendar, Trello), they rarely used them for academic writing and almost never as part of a reflective process. While students use independent tools such as calendars, notes, or to-do lists, this fragmented approach to managing writing tasks limits their effectiveness. These tools are rarely integrated into the writing process itself, and as a result, they provide little structured support for planning, reflection, or progress monitoring. Our data indicate that students often rely on internalised strategies, such as mental checklists or spontaneous decisions, rather than leveraging tools that connect directly to their writing activity. Fragmentation across platforms or tools may contribute to a disconnect between planning and execution, where opportunities for metacognitive engagement, timely review, or feedback application are easily missed. This reflects broader concerns in the literature that such disconnected tool use can impair focus and time regulation without clear learning benefits (Berei & Pusztai, 2022).

Previous research found that introducing a standalone tool in a study skills and writing course led to high attrition rates within two weeks, as it provided little independent value. Additionally, even when endorsed by instructors

and tailored to specific modules, students may resist using such tools, despite recognising their potential benefits.

4.2 Overall design

The overall design of the STARS tool is that each star visually represents a different SRL strategy, and learners can deploy one or more of these strategies. For some of the stars, there is a digital component to help a learner deploy the strategy. This section describes a selection of prototypes of these components, which can be reached from a unified STARS home screen.

4.3 Components

4.3.1 Artefacts/Review Component

Teachers can set a brief (see Figure 1) and give feedback, and learners can set/update goals, submit work, self-review, and get AI review.

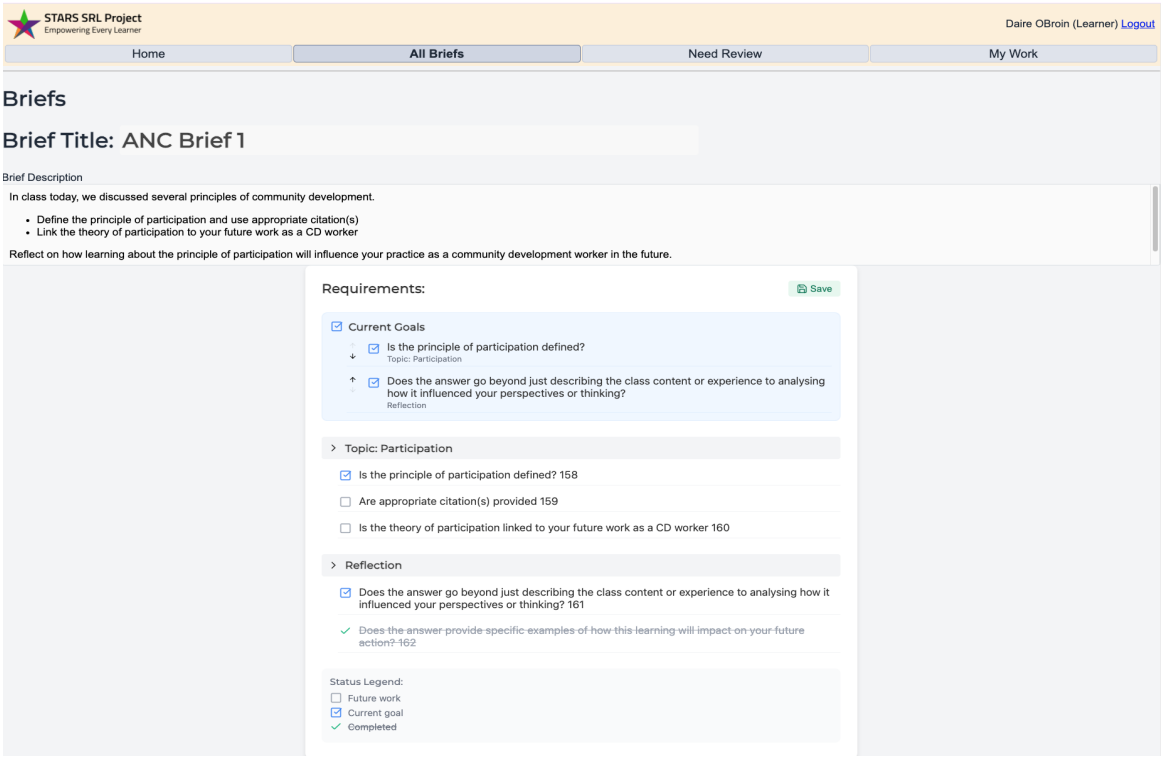


Figure 1: A learner setting a goal in the Artefacts/Review component.

4.3.2 Scheduler Component

The Scheduler allows learners to plan writing sessions by day and time, set measurable goals (see Figure 2), and use past data to inform weekly targets. It connects scheduling to actual writing behaviour and provides visual progress feedback.

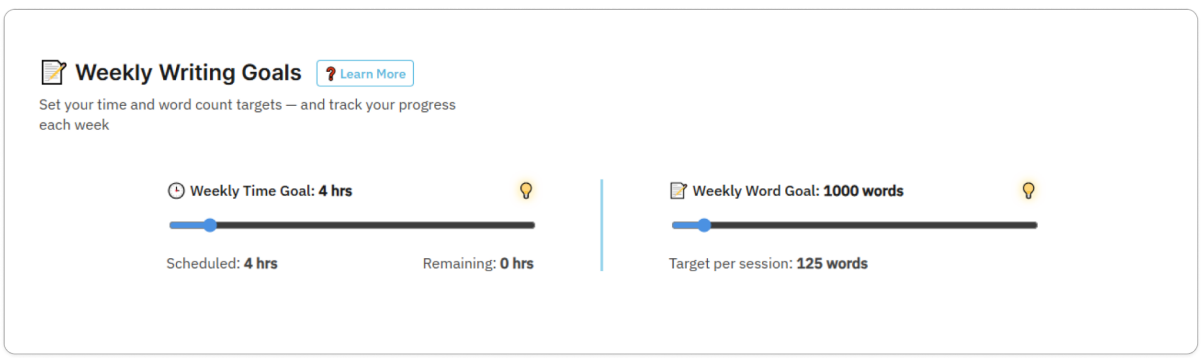


Figure 2. Used to set weekly goals: time spent on writing and a word count.

4.3.3 *Writing Analytics Component*

The Writing Analytics module tracks productivity across sessions, documents, and timeframes, providing visual feedback of effort. Users upload a document, specify time spent (see Figure 3), and view real-time analytics (see Figure 4).

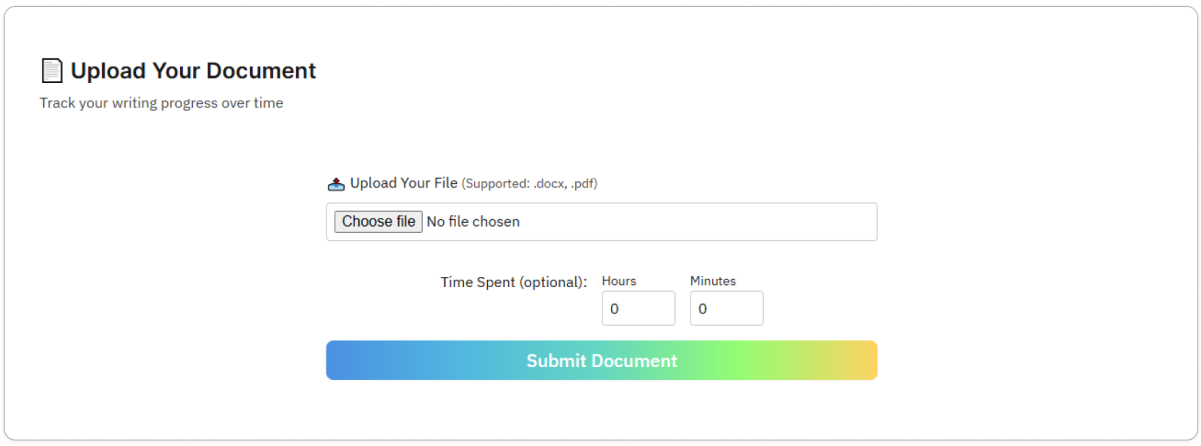


Figure 3. Allows the user to select a Word or PDF document to upload at the end of their session, including the duration.



Figure 4. The number of words produced and time spent writing in the past seven days. The star indicates the user has achieved the minimum word count goal.

4.3.4 *Needs-Features Matrix*

Table 2 illustrates the degree to which each component satisfies a particular need.

Table 2: Needs-Features Matrix

✅ = expected to meet need; ⚠️ = expected to meet need; ❌ = does not meet need (in the current version)

Needs	Artefacts/review	Skills	Scheduler	Writing analytics
Easily set goals and track their progress	✅ Can set goals and see progress	✅ Set which skills to work on, track mastery level	⚠️ Set goals for word count and time, track progress visually in real time.	✅ Tracks writing output over time, aligning with sessions.
Manage overwhelm/anxiety	✅ Enables current goals to be reduced, reducing anxiety.	✅ By focusing on 1-2 skills at a time	✅ Sessions can be broken into flexible and manageable time blocks.	✅ Transforms effort into visual data, helping to recognise progress.
Low effort expectancy	⚠️ Pilot tests showed some guidance was needed.	⚠️ Minor usability issues identified	⚠️ Integration with third-party calendars might require some effort.	✅ Updated automatically whenever the user submits their document and duration.
Help to reflect on SRL strategies	❌ Not yet; planned: comparison between self review and teacher review/AI review	⚠️ Individual skill mastery only; Planned: time series, goal completion	⚠️ Limited to writing sessions; will include customisable blocks like reading.	✅ Helps evaluate habits and outputs.

5. User Test (Pilot)

The pilot's objectives were (i) to test the prototypes for value, usability, and technology acceptance for tutors and learners, and (ii) to determine which SRL strategies the tutors could embed with their selected modules running in the next semester and how specifically they could be embedded. Table 3 provides an overview of the tasks given to the participants during the pilot, and Table 4 contains the results from the pilot study.

Table 3: Overview of the tasks given to the participants.

Artefacts/Review system:	Scheduler and Writing Analytics
As a learner, you are tasking with completing a cycle: ● Set a goal ● Submit your work (with an issue) ● Self Review ● Request an AI Review ● Submit your work (with the issue fixed) ● Update the goal	As a learner, you are asked to complete the following set of instructions: ● Schedule a weekly time goal of 4.0 hours. ● Schedule two sessions (e.g., Thur, 19:00 – 21:00 and Wed, 13:00 – 15:00) ● Upload a Word document and set duration to 2.0 hours. ● Review Writing Analytics

Table 4: Overview of results from the pilot user study.

Prototype	Main Result	Main issues
Artefacts/Review system	100% of participants completed the task with minor guidance	Users locating their place and navigating in the set goal/submit work/self review/AI review cycle.
Scheduler and Writing Analytics	100% of participants completed the task with minor guidance	Understanding how to schedule a session and understanding the writing session graph.

6. Conclusion and Future Work

This paper describes the steps in the action research process that have led to the first version of STARS, which will be deployed next semester (September 2025), embedded into 10+ modules in three EU countries (Ireland,

Estonia, and Finland). Three SRL strategies with digital counterparts will be available (goal setting, self evaluation, and time management). Each week, learners will use reflective journals to compare their current practice with their enhanced practice through these three SRL strategies. Data will also be gathered from the tool to enable learners' use of SRL strategies to be tracked over time, determine how well learner needs are met, and crucially, the barriers and enablers learners experience when attempting to deploy SRL strategies. This will help bridge the gap found in most existing SRL studies which do not directly measure changes in students' SRL strategies (Edisherashvili et al., 2022). The design of STARS will be iterated upon and deployed in more modules over the subsequent two semesters.

Ethical Declaration

This study has been approved by the SETU Ethics Research Committee (Ref: SETU/REC/24/25/055)

AI Declaration

ChatGPT was used for brainstorming, proofreading, and evaluation of drafts.

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Beyond AI: How Business Simulations Preserve Human-Centric Learning

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Abstract: As artificial intelligence becomes more integrated into higher education, it is increasingly capable of supporting decision-making, modelling complex systems, and accelerating technical learning. While these capabilities are welcomed and offer learning opportunities for students, AI does not account for dimensions of human learning, or the development of human-centric skills. This human-centric learning is essential for cultivating collaborative, responsible, and reflective graduates. Therefore, value must be placed on the intentional development of both technical and human-centric learning to complement each other in the age of AI. This study employs a qualitative methodology through the thematic analysis of 45 student reflections from a postgraduate business simulation module to investigate how business simulation promotes technical learning while preserving human-centric learning. Using a thematic coding framework, the study categorises learning into human-centric themes and assesses each for its replicability by AI. The findings highlight that while simulation integrated AI-enhanced tools (i.e. forecasting dashboards and scenario rewinds) aided student learning, the most meaningful learning described by students focuses on human-centric dimensions - resilience, collaboration, ethical reasoning, and reflective insight, and not on algorithmic optimisation through AI. The findings reveal that while AI enhances learning, it cannot replicate the emotional, ethical, and relational growth students undergo when confronting uncertainty, navigating team dynamics, and learning from failure. The paper argues for a pedagogical approach that defends and designs for human-centric learning - particularly in fields where leadership and judgment development are core. As education evolves alongside AI, it becomes essential to clarify not only what AI can do, but what it must not replace.

Keywords: e-learning, Simulation, Higher Education, Sustainability, Game-based Learning, Interactive Learning, Educational Gamification

1. Introduction

The rapid integration of artificial intelligence (AI) is fundamentally reshaping the landscape of teaching and learning across higher education. From adaptive tutoring systems to generative content creation tools, AI offers unprecedented speed, scalability, and precision - capabilities that are transforming not only how students access and consume information, but also how they create original work and engage with academic content (Atchley et al., 2024). In the domain of business and management education specifically, AI technologies are already assisting with a wide range of tasks, including market analysis, real-time performance feedback, and predictive scenario forecasting. These tools enhance the efficiency and depth of learning by simulating complex business environments, offering dynamic data-driven insights, and enabling learners to interact with sophisticated models of real-world decision-making.

Recent research has highlighted both the potential benefits and the inherent limitations of AI in supporting student skills development. On the one hand, AI can significantly expand access to diverse perspectives, aid in the construction of logical arguments, and tailor learning pathways to individual needs. On the other hand, over-reliance on AI tools risks diminishing students' intrinsic motivation for critical thinking, self-reflection, and ethical reasoning. AI can deliver outputs based on existing data and algorithms, but it lacks the capacity to engage in the nuanced, often uncomfortable, process of critical introspection that is vital to personal and professional growth.

A more profound limitation - central to this research - is AI's inability to cultivate human-centric dimensions of learning. Skills such as empathy, moral judgment, collaborative problem-solving, and the capacity for critical self-reflection are cultivated through human interaction, dialogue, and lived experience. These qualities cannot be replicated or replaced by algorithmic logic or machine learning, no matter how advanced the system. As AI becomes more embedded in pedagogical practice, this raises urgent questions about the evolving role of educators and the shifting nature of student engagement. What is at stake is not simply how we teach, but what kind of learning we value and preserve. It challenges us to consider the preservation of pedagogical approaches that emphasise human interaction, emotional intelligence, and experiential engagement - qualities essential for the development of responsible, ethical, and effective future leaders.

One such pedagogical approach that holds promise for sustaining human-centric learning is experiential learning. This mode of learning emphasises active participation, iterative reflection, and the application of theoretical knowledge in real-world contexts. Experiential learning is uniquely positioned to integrate both technical competencies and human skills by immersing students in scenarios that require ethical judgment, collaborative negotiation, and reflective practice. It enables students not only to understand business concepts, but to embody them in a way that fosters deeper comprehension and moral awareness.

This paper explores these themes through the lens of a business simulation module, examining the extent to which AI can replicate various learning outcomes, but more importantly, identifying which aspects of learning remain irreducibly human. It argues that as we move forward in integrating AI into higher education, we must also articulate and defend the pedagogical spaces where human-centric learning thrives - spaces that are essential for cultivating the reflective, ethical, and empathetic capacities of the next generation of business leaders.

2. Literature Review

2.1 AI in Education

Artificial intelligence (AI) is rapidly becoming embedded across the education landscape, with applications spanning adaptive learning platforms, automated feedback systems, chatbots, and intelligent tutoring systems. These technologies are redefining how educational content is delivered, managed, and experienced by both educators and learners (Luckin et al., 2016). In higher education, the emergence of generative text models such as ChatGPT, recommendation engines embedded in learning management systems, and real-time learning analytics platforms are increasingly influencing how students engage with content, complete assignments, and receive feedback (Holmes et al., 2022; Zawacki-Richter et al., 2019).

The promise of AI in education lies in its potential to enhance efficiency, offer scalable and personalised learning experiences, and generate actionable insights from large volumes of educational data. For example, AI can support differentiated instruction by tailoring content to individual learners' needs, track performance patterns to identify at-risk students, and automate administrative or assessment tasks to reduce educator workload (Ferguson et al., 2023; Chen et al., 2020). These developments are helping institutions respond to the increasing demand for flexible, student-centred, and data-informed approaches to teaching and learning.

However, alongside these innovations is growing concern about the potential narrowing and depersonalisation of the learning experience. As AI becomes increasingly competent at generating answers, producing feedback, and even recommending strategic decisions, there is a risk that educational priorities may shift toward outcomes that are easily quantifiable or automatable - while sidelining the less tangible, more iterative aspects of deep learning such as critical thinking, ethical reasoning, and emotional engagement (Selwyn, 2019; Knox, 2020). The affordances of AI are fundamentally statistical: it excels at pattern recognition, probabilistic forecasting, and performance optimisation within defined parameters. In business education, for instance, AI systems can simulate market dynamics, predict the success of strategic choices, and generate data visualisations far more quickly than a human team.

Yet, despite these strengths, AI remains limited in domains that require human-centric qualities - such as empathy, cultural sensitivity, creativity, ethical deliberation, and collaborative problem-solving. These dimensions of learning are not easily reduced to data points or algorithms and remain largely beyond the reach of current AI technologies (Williamson & Eynon, 2020). Furthermore, there is a concern that excessive reliance on AI may erode students' motivation to engage in self-directed learning and diminish their opportunities for reflection, dialogue, and interpersonal learning - elements that are foundational to holistic education.

As AI systems become more pervasive in higher education, the question is no longer whether they will shape learning, but how educators can ensure that the human dimensions of learning are preserved and prioritised. This includes reasserting the value of pedagogical approaches that promote dialogue, critical inquiry, ethical reasoning, and relational learning - areas where AI remains profoundly limited.

2.2 Human-Centric Learning

The limitation of AI is not merely technical; it is ontological in that AI cannot experience a decision or feel its consequences. It cannot draw conclusions or meaning in the same way that humans do, as it does not take account of interpersonal nuances (e.g. conflict resolution, trust-building); ethical judgment (e.g. weighing trade-

offs between profit and values); emotional processing (e.g. recovering from failure, managing team stress); or reflection insight (e.g. learning from mistakes through shared team dialogue and communication)
Edmondson (2023) argues that learning is not just feedback but reflection, context, and emotional processing. Similarly, leadership theorists point out that trust, moral courage, and vulnerability are core to professional growth - qualities that AI cannot authentically simulate (Denning, 2020; Brown, 2012). This, as AI grows more powerful, there is a need to protect and preserve human dimensions of learning, essential for developing future leaders. An effective pedagogical approach to promote human-centric learning is through experiential learning, which not only facilitates technical learning but also develops human-skills.

2.3 Experiential Learning Through Simulation

Experiential learning theories emphasise learning as a cyclical process of doing, reflecting, adapting, and applying (Kolb, 1984). These approaches value not only technical learning and skills development but also personal transformation - how learners grow in self-awareness, judgment, resilience, and ethical capacity through experience. One way this experience can be delivered to students is through simulation-based learning which creates opportunities for students to confront uncertainty, make decisions under pressure, and reflect on the interpersonal and emotional consequences of their decisions (Gosen & Washbush, 2004; Bellotti et al., 2012). Research (Washbush and Gosen, 2001; Faria et al., 2009; Wood et al., 2009, Costin et al., 2018) advocates the use of simulation games as an innovative learning tool. Learning in simulations is often emergent and relational and does not come from content delivery or data but from lived experiences of acting, failing, negotiating, communicating within a team (Lean et al., 2020). Further, simulations reflect and mirror the imperfect nature of business environments (Costin et al., 2018), offering a dynamic environment where students can navigate complex scenarios and make decisions, developing both technical and human-centric skills. They also feature a teams-based approach connecting students to the outside world and letting students act on their knowledge and skills, resulting in deeper learning (Costin et al., 2018). By engaging students in active participation, critical reflection, and the application of knowledge in real-world context, experiential learning through simulation, fosters deeper student understanding from both a technical and human perspective and so is explored in this research.

3. Pedagogical Design of the Business Simulation Module

The module at the centre of this research is a postgraduate business simulation module designed to develop strategic thinking, decision-making, and reflective learning through an immersive experience. Delivered via SimVenture Evolution (www.simventure.com/products/evolution/), the simulation tasks students with managing a virtual bicycle manufacturing company over a multi-year timeline (See Fig. 1). The module was intentionally structured to stretch both individual and team capabilities - not only in terms of technical skills, but also human-centric skills e.g. emotional resilience, ethical decision-making, and interpersonal and team collaboration dynamics.



Figure 1: The SimVenture Evolution Interface

The simulated learning experience adopted a structured approach which was divided into two key phases:

- *Phase 1: Individual Simulation* (Business Growth Activity – Years 4 Q1 to 7 Q4):

In this phase, students operated independently and were given a generous allowance of rewinds - a feature allowing them to revisit previous quarters to revise and reflect on decisions, encouraging experimentation, risk-taking, and learning from trial and error. Students tested pricing strategies, staffing models, and investment decisions in a controlled environment where failure was recoverable.

- *Phase 2: Team Simulation* (Seed-to-Scale Activity – Years 1 Q4 to 10 Q4):

In this phase, the team simulation imposed limited rewinds and increased the stakes of each decision. Teams were required to collaborate across finance, marketing, operations, and HR functions. Of note to this phase, two "blind spots" were built into the design: Years 1 Q4 to 3 Q3 and Years 8 Q1 to 10 Q3 were not accessible through the individual simulation, meaning students had no individualised preview of these periods. During this phase, teams had to rely entirely on shared judgment, dialogue, and consensus to guide the business forward.

This progression - from individual control to collective interdependence was not incidental. It was designed to mirror real-world business conditions where perfect information is rare, trade-offs are ethical as well as financial, and success depends on collective, and not solo decision-making.

At the outset of phase 2, students co-created Team Charters i.e. mutual agreements outlining how decisions would be made, how disagreements would be addressed, and what values would ultimately guide the team. Though not graded, these charters created a framework for teamwork and collaborations, allowing students to speak openly, challenge ideas, and process conflict without fear of reprisal (Edmondson, 1999). Reflections later revealed that these charters were not only respected - they were vital in helping teams navigate breakdowns, distribute leadership flexibly, and create the interpersonal trust needed to make decisions under pressure. The charters also laid the groundwork for students to take interpersonal risks - a necessary condition for human-centric learning.

Students were assessed through a structured individual reflection report, submitted on completion of the module. The reflections submitted served as the primary methodological tool for this study, providing qualitative data on student learning experiences, discussed in the next section.

4. Research Methodology

This study employed a qualitative methodology thematic analysis of 45 individual student reflections submitted as part of the summative assessment for a postgraduate business simulation module. These reflections were chosen as the primary data source as they offered unstructured, first-person accounts of the lived simulation experience. Students were not asked to comment on AI directly, making their insights into learning processes authentic and emergent. Each student submitted a reflective report of 1,500-2,000 words, guided by prompts related to: Individual and team decision-making; Role negotiation and leadership; Risk-taking and dealing with uncertainty; Ethical trade-offs and sustainability; Conflict, collaboration, and learning from failure.

4.1 Data Analysis

A two-layered thematic coding process was used to analyse the reflections. The first coding process centred on both human-centric and technical learning, focusing on the following themes: team collaboration & communication; resilience & recovery; ethical reasoning & values-based decisions; metacognition & self-awareness; leadership skills and technical skills. The second coding process focused on assessing AI replicability. Each theme (outlined above) was evaluated on whether the learning experience documented by the students in their reflections could plausibly be: (1) Fully replicable by AI (e.g. technical forecasting); (2)
Partially replicable (e.g. decision support augmented by human judgment); (3) Not replicable (e.g. emotional recovery after failure, moral courage, or interpersonal negotiation). This framework was adapted from Edmondson (2023) which placed emphasis on learning from intelligent failure, echoing other studies (Selwyn, 2019; Holmes et al., 2022) on AI in education.

Each reflection was read line by line and coded using a spreadsheet-based matrix. Key quotes were extracted and assigned both a learning theme and a replicability classification. Patterns were then reviewed across the dataset to identify dominant themes and moments of divergence between human and AI-supported learning.

Coding was conducted by the lead researcher and verified against assessment criteria, simulation structure, and anonymised team outcomes.

The goal was not to measure AI capability, but to explore learning that AI cannot see, feel, or simulate - with a view to preserving human-centric learning in future learning design.

5. Findings

The research findings centre on human-centric student learning and transversal skills developed through completion of the business simulation module, each of which will be discussed below:

The analysis of reflections revealed several key themes central to human-centric learning, namely team collaboration and communication, resilience and recovery, ethical reasoning and values-based decisions, and metacognition and self-awareness. Table 1 outlines a sample of student reflections, which support the importance of interpersonal engagement, self-awareness, and value-driven leadership. These findings underscore the unique role of experiential learning environments, such as business simulations, in fostering human-centric skills and capabilities which are essential for responsible and adaptive leadership in complex, real-world contexts. Evidently, the student reflections show that their learning occurred not from mastering the simulation's technical systems, but from navigating interpersonal, emotional, and ethical challenges.

Table 1: Human & Technical Student Learning

Theme	Description	Student Reflection
Team Collaboration & Communication	This theme encompassed inclusive decision-making, conflict resolution, and shared accountability. These experiences required vulnerability, compromise, emotional maturity and trust.	*"Our meetings were chaotic at first, but once we agreed on clearer roles, the communication improved and so did our outcomes".* *"We argued a lot in the beginning - about strategy, pace, everything. But once we agreed to rotate leadership, things started to click. We learned to listen and trust."* *"We stopped making top-down decisions and moved to full-team voting. That's when our performance- and trust-started to improve".*
Resilience & Recovery	Students spoke openly about disappointment, frustration, and regaining motivation - emotional processes far outside the scope of AI.	*"After our poor performance in Q3, we had to regroup. It was frustrating, but owning the mistake together made us stronger".* *"There was a point when I felt like giving up….. but the feedback loop kept us going". Small wins rebuilt our energy"* *"I was convinced my strategy would work. It failed. I wanted to give up. But the team helped me reframe it, and we bounced back."*
Ethical Reasoning & Values-Based Decisions	These reflections revealed how students weighed financial performance against moral considerations - something AI can model but not experience.	*"We could have made more money by cutting staff or reducing quality, but that didn't feel right. We decided to prioritise sustainability even if it cost us."* *"We debated whether to lay off staff to boost profit. It sparked a serious ethics discussion. In the end, we cut bonuses instead".* *"It didn't sit right to prioritise sales over staff wellbeing, even in a simulation. We chose to keep morale high instead".*
Metacognition & Self-Awareness	Learning here was deeply personal, arising from reflection, feedback, and internal shifts - not from outcomes alone.	*"I realised I tend to dominate in group settings. This time, I stepped back. It changed the way we worked - and the way I see myself as a leader."*

Theme	Description	Student Reflection
		"Usually I avoid conflict, but I learned that discomfort is where the growth is. That's new for me". *"I used to focus only on outcomes, but I started reflecting more on why I made certain decisions. That changed how I learn".*
Leadership Skills	Student learned here centred on leadership in action but also on personal development, encompassing conflict mediation, initiative-taking.	*"There was a shouting match mid-project. Instead of avoiding it, we brought it up and reset our charter. That was the moment we became a real team."* *"At one point, no one was stepping up. I volunteered to lead a turnaround strategy. It wasn't perfect, but it gave the team direction".* *"I didn't see myself as a leader, but I stepped up when no one else would. That changed how I see my potential".*
Technical Skills	Students learning centred on technical forecasting, planning, and scenario testing, along with developing financial literacy skills.	*"I experimented with pricing and marketing changes to model different customer responses. It helped me understand the knock-on effects across departments."* *"Using the simulation dashboard to predict outcomes made me realise how data-driven thinking can improve confidence".* *"I built a model to test our pricing strategy across different quarters. That helped us avoid risky decisions"*

Coupled with the human-centric skills, student also developed a range of technical skills, including forecasting, planning, and scenario testing, along with developing financial literacy skills. These skills were not developed in isolation - they were activated through the business simulation experience, shaped by team interactions and reflective insight, combining both human and technical skills.

In developing the research further, student learning from the simulation was assessed through the lens of AI replicability, evaluating the extent to which the skills demonstrated, both technical and human-centric- could be replicated by AI, with a view to investigating what skills need to be preserved. Table 2 below outlines the learning in terms of AI replicability:

Table 2: AI replicability?

Learning	AI Replicable?	Why/why not?
Team Collaboration & Communication	No	Requires emotional nuance, empathy, and live negotiation.
Resilience & Recovery	Partially	AI can simulate options but doesn't experience consequence or fear.
Ethical Reasoning & Values-Based Decisions	No	Involves subjective values, trade-offs, and moral judgment.
Metacognition & Self-Awareness	No	Metacognition and self-awareness are grounded in lived experience.
Adaptable leadership	No	AI lacks emotional intelligence, contextual judgment, & human intuition required to navigate complex, evolving interpersonal dynamics.
Technical Forecasting planning, and scenario testing	Yes	AI excels at modelling outcomes and optimising inputs.

The analysis of 45 student reflections revealed a consistent pattern that while AI can support or replicate the technical aspects of the business simulation i.e. technical forecasting and scenario planning, the most transformative learning experiences described by students were human in nature.

6. Discussion

This study set out to explore to what extent can AI replicate learning through business simulations, but more importantly what aspects of learning remain human-centric and need to be preserved? The business simulation design for this research intentionally created conditions for technical and human learning. This simulated design ensured that the module was not just a decision-making platform, but also a human-centric learning space for real-world business leadership, where information is imperfect, outcomes are unpredictable, and the quality of the team relationship often determines success or failure. Through the creation of combined scenarios requiring both technical and human-centric capabilities, the student learning was captured through structured reflections that not only documented what they did, but what they felt, and the impact of this. The business simulation student experience revealed that AI excels at simulating environments, modelling outcomes, and providing instant feedback. In this research, AI-supported tools such as dashboards, rewind functions, and forecasting models played a valuable role in helping students manage complexity, enhancing decision quality, and facilitating accelerated technical learning.

While the technical learning enhanced by AI offered an invaluable learning experience, the human-centred insights shared through student reflections were equally enriching. The human-centric learning provided students with the opportunity to build resilience by making wrong decisions and experience negative learning; facilitated teamwork and collaboration to effectively develop their communication skills; it allowed them to make value-based decisions with moral reasoning and overall changed how they understood themselves as leaders. These experiences required emotion, reflection, trust, and accountability - qualities that AI cannot simulate because they are not data-driven, but human-driven.

As AI tools continue to improve, there is a risk that educational systems will gravitate toward what is easiest to measure or automate - prompting a shift away from human-centric skills development. If educators design learning environments around what AI can do, it may undervalue what only humans can do: feel regret, extend trust, choose courage, listen deeply, and change direction not because a model told us to, but because someone helped us see different perspectives.

7. Conclusion and Recommendations

As artificial intelligence becomes increasingly embedded in education, it is tempting to imagine a future where machines optimise learning as efficiently as they analyse data. But this study shows that in some of the most meaningful domains of development - resilience, reflection, ethical decision-making, interpersonal trust - learning is not something AI can replicate.

Through the analysis of student reflections, this paper has illuminated the boundary between what AI can support and what remains human. While students benefited from AI-enhanced tools like forecasting dashboards and rewind functions, their most powerful learning moments arose not from efficiency, but from tension: the discomfort of failure, the challenge of team conflict, the vulnerability of ethical compromise, and the courage of self-reflection.

This paper acknowledges the valuable role AI can play in education, particularly in modelling systems, real-time feedback, and supporting technical learning. More importantly, this research promotes that the real work of business education must remain grounded in human-centric learning. If educators want to prepare graduates for a business environment that is both automated and ambiguous, learning must be designed to accommodate not solely technical learning that AI can replace, but human-centric learning that develops not just competence, but character. Thus, educators in designing simulation-based or AI-augmented learning experiences should preserve human-centric learning by intentionally embedding design principles that accommodate both technical and human-centric student learning. Such an approach will ensure that as technology and AI advances, the core of learning remains anchored in the complexity, emotion, and ethics of human experience.

Ethics Declaration

This study involved human participants in the form of student engagement, and formal ethical approval was obtained from the university's ethics committee prior to data collection. All participants were informed about

the purpose of the study and provided informed consent in accordance with ethical guidelines. Participation was voluntary, and confidentiality and anonymity were maintained throughout.

AI Declaration

Artificial intelligence tools were used during the development of this paper to support tasks such as proofreading, language refinement, and idea clarification. All intellectual contributions, critical analysis, and final content decisions were made by the authors.

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How EdTech Companies Are Considering Digital Well-Being in Product Development

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Abstract: Digital well-being has become an essential factor in daily life, also in education. Over the years, digital tools have supported learning processes, but as these tools gain prominence, the focus has expanded beyond innovation to include their impact on well-being. Research emphasizes that digital well-being should be integral to the design of digital learning environments. With the potential benefits and drawbacks of digital tools in mind, it is vital to understand how these tools can be designed to foster a positive learning experience without compromising one's well-being. Digital well-being means a balanced interaction with technology, optimizing benefits while minimizing harm. It is too simplistic to equate digital well-being with screen time or addictive behaviour. Discussion should include understanding on how EdTech products can enhance social connections, enable flexible learning, and support well-being. In line with this, recent research underscores the need to define digital well-being clearly, to avoid confusion between positive and negative impacts of digital learning tools. In recent years, research on digital learning has emphasized the need to prioritize not only cognitive outcomes but also the holistic well-being of learners. The design of digital learning environments must carefully consider the cognitive load imposed on learners. As EdTech products shape how teachers and learners engage with digital education, the design choices made by companies can significantly influence learning experiences and well-being. This case study aims to explore how Finnish EdTech companies are incorporating digital well-being into their product development. Through a series of semi-structured interviews with companies, we seek to understand how these companies integrate features that support learners' digital well-being, such as self-monitoring tools, gamified elements, and systems that encourage breaks or provide feedback. Moreover, we will examine how companies involve their end-users and educational institutions in the design process, and whether they utilize pedagogical and learning research expertise alongside technical development. The findings of this case study indicate that EdTech companies consider digital well-being primarily through pedagogically meaningful content, ease of use, and features that support personalised learning and self-regulation. Collaboration with educators, ethical data use, and efforts to align product design with learner's cognitive and emotional needs were also seen as essential to promoting digital well-being. Through a deeper understanding of these design processes, we aim to support the EdTech ecosystem to develop EdTech products that prioritize both educational effectiveness and well-being.

Keywords Digital Learning, Edtech, Product Development, Digital Well-being

1. Introduction

In today's interconnected world, digital well-being has become a crucial aspect of our daily lives. Digitalization is present in all areas of life, also in education. Students and teachers might be deeply engaged with technology for most of their social, personal, educational, and professional activities (Nageswaran et al, 2022). Digital tools have been used in education for several decades to support learners' learning processes. As digital applications and environments have taken a larger role in learning, researchers have highlighted that digital teaching methods should not only focus on defining innovative educational styles but also consider their impact on well-being. The digital well-being of both teachers and students should be considered, when developing new learning environments or programs, alongside accessibility and inclusion (Nageswaran et al, 2022). A recent OECD paper (2025) explores strategies to enhance child well-being in digital environments and notes that it's important that children are both protected and empowered to use digital media positively while managing potential risks (OECD, 2025).

Al Mansoori, Al-Thani and Ali (2023) conducted a comprehensive review of digital well-being and its relationship with technology design. They identified diverse interpretations of digital well-being and research gaps in its integration into design processes. The authors recommend developing a consensus definition of digital well-being, along with validated tools and frameworks. They also emphasize the need for a broader research agenda. That would enable Human Computer Interaction (HCI)- researchers and professionals to address the roles of planners and social institutions in creating inclusive and well-being-sensitive digital design. (Al Mansoori, Al-Thani and Ali, 2023)

EdTech companies' products shape the environment in which the learners, teachers and educators interact and work. The design choices of EdTech companies influence the learning and digital well-being experiences in education. This case study aims to explore how EdTech companies take digital well-being into account during product development. Specifically, the study examines how EdTech companies design their products to support digital well-being for instance through providing learners with opportunities to track their progress and shape their own learning paths. The edtech products offered by the companies participating the study have different characteristics. Some products are designed to be interactive and support collaborative learning in a school context, while others are designed for independent learning. The study focuses on examining the product design processes of EdTech companies, not the companies' individual products. The case-study is based on semi-structured interviews conducted online in early 2025 with representatives of six (N=6) Finnish EdTech SMEs.

2. Defining Digital Well-being

It is important to define digital well-being clearly, so that it can be understood across different contexts and studied in a consistent and meaningful way. The term needs to be set apart and expand from the associated discussion on digital harm, such as excessive screen time or addictions to mobile phone use. It should be noted that digital technologies are useful for people, for example to support the creation of social relationships, to enable learning at any time and place, to support health maintenance, etc. (Vanden Abeele, 2021).

The Council of the European Union (2022) defines well-being in digital education as a state of physical, cognitive, social, and emotional contentment that enables individuals to engage positively in digital learning environments. This includes using digital education and training tools and methods to maximize their potential and self-realization, act safely online, and support their empowerment in online environments (Council of the European Union, 2022, p. 5).

Personalised learning supports student well-being by addressing individual needs, preferences, and learning styles in digital environments. According to the Council of Europe (2024), digital well-being can be supported by adapting devices and tools to the specific needs of learners. However, and at the same time, there is also a risk that digitally personalized learning will increase inequality between students who have access to the latest digital learning environments and those who do not have the necessary computers and connections (Council of Europe, 2024). Vanden Abeele (2021) expands on this by describing digital well-being as a subjective individual experience of optimal balance between the benefits and drawbacks of mobile connectivity. This individual, subjective experience involves emotional and cognitive elements from the individual's everyday life. People achieve digital well-being when they experience maximal controlled pleasure and functional support, along with minimal loss of control and functional impairment. Vanden Abeele (2021) emphasizes that digital well-being is a dynamic system influenced by person-, device-, and context-specific factors. To understand how individuals can attain digital well-being, it is essential to examine the interactions between persons, devices, and contexts. (Vanden Abeele, 2021)

3. Digital Well-being in Education

Recent studies have shown that digital teaching and learning have both beneficial and detrimental effects. This ongoing discussion about online learning design emphasizes the importance of approaches that support the overall well-being of learners, not just their cognitive achievements (Palalas and Doran, 2024). Nageswara et al. (2022) review highlights the profound impact of the digital learning revolution, which has enabled almost all learning outcomes to be achieved or assessed online. This shift has potentially contributed to an 'always on' culture, with students spending extended periods in digital environments. The researchers highlight the importance of balancing education and technology to promote safe digital well-being. They argue that while developing innovative educational methods is crucial, equal attention must be paid to understanding the potential well-being implications of these digital transformations. The key concern is not just about creating new digital learning approaches, but also about thoughtfully examining their broader impacts on students' holistic well-being. This perspective underscores the need for a nuanced approach to digital learning that prioritizes both educational effectiveness and individual wellness. (Nageswara et al, 2022)

The contextual nature of digital well-being is particularly evident in digital learning applications, where individuals often have limited choice in using digital tools to complete their studies (Vanden Abeele, 2021). Skulmowski and Xu (2022) provide insights into the critical relationship between cognitive load and digital learning environments. Their research review emphasizes that while learners must invest some extraneous cognitive load to enable meaningful learning processes, excessive cognitive burden can undermine learning

effectiveness and digital well-being. The design of learning, support, and assessment in digital environments is crucial. The researchers argue for a nuanced, cost-benefit approach to digital learning, highlighting the importance of carefully aligning design factors, cognitive processing, and assessment methods. If this alignment is not achieved, the potential benefits of digital learning may be overshadowed by cognitive costs. At a practical level, supporting learning and well-being in technology-enhanced environments depends on two key factors: the tools and features of educational technology platforms, and the teacher's competence in designing learning situations that facilitate learning without unnecessary cognitive burden. (Skulmowski and Xu, 2022)

3.1 Promoting Digital Well-being in Learning

Digital learning environments are created and used in different ways to support the individual learning process. Some environments may emphasize interactivity, and others may be designed to support independent learning. It is important to utilize the various tools and features of the environments so that the learning process is as smooth as possible. Designing such learning contexts requires pedagogical and digital competence from the teacher (Haarala-Muhonen et al, 2023).

Salmela-Aro et al, (2022) emphasize the need for targeted support in developing teachers' digital skills, along with new training opportunities during the implementation of technology in education. According to Salmela-Aro et al, distance and hybrid learning platforms should be built to support genuine seamless interaction. Their research shows the potential of educational games and apps to support young people's motivation to learn and their well-being. Instead of banning the use of digital devices, young people should be taught to use them in meaningful ways to support their learning and well-being. Salmela-Aro et al. (2022) research also noted that young people should be offered support to regulate their own digital activities. This will enable them to use digital solutions appropriately and find a balance between different aspects of their lives.

The capabilities of digital environments and EdTech applications enable diverse learning opportunities and support the design of effective learning strategies. Balica (2021) has highlighted several useful strategies that support learning. The first strategy is increasing the engagement of learners. Student engagement is determined by the interaction of time, effort and other essential resources that optimize the student experience and learning outcomes. This strategy includes features that enable gamification of learning, digital stories, digital engagement and resilience. The second key element is improving self-directed learning skills. The assumption is that students who consider themselves highly competent in self-directed learning are more motivated to learn. Several practices can support self-directed learning in the digital environment and have shown promising results e.g. support for metacognitive skills, workload management and mindfulness. The third element is overcoming isolation. While there is wide evidence on the impact of loneliness and social isolation on the well-being of children and young people, there is still little evidence on the effectiveness of specific interventions in preventing or reducing the effects of loneliness in the digital environment. However, several practices have shown promising results. These include the social presence model, peer counselling and backchannelling opportunities in digital environments. (Balica, 2021)

According to the OECD (2025) report *How's life for Children in the Digital Age?* supporting the digital well-being of children requires a comprehensive, whole-of-society and rights-based approach that balances opportunities and risks. Key strategies include implementing effective legal and technological safeguards that prioritise child safety, enhancing digital literacy through schools and teachers, providing parents and caregivers with practical guidance, and ensuring children's voices are reflected in digital policymaking. (OECD, 2025)

4. Research Design

This study used a qualitative research design to explore how educational technology (EdTech) companies consider digital well-being in the design of their products. Given the exploratory nature of the research question and the limited existing literature on the topic a qualitative approach was chosen. Semi-structured interview was selected as the method of data collection. This allowed the in-depth exploration of participants' perspectives while allowing flexibility to include emerging topics during the conversations.

4.1 Participant Selection, Data Collection and Analysis

Participants were selected from among the members of a national EdTech association, which represents a broad range of companies operating in the EdTech sector. The inclusion criteria focused on founders and employees of small and medium-sized enterprises (SMEs) as these types of companies often have a significant role in

innovation and product development in the field. A total of six companies participated in this case-study. Each company contributed one or more participants involved in product design, development or strategy ensuring a relevant and informed perspective on the topic.

The data were collected through semi-structured interviews conducted online. This format allowed access to participants across different geographic locations and allowed for scheduling flexibility. All interviews were video recorded with participants consent and then transcribed for analysis. The interview included open-ended questions designed to produce rich narratives around digital well-being considerations in EdTech product design, while allowing participants to bring up unanticipated topics.

The interview transcripts were analysed using content analysis. Multiple researchers were involved in the coding process employing investigator triangulation to enhance the credibility and trustworthiness of the findings. This included cross-checking each other's coded data and interpretations helping to ensure consistency and reduce individual research bias.

4.2 Ethical Considerations and Researcher Positionality

The ethical principles of the Finnish National Board on Research Integrity were upheld throughout the study (TENK, 2019). Informed consent was obtained from all participants prior to the data collection. Participants were assured of the confidentiality and anonymity of their responses, and all data were stored securely.

The research team conducting this study has a background in education, with practical experience in supporting and training teachers in the use of EdTech tools. While the members of the team have previously collaborated with some companies in the Finnish EdTech ecosystem, none of the companies included in this study were personally known to the team members at the time. Although the members of the research team were familiar with some of the products developed by the participating companies there had been minimal prior contact with the individuals who took part in the interviews.

The study was collaboratively designed by the research team and all the interviews were conducted by members of the team. Data analysis was led by two researchers while the remaining team members reviewed and cross-checked the coded material. This collaborative approach, including investigator triangulation, was used to minimize individual bias and strengthen the trustworthiness of the analysis. The team's professional background in education and existing knowledge of the EdTech sector informed the interest in the topic of digital well-being, while ongoing reflective discussions within the team helped remaining critically aware of how individual perspectives may have shaped the research process.

5. Results

This chapter explores how EdTech companies develop their products in collaboration with pedagogical and technical experts, as well as end users such as teachers and learners. The findings from the interviews show that user feedback, research-based knowledge, and iterative design processes play a key role in product development. Particular attention is paid to how digital well-being is supported through intentional product design that prioritizes pedagogical relevance, user-friendliness, and meaningful use of screen time. The chapter also discusses product features that promote digital well-being, such as personalization, time management tools, and feedback mechanisms. Furthermore, challenges related to implementing these tools in educational settings are addressed, along with suggestions for improving collaboration between schools and EdTech developers. Finally, the chapter looks ahead to future developments, including the role of artificial intelligence, the need for national evaluation frameworks, and the importance of accessible, mobile-friendly learning solutions.

5.1 Edtech Companies' Perceptions on Digital Well-being

In the interviews, participants discussed both the concept of digital well-being in general and the specific features in their own companies' products. Interviewees viewed the ability of digital solutions to enable personalized learning and tailored support as a key aspect of digital well-being. The participants also emphasized the importance of using the latest research to guide product design and promote the digital well-being of the users. Moreover, the interviewees referred to the ongoing debate about screen time and pointed out the importance of a pedagogical approach to product design. They noted that with thoughtful pedagogical planning, screen time can be meaningful and support learning.

From the perspective of the interviewed EdTech companies' representatives, digital well-being is supported when a product remains focused on the specific educational need it was designed to address. The responses emphasized the importance of the product's content, and the pedagogical considerations integrated into the design process of the product. EdTech companies recognize that their products contribute to the daily total amount of screen time for their users. According to the interviewees an EdTech product should be purpose-driven, addressing the specific educational need for which it was developed. It should also be user-friendly and free from e.g. unnecessary gaming elements. A key factor identified as supporting digital well-being was the product's capacity to help learners to visualize their learning journey and monitor their progress.

5.2 How EdTech Companies Collaborate With Users and Professionals

All participating companies acknowledged the importance of collaborating with users and gathering feedback as an essential part of product development. Feedback was collected in various ways, for example through user interviews, observing classroom situations, sending email surveys, and through feedback mechanisms in the product itself. Companies also received indirect feedback from end users of the product through their customers.

The interviews indicated that most companies involve a multidisciplinary team in product development, including pedagogical and technical experts, as well as end users such as teachers and learners. The methods for collecting feedback varied depending on the type of product. For example, feedback for products designed for independent learning was often gathered online, while products intended for use in structured classroom environments allowed for more direct interaction and discussion with users.

In addition to the company's own staff, companies also engaged external experts in the product development process when appropriate. Some interviewees also noted that current research played a role in product development, and in some cases the product may have also received its initial impetus through research.

5.3 EdTech Product Features Supporting Digital Well-being

EdTech companies seek to promote users' digital well-being by ensuring that their products are pedagogically relevant and that the time spent using them effectively supports learning. Interviewees pointed out that digital well-being is fostered when products are both easy to use and aligned with the user's learning needs. Depending on the product's purpose, some applications include features that track time usage or put time limits on use. These features are often designed with attention to cognitive load and learning efficiency – for example, by considering how much new information a learner can reasonably process within a given time. In some cases, the application may restrict usage to a single training session per day or limit session duration to a set number of minutes.

Some products include gamified elements into their products with to motivate and engage learners. However, the interviews made it clear that such features were included only when they were thought to add value for the learner and the learning process. From the perspective of digital well-being, it was considered important that the time spent using the application directly contributes to learning. To support this, some EdTech products employed algorithms adapt to the learner's individual progress, thereby personalising the learning path. In addition, these applications could provide immediate feedback on the learner's actions and tips for moving forward.

In some cases, the algorithm's functioning and the resulting recommendations for the learner's next steps were made directly visible to the user. In other products, the data collected by the application was shared with the teacher, enabling them to monitor progress and intervene when necessary. The ability to use the application independently, regardless of time and location, was also seen as a feature that supports digital well-being, as it allows learners can determine when and where they study. Table 1 describes the design aspects that EdTech companies consider in their product development and how they believe these principles impact digital well-being.

Table 1: Designing EdTech products that promote digital well-being

Aspect	How it Supports Digital Well-being
Pedagogical focus	Ensures that all content serves a clear learning purpose; avoids unnecessary or distracting features
Ease of use	Reduces cognitive load and makes the product accessible for diverse users
Meaningful use of time	Encourages screen time that is directly tied to learning goals; includes timers or use limits
Personalisation and autonomy	Supports learner agency through adaptive learning paths and progress tracking
Feedback and guidance	Enhances motivation and reflection through timely, learner-specific feedback
Collaboration with users and experts	Involves teachers, learners and experts in designing and testing to ensure relevance and usability
Teacher support	Helps educators implement the product effectively with training
Responsible data use	Use of learning data ethically to personalize and inform educators

5.4 Challenges and Suggested Solutions in Supporting Digital Well-being Through EdTech

One of the key challenges identified in promoting digital well-being was the effective implementation of an application's pedagogical approach, especially in classroom settings. To integrate these tools successfully into classrooms, teachers need strong pedagogical skills and continuous, open communication with EdTech developers. This cooperation was viewed as essential for both sustaining and enhancing the meaningful use of educational technologies.

Another challenge mentioned was the limited expertise among school and educational staff in evaluating and procuring appropriate digital products. The interviewees expressed the need to develop this capability to ensure that the tools used in schools align with their pedagogical goals. Teachers also needed more support to learn how to use EdTech tools effectively in their teaching. One interviewee stated that the game elements of the products can distract the learner if no guidance is given. It was also noted that there can be confusion due to a lack of shared language – both about how the product works and how it is designed to support learning. A suggested solution to these problems was closer cooperation between EdTech companies and schools, especially when putting the tools into practice.

The recent widespread debate about screen time and its effects on children and young people was also mentioned by several interviewees. As a solution to this issue, representatives of the EdTech companies stated that this is precisely why their products are easy to use and focus specifically on supporting learning without additional sections or features. The importance of developing nationally recognized criteria for assessing EdTech products was also highlighted. Such criteria would support schools and teachers in selecting safe and reliable EdTech tools.

Some company representatives expressed frustration with the often-polarized nature of public discourse surrounding digital well-being, where EdTech is seen as inherently harmful or entirely beneficial. They pointed out that this kind of thinking ignores the fact that well-designed products, which follow principles that support digital well-being, can also enhance learning and provide practical solutions for today's educators and learners.

5.5 Future Perspectives on Digital Well-being in the EdTech Sector

Discussing future development, artificial intelligence and its possible effects on product development and supporting learning was mentioned by all interviewees. There was some concern about whether the use of artificial intelligence would make learners lazy and their learning processes would remain superficial. However, AI agents were also considered having the potential to support the learners. It was also emphasized that only pedagogically effective digital tools should be made available to schools. Products that focus on entertainment should be restricted from lessons. At the same time, the need for a national evaluation framework, that could identify and implement the best solutions for schools and teachers is recognised. As some of the interviewees expressed, there is a need for national-level dialogue and collaboration to guide the efforts of teachers, schools, and procurement officials. They also emphasized the need for a shared framework that would provide decision-

makers with sufficient information to support informed choices regarding the procurement and use of Ed Tech solutions.

According to answers, it remains crucial that EdTech products support teachers' work as well as students' learning and the products should not unnecessarily burden them. On an international level, it emerged that learning solutions should be developed primarily for mobile devices which can also operate with weak or no network connection ("semi-offline"). The goal is a wider accessibility globally and a better scalable user experience, especially on mobile phones.

6. Conclusion

From the perspective of digital well-being, EdTech companies report that they aim to create easy-to-use and pedagogically sound products that support learning in different ways. The products may contain gamified elements, provide feedback on learning and insight on one's own learning path. They also may include opportunities for community building and interaction. Based on previous research, these elements are known to support digital well-being (e.g. Balica, 2021). The companies use experts in pedagogy, learning content and technology to design their products, and they also gather a wide range of feedback from users. Despite the positive cooperation to date, this case study revealed that EdTech company representatives expressed a wish for deeper engagement with end users (schools, teachers) to ensure that their products are effectively integrated into the school or educational context for which they are designed. Furthermore, the findings also underscored the critical role of teachers' digital pedagogical skills in maximizing the educational value and practical use of these products.

In Finland, schools and teachers have considerable autonomy in selecting EdTech applications (e.g. Kupiainen, 2022). However, this choice can be challenging due to various security and usability concerns that may be difficult for individual teachers to evaluate. Sometimes the application might be avoided altogether for safety reasons. A more structured cooperation between EdTech companies, educators and policymakers appears essential for fostering sustainable, pedagogically grounded and digital well-being-oriented use of digital tools in education. The interviews highlighted the need to maintain an active EdTech ecosystem that would enable, at least nationally, ongoing dialogue with EdTech application creators and education representatives. The point was also made that the EdTech field should take more account of scientific research results on individual and group learning in technology-enhanced learning environments

Future research could benefit from expanding the sample to include a broader range of perspectives beyond Finnish EdTech companies. It could also be valuable to investigate how teachers understand and address digital well-being in their everyday work when using EdTech tools in classroom. Additionally, further research is needed on how to build an active and collaborative EdTech ecosystem, that brings together developers, educators, researchers and policymakers.

Ethical Declaration

The ethical principles of the Finnish National Board on Research Integrity were upheld throughout the study.

AI Declaration

Artificial intelligence tools have been used text formatting to improve the readability of the text.

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School Leaders' Perceptions on the Potential of Using Artificial Intelligence (AI) in Leadership Practices

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Abstract: Artificial Intelligence (AI) has become a transformative force across various sectors, reshaping societal dynamics and fundamentally altering how individuals interplay with technology. In the realm of K–12 education, AI offers many opportunities and challenges that extend to school leaders' practices. AI has the potential to enhance and support leadership practices. A significant aspect of school leadership is decision-making. School leaders are tasked with navigating a complex landscape of choices, both formal and informal, that wield profound influence over their schools. The decisions made by school leaders are crucial components of school governance and management and are worth exploring as these decisions directly impact student education. In Sweden, the Education Act states that school leaders are responsible for making decisions about the organisation of the school. To deepen the understanding of AI as a decision-making tool among school leaders, a survey was undertaken, targeting approximately 165 school leaders within three municipalities in Sweden. The survey assessed school leaders' familiarity and proficiency with AI while exploring their perceptions of its potential applications in educational leadership. School leaders perceive AI in K–12 education as a valuable tool for enhancing efficiency in teaching and administrative tasks. However, school leaders face challenges related to academic integrity and the potential for cheating, along with ethical issues like biases in AI outputs. While school leaders recognise opportunities for AI to improve processes and support decision-making, they stress the need for professional training and support to ensure responsible integration, influencing strategic decisions in schools.

Keywords: Artificial Intelligence (AI), Decision-maker, Education, Leadership practice, Principal

1. Introduction

Artificial Intelligence (AI) is changing the way schools are run and how it impacts educational leadership. It no longer plays a peripheral role but constitutes a growing and important part of modern and effective school leadership (Adams and Thompson, 2025, Fullan et al., 2024, Tyson and Sauers, 2021). Dai et al. (2024) explain that school leaders need to make big decisions, and AI is a good tool for tasks like collecting and analysing data. AI also helps school leaders identify potential issues early and take action, while supporting better decisions through data (Fusarelli and Fusarelli, 2024).

School leaders' daily leadership practices encompass several decisions, including quick, unplanned ones, as well as more strategic decisions related to economic planning and staff recruitment within schools (Fullan et al., 2024). As technology becomes more integrated into daily life, and AI plays a bigger role in leadership practices. However, using data to improve practices in schools has many challenges. According to Torres-Santos and Castulo (2025), one important challenge is a lack of digital competence. It makes it difficult for school leaders to interpret data and make informed decisions. They may also face obstacles such as a lack of knowledge about AI, costs, a lack of standardisation and compatibility between AI products, staff development, and resistance to change within their organisations (Marrone et al., 2025, Tyson and Sauers, 2021, Zawacki-Richter et al., 2019). It is important that school leaders overcome their barriers to use data effectively, especially because leadership plays a big role in how data is used. At the same time, it is important to understand the impact of AI on education, especially because "education is slow to change," according to Holmes et al. (2019). AI can impact the effectiveness of school leadership, and its use should be included in school leaders' education (Marrone et al., 2025, Weng and Tang, 2014).

Although school leaders face numerous obstacles when integrating AI into their leadership practices, current research also highlights promising applications of AI that can support and enhance their work. AI can offer concrete solutions to many of the challenges faced by school leaders, particularly by streamlining routine tasks and allowing more time for strategic work. AI tools, such as ChatGPT, can help anticipate trends and outcomes and support school leaders in developing data-driven strategies, formulating goals, and checking progress systematically (Adams and Thompson, 2025, Karakose and Tülübas, 2024, Schildkamp et al., 2019). AI tools can also enhance external communication by drafting emails, invitations, and reminders addressed to guardians (Adams and Thompson, 2025, Chiu, 2024). Furthermore, these tools can be used to quickly generate surveys and questions that provide qualitative feedback from the school community. Nevertheless, Fusarelli and

Fusarelli (2024) point out that several ethical challenges must be addressed to ensure the integration of AI into school leadership. School leaders need to understand how AI works to ensure fair and ethical application. Even Aldighrir (2024) highlights that ethics in AI plays a role in shaping how educational leaders make decisions and explains that school leaders who have positive attitudes toward the ethics of AI are more aware of the ethical implications of their decisions, which enhances their rational decision-making.

Research on school leaders' decision-making encompasses a broad spectrum of inquiry (Dai et al., 2024; Tyson & Sauers, 2021), including how data is utilised to inform decisions and how data can improve resource allocation to enhance teaching and student learning (Martin et al., 2023). For example, school leaders can utilise AI to analyse data, enabling informed decision-making within their schools. While using digital technologies to support decision-making is not new, understanding AI as a potential tool to enhance leadership decisions requires attention.

The aim of this paper is to explore the potential of AI as a decision-making tool for school leaders in K–12 education. School leaders are defined here as principals and assistant principals. Two research questions have been formulated:

- How do school leaders perceive the potential applications of AI in leadership practices?
- What challenges and opportunities related to AI in leadership practices do school leaders describe?

This paper aims to contribute to new knowledge regarding how school leaders perceive the professional use of AI in their practice.

2. Method

This study used a qualitative approach involving a survey (Cohen et al., 2017) with school leaders. Surveys can be used not only for measurement or generalisation but also to capture local, institutional, or small-scale factors and variables, highlighting the uniqueness of a situation (Cohen et al., 2017). To explore the comprehension of school leaders' perceptions of AI as a tool for decision-making, a survey was conducted to gather insights on school leaders' experiences and attitudes towards AI technologies. The survey was sent to school leaders in three municipalities in Sweden. The survey was sent by e-mail to a total of 165 school leaders, encompassing preschools, compulsory schools, and upper secondary schools in three municipalities in Sweden.

The survey consisted of 10 questions, including five background questions such as gender, position, and school type, and five open-ended questions. Examples of the open-ended survey questions were: *How would you define artificial intelligence (AI), and what do you consider to be the challenges and opportunities in using AI in education? Can you describe three key areas where you believe AI can serve as a tool to assist in decision-making regarding the school's organisation? Please provide examples of how AI can specifically support these decisions.* Of the 165 school leaders surveyed, 24 responded, which corresponds to 15% of the total school leaders. Of the school leaders who responded, most were women and some were men. The school leaders who participated in the study represented different school forms and were either school leaders or assistant school leaders.

The data analysis was conducted using a combination of thematic analysis (Braun and Clarke, 2006, Braun and Clarke, 2021). The data analysis was guided by the six-phase (Braun and Clarke, 2006) framework of thematic analysis. In the first phase, the survey responses were thoroughly read and reread with notes taken. During the second and third phases, the data were systematically organised, allowing for the generation of initial codes and the identification of potential themes. The school leaders addressed various topics, including the benefits of AI in education, concerns about AI and integrity in student work, ethical considerations, and the necessity for enhance digital competence. In phase four, these themes were refined, and a clustering process was initiated. Phase five involved merging themes of similar nature. Finally, in the sixth phase, the report was generated, incorporating selected quotes to support the identified themes.

The study adhered to the ethical guidelines set by the Swedish Research Council (Vetenskapsrådet, 2024) and aligned with best practices in qualitative educational research (Cohen et al., 2017). All participants were informed of their right to withdraw at any time, and strict confidentiality measures were applied throughout the research process.

3. Results

This section outlines the results of the open-ended survey questions in relation to the research questions. The results are organised thematically, with five themes constructed. The themes are: *Perceived benefits of AI in K–*

12 education, Concerns about AI and academic integrity, Need for ethical considerations and digital competence, Limited familiarity and implementation of AI, and Challenges and *support needed for AI integration.*

3.1 Perceived Benefits of AI in K12-education

Many school leaders view AI as a tool for enhancing efficiency in both teaching and administrative tasks, such as lesson planning, budget management, and personnel hiring. For example, one school leader stated, "One can use AI to gather different questions and answers to make a decision," while another noted, "Tasks that are currently handled manually could be automated for decisions where there are clear procedures regarding administration." There is also a sense that AI can provide quick support for both teachers and students, improving processes like writing and content development. However, a school leader explained that "It is essential that we design assignments and tests in such a way that students are not tempted to use AI to cheat."

Beyond administrative functions, AI was also perceived as a valuable pedagogical aid. Several participants highlighted how AI can offer rapid access to information, support writing processes, and serve as a flexible training tool for students. One participant described AI as having "endless possibilities for both students and teachers," especially in relation to practice and feedback. From a teaching perspective, AI was seen as potentially time-saving, particularly in relation to lesson planning and content preparation. There was a general sense that AI could enhance the efficiency of daily practices, improve accessibility to learning support, and contribute to a more responsive learning environment. These perspectives suggest that many school leaders recognise AI's potential not only to streamline tasks but also to expand the pedagogical toolkit available in classrooms.

3.2 Concerns About AI and Academic Integrity

A common concern among the school leaders was the risk of students using AI to cheat on assignments, leading to difficulties in distinguishing between the student's work and AI generated content. A school leader pointed out that "students need to understand how to use AI as a reference tool rather than getting completed work for AI." This brings up issues of maintaining academic integrity in schools.

Participants expressed concerns about the challenges of distinguishing between students' own work and AI-generated content. As one school leader put it, "It is difficult for teachers to see what the student has done versus what AI has done." The risk of students relying on AI was linked to worries about reduced learning outcomes and dishonest practices. One participant noted that "If misused, no learning takes place," while another pointed to the risk of "cheating." These concerns highlight the need for clear guidelines to maintain academic integrity in AI-supported learning environments.

3.3 Need for Ethical Considerations and Digital Competence

Ethical concerns were frequently mentioned, particularly regarding the need for source criticism, biases in AI outputs, and the ownership of AI-generated content. A school leader explained that "ethical considerations in this case are about the copyright perspective, who owns the content, and how can it be used or distributed?" School leaders also emphasised the importance of ensuring that both students and staff understand how to use AI responsibly. One school leader stated, "It is necessary to provide extensive professional development for staff in schools to understand AI and its possibilities," while another added "Support is needed from the school organisers, centrally, to achieve some level of equality."

One school leader illustrated concerns about information quality by starting, "The advantage is that it can retrieve information from many different sources, the disadvantage may be the reliability of those sources." The responses suggest that both students and teachers need to strengthen their digital competence and awareness of ethical issues when using AI, particularly in relation to evaluating information and using the technology responsibly in educational contexts.

3.4 Limited Familiarity and Implementation of AI

Several school leaders admitted to having limited experience with or knowledge of AI. Some school leaders reported that they had not yet integrated AI into their leadership practices or school processes. They shared comments such as, "I have not prioritised taking the time to learn about AI," "I am probably sceptical of AI because it is so new," and "I have no experience today". Other school leaders recognised the potential for AI in areas like decision-making but had not yet explored its application in depth.

One school leader noted, "I have not prioritised taking the time to learn about AI," reflecting a broader sense of uncertainty and hesitation surrounding the topic. This limited familiarity appeared to hinder meaningful integration of AI in school environments and highlighted the need for further support and knowledge development.

4. Challenges and Support Needed for AI Integration

Some school leaders pointed out that for AI to be effectively integrated into schools, support from central authorities or school districts is crucial. They acknowledged that AI has the potential to significantly impact the education system but emphasised that substantial professional training and resources are needed for school leaders and teachers to harness its potential. One school leader noted, "AI could have a significant impact on the education system, both positively and negatively."

The challenges include difficulties for teachers in distinguishing between what the student has done and what AI has done, the risk of cheating in written assignments, the difficulty to finding areas where AI can be used correctly, and the challenge of finding time to prioritise learning how to use AI in leadership practices. The opportunities include, for example, using AI as a training tool for students, teachers and leaders, the ability to quickly and easily get help by asking questions, time savings, and support for increased efficiency in lesson planning for teachers.

One school leader pointed out, "For example, with the work of school leaders, it is still based on a rather limited scope for Swedish conditions, and it is not always easy to find areas where it fits." The responses reflect a tension between the potential benefits of AI and the current lack of preparedness, pointing to a need for clearer strategies, time allocation, and external support to ensure successful implementation.

In summary the results can be summarised as illustrated in Table 1.

Table 1: Five Key Themes on AI in K–12 education

Themes	Description
Perceived benefits of AI in K–12 education	AI is seen as a tool to enhance efficiency in teaching and administrative tasks.
Concerns about AI and academic integrity	Concerns exist regarding AI's potential to facilitate cheating and undermine student honesty.
Need for ethical considerations and digital competence	Issues such as bias in AI outputs and content ownership highlight the need for ethical guidance and digital competence.
Limited familiarity and implementation of AI	There is a need for increased professional development among staff to use AI responsibly.
Challenges and support needed for AI integration	Many school leaders acknowledge limited knowledge of AI and find it challenging to integrate into leadership practices.

The study reveals five key themes regarding AI in K–12 education. first, school leaders perceive AI as a valuable tool for enhancing efficiency in teaching and administrative tasks, though concerns exist about academic integrity and the risk of cheating. Ethical considerations, such as biases in AI outputs and ownership of generated content, highlight the need for digital competence and professional development for staff. Many school leaders acknowledged their limited familiarity with AI and the challenges of integrating it into leadership practices. Ultimately, while AI presents opportunities for improved efficiency, support and resources are necessary for effective implementation in schools.

5. Discussion

The aim of this paper was to explore the potential of AI as a decision-making tool for school leaders in K–12 education. School leaders are defined here as principals and assistant principals. Two research questions were formulated: *How do school leaders perceive the potential applications of AI in leadership practices?* and *What challenges and opportunities related to AI in leadership practices do school leaders describe?*

The first research question aimed to explore insight into the school leaders' perceptions regarding the potential applications of AI in leadership practices. The themes one, three and four answer this question. School leaders perceive the potential of AI, particularly in areas like improving efficiency in teaching, lesson planning, and

administrative tasks, in line with Dai et al. (2024). They also note AI's ability to streamline operations and provide quick, efficient solutions in education, which shows how AI is an enabler of more effective leadership practice, highlighting opportunities AI presents for leadership practices. School leaders need to understand the ethical implications of AI, as highlighted by Martin et al. (2023), and the need for enhancing digital competence to responsibly integrate AI into leadership practices.

Many school leaders in the study view AI for enhancing efficiency in both teaching and administrative tasks, such as lesson planning, budget management, and personnel hiring. AI is seen to support daily responsibilities that demand both immediate responses and strategic planning – areas that reflect the broader leadership responsibilities described by Fullan et al. (2024). These findings support earlier research indicating that AI is no longer peripheral but is becoming an integral component of effective educational leadership (Adams & Thompson, 2025; Tyson & Sauers, 2021).

School leaders noted that AI could help streamline repetitive or time-consuming tasks, allowing them to dedicate more time to school improvement efforts. These perspectives align with Karakose and Tülübas (2024), who emphasise AI's potential to reduce administrative workload. Moreover, the ability to quickly generate ideas, structure plans, and provide instant feedback supports more dynamic and informed leadership practices, outcomes highlighted by (Schildkamp et al., 2019).

Moreover, AI tools such as ChatGPT were viewed as helpful for generating content, drafting communications, and providing instant information, a view supported by Chiu (2024), who highlights AI's communication-enhancing potential. These findings suggest a growing recognition among school leaders that AI can meaningfully contribute to both educational quality and operational efficiency.

School leaders also need to understand the ethical implications of AI, as highlighted by Martin et al. (2023), and the need for enhancing digital competence to responsibly integrate AI into leadership practices. Some participants raised ethical concerns about AI-generated content, bias, and data privacy. These concerns are consistent with Fusarelli and Fusarelli (2024) and Aldighrir (2024), who stress the importance of ethical decision-making frameworks in AI use. School leaders must be able to critically assess how AI tools are used in both instruction and administration to support equitable outcomes.

The second research question aimed to understand the challenges and opportunities related to AI in leadership practices. The themes two, three, four and five answer this question. According to school leaders, there is a risk of cheating and a difficulty to ensure academic integrity, as Fullan et al. (2024) outlined. It outlines the ethical concerns that school leaders perceive when considering AI in leadership decisions (Tyson and Sauers, 2021). AI might complicate decision-making in schools, particularly around evaluations and student learning. A major challenge for school leaders is the lack of familiarity and practical experience with AI tools. It reveals a gap between the potential of AI and its current application in leadership practices. One opportunity that AI provides school leaders related to decision-making is enhanced decision-making with proper professional training.

One of the most consistent concerns in the findings is related to academic integrity. School leaders expressed unease about students misapplying AI to complete assignments dishonestly, which complicates teachers' ability to assess actual learning. Several school leaders in the study discussed how AI-generated work can confuse the lines between student input and machine assistance.

The school leaders' concerns align with the literature, particularly Fusarelli and Fusarelli (2024) and Tyson and Sauers (2021), who emphasise the need for school leaders to establish ethical standards and ensure transparency in AI use. Fullan et al. (2024) also point out the increased complexity AI brings to leadership decisions, particularly when evaluating student outcomes and maintaining fairness in assessments.

Despite recognising its potential, many school leaders reported limited familiarity and experience with AI tools. Responses indicated a lack of time to explore new technologies, a sense of scepticism, and uncertainty regarding practical applications. These findings confirm earlier research by Holmes et al. (2019), who argue that educational systems are slow to adapt to change. This lack of competence hinders meaningful integration and illustrates the gap between AI's potential and its current use in leadership. Respondents highlighted the importance of professional development to build digital competence, findings that align with Torres-Santos and Castulo (2025) and Zawacki-Richter et al. (2019), who note the importance of equipping leaders with foundational digital skills for successful AI implementation.

The study also highlights a strong need for external and systemic support. Several school leaders noted that AI integration will only be successful with clear strategies, time allocation, and support from school organisers or

district authorities. These findings reinforce Weng and Tang (2014) and Marrone et al. (2025), who stress that school-level initiatives must be supported by national or regional efforts, including funding and policy development.

Despite these challenges, school leaders acknowledged several opportunities, including enhanced efficiency, better communication, and support for data-driven decision-making. These opportunities are in line with Adams and Thompson (2025) and Martin et al. (2023), who discuss AI's capacity to improve leadership outcomes when used strategically and ethically.

In summary, to explore AI as a decision-making tool, it is essential to understand what support school leaders need to adopt it effectively. A lack of support and resources may constrain the use of AI's potential in decision-making. For example, school leaders' unfamiliarity with AI is a major obstacle to its adoption in leadership practices, which highlights the need for professional training and resources to overcome this challenge.

6. Conclusions

The aim of this study was to explore the potential of AI as a decision-making tool for K–12 education leaders. The research addressed two primary questions: first, to understand the perceptions of school leaders regarding AI's applications in leadership practices; and second, to identify the challenges and opportunities AI presents in this context. The findings revealed that school leaders perceive AI as a valuable tool for enhancing efficiency in teaching and administrative tasks while also streamlining decision-making processes.

In response to the first research question, school leaders acknowledged AI's potential to improve both administrative and pedagogical efficiency. AI tools were viewed as essential in enhancing leadership practices, particularly by optimising repetitive tasks and providing real-time insights for more informed decision-making. However, the second research question brought to light the challenges school leaders face, especially with regard to academic integrity concerns, lack of familiarity with AI tools, and the necessity for further professional training to effectively integrate AI into leadership practices.

The study also underscored the importance of addressing ethical considerations, such as ensuring fairness, transparency, and accountability in AI's application within educational settings. Additionally, school leaders identified a critical need for digital competence, not only among teachers but also for themselves as leaders, to responsibly navigate the growing presence of AI in schools.

The theoretical significance of this research lies in its examination of AI as a decision-making tool for K–12 education leaders. By exploring their perceptions of AI's applications, as well as the associated challenges and opportunities, this study provides valuable insights into how AI can transform educational leadership. It shows that AI has the potential to enhance leadership practices, optimise administrative tasks, and offer support for more effective decision-making in schools.

The educational significance is underscored by the emphasis on data-informed decision-making and the ethical considerations related to academic integrity and the need for digital competence among leaders and teachers. The findings highlight the need for school leaders to possess digital competence to responsibly incorporate AI into their leadership practices. Additionally, the study stresses the importance of supporting school leaders in overcoming barriers and integrating AI effectively. Addressing these needs will be critical for realising AI's full potential in educational practices.

In conclusion, this research highlights that while AI presents numerous opportunities for enhancing educational leadership, there are significant challenges related to ethical concerns, digital competence, and the integration of AI into existing school structures. Addressing these challenges will be key to ensuring that AI can be used effectively and responsibly in K–12 education settings.

This study highlights the importance of ethical considerations in using AI for school leadership. Key ethical issues include maintaining academic integrity, ensuring data privacy, and addressing potential biases in AI tools. School leaders must be aware of these challenges and be trained to use AI responsibly. It is essential to ensure that AI is used in ways that support fairness and transparency, while promoting equitable educational opportunities for all students.

6.1 Limitations and Future Research

In regard to limitations, it is important to acknowledge the low survey response in this small study. Nevertheless, the analysis of the open-ended questions in the surveys has provided a picture of how school leaders perceive the potential of using AI in leadership and learning practices. Future research could include interviews with school leaders to deepen the understanding of the potential and constraint in the use of AI for leadership and learning. Other studies could involve focus group interviews to widen the understanding of how school leaders view the use of AI to support teacher and student learning through the reflective use of AI.

Ethical Declaration

An ethical declaration was not required.

AI Statement

Artificial intelligence tools, specifically ChatGPT (by OpenAI), were used during the writing process of this paper to support language editing and improve clarity. All content and ideas remain the sole responsibility of the author(s).

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Art and Education: Cultivating Active Citizenship Through Game-Based Storytelling

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Abstract: This paper presents “The Other Half”, a collective game aiming on the one hand to encourage creative expression through the writing of dialogues, and on the other to foster students’ understanding of and critical reflection on aspects of the democratic citizenship education. The game was played within two teaching sessions of the course “Art Didactics and Creative Technologies”, which is taught by the authors as part of the "Special Program of Studies for the Pedagogical and Didactical Sufficiency Certification" (PDSP) at the Department of Audio and Visual Arts of the Ionian University. The authors employed mechanics that require players to first complete individual and collaborative creative assignments and then negotiate in the context of secret and open voting sessions to weave them into a common work, while given the ability to modify the game’s own rules and scope. E-learning affordances facilitated the coexistence of both physically present and remote players. Emphasis was placed on the role of the majority and the importance of participation in decision-making, as well as on flexibility and agreement in the process of dynamically exploring a common goal. The game was evaluated through a focus group discussion, whose thematic analysis suggests that the game was found interesting and creative, especially in terms of voting for dialogues and changing rules, and suitable for use in the classroom. However, the total freedom to shape the game’s end-goal, the complexity of rules, and the time constraints resulted in some cases in confusion and anxiety, whereas the game’s hybrid form was found to weaken participation.

Keywords: Active Citizenship, Game-based Learning, Gamification, Democracy, Art Education, Storytelling

1. Introduction

Undertaking their societal role, young people question and reflect, form opinions and advocate. In the social arena, groups with conflicting objectives are formed based on various interests and different understandings of events. Controversial issues tend to instil a "binary code" in the public, i.e. being for or against, causing most refined opinions to disappear. In the beginning of the 2024-2025 academic semester, during the teaching of the lesson “Art Didactics and Creative Technologies” as part of the "Special Program of Studies for the Pedagogical and Didactical Sufficiency Certification" (PDSP) at the Department of Audio and Visual Arts of the Ionian University, the class investigated what social influence means. The instructors and authors of this paper raised the key question whether social influence is considered a process that involves the majority. It was argued that the term majority is defined numerically and in relation to the term minority. Besides its smaller numbers, it is the determination of the latter to participate or not in the dominant social norms that plays a vital role. Many of us often adopt an attitude of obedience when we are in a collective situation and our assessments are mitigated due to the fear of differentiating ourselves from others. Trying to avoid a conflict, we expect/desire a negotiation that progresses with equal and mutual concessions.

This paper suggests a game-based educational approach seeking to prepare prospective Art educators for raising the awareness of their class about the challenges that modern reality poses to a democratic system of government. In the 21st century, liberal democracy seems to be well established and rarely questioned (at least in the West), yet faces a complex array of challenges, including the rise of populism and the impact of technology on democratic processes and public discourse. In order to something different and innovative to come, everyone has to be alert and participate actively. In the suggested game-based approach, by creating dialogues that deal with characters who are diametrically opposed and by combining the dialogues with the ones of their peers into a common narrative, players are guided to justify conformity through personality traits and place emphasis on social situations. Through negotiating and voting they are confronted with the notions of majority, social influence, unanimity, pluralism. They are prompted to be subversive, playful, imaginative. By deciding themselves their common goal they become the “agents” of a social interaction that they envision.

In these challenging times, art sharpens citizens personal responses to the contemporary theories, challenges and problems (Papadopoulou, 2019). Art can provide a sense of optimism; in Gerhard Richter’s words “art is the highest form of hope” (Phaidon Editors, 2016). Art education can foster a greater social tolerance and civic engagement. More specifically, it can highlight the problem of selective attention, which accounts for arbitrarily dismissing or emphasizing certain issues (Papadopoulou, 2013). Through active participation in a creative game environment facilitating free and safe experimentation (Huizinga, 2014), students are guided to appreciate the

importance of dialogue and solidarity within a dynamic community, which is not clinging to comforting assumptions and oversimplified solutions (Papadopoulou, 2023). The true reward of connecting different viewpoints is the broadening of perspectives and knowledge, the cultivation of inner discipline, vigilance, constant introspection. Fostering a positive stance towards synthesizing crises is expected to unite unique –and otherwise isolated- instances and pave the way for discovering the common good (Papadopoulou, 2019).

Focusing on games, they are considered complex learning environments, which require careful design for their motivational and cognitive affordances to be effectively realized. The appropriate mechanisms must be provided that allow for meaningful exchange of ideas in ways that build collective knowledge and trust to meet shared goals (Plass, Homer & Kinzer, 2015). ICT can further enhance the playful learning environment by extending its creative capabilities and facilitating remote access and communication. Heading towards a new paradigm in education, one that is deeply grounded to digital revolution (Collins & Halverson, 2018), universities are starting to adopt hybrid learning practices that blend the physical classroom with online space (UNESCO, & NETEXPLO, 2019).

Considering all the above, the collaborative game "The Other Half" was designed with a dual purpose: i) to encourage and foster, both individually and collectively, players' creative and expressive skills in storytelling and dialogue writing; and ii) to raise awareness and cultivate players' critical thinking regarding issues, concepts, and concerns related to Democracy. This paper presents the game's content and rules, as well as its first evaluation through a focus group discussion.

2. Game Design

2.1 Curricular Integration

"The Other Half" served as the backbone of the "Art Didactics and Creative Technologies" course in the winter semester 2024-2025. It was structured in three stages: Preparation, Application, and Evaluation, providing a framework for focused study and reflection upon democratic concepts and practices.

- In the stage of Preparation, students were tasked with seeking and studying literature related to Democracy (Böckenförde, 2022; Riesman, 2001; Runciman, 2019; Tocqueville, 2004; Weale, 2018). Excerpts from Steiner's work on the Ancient Agora (Steiner, 2015) were also examined. Two main pylons are used as guidance: i) Democracy and its two core principles: majority rule and the principle of popular sovereignty, and ii) serious games that address aspects of Democracy. Each student presented their research findings to the class for feedback. Each presentation lasted 7 minutes, followed by an 8-minute discussion.
- In the stage of Application, the students played the game "The Other Half" during two weekly sessions with a total duration of approx. 4 hours. The game was conducted in a hybrid format, with undergraduate students physically present in the classroom, while alumni joined online. Both groups were connected to the same online platform to enable private chat communication among team members in isolated virtual rooms.
- The stage of Evaluation involved a focus group discussion about the participants' experience. With their consent, the conversation was recorded and later transcribed. The authors fuelled the conversation with questions exploring the role of the gaming process in the construction of narratives and in the reflection on matters pertinent to the quality of Democracy.

2.2 Gameplay Mechanisms

Drawing upon their prior engagement with projects realizing playful learning approaches (Papadopoulou, 2018; Papadopoulou et al., 2023) the authors employed game mechanics that require players to compose, evaluate, negotiate, and make decisions. The aim was to examine democratic notions pertaining to active participation and the majority required for decision-making: what it means for groups to form coalitions that constitute an absolute majority, a relative majority, or situational majorities that arise depending on how people vote on a specific issue (Weale, 2018). Time constraints were utilized as a mechanism to challenge players to quickly generate and adapt ideas. A virtual meeting platform supported gameplay between undergraduate students, who were physically present in the classroom, and alumni, who joined from their homes. The option to form breakout rooms gave teams the opportunity to convene in private before joining the plenary. A virtual-dice application was used for adding randomness.

Of core importance is the mechanic to modify any one of the game rules including the initial “endgame” that all selected stories must somehow be intertwined; upon completing each game stage and reaching a successful decision, players are granted the opportunity to discuss suggestions for modifications. The aim is to formulate a constructive position that recognizes all perspectives and confronts their inherent bias (Russell, 2014; Tocqueville, 2004). The focus was placed on the problem of conflicting motives, positions, and forces, on the basis that a romanticized projection of democratic values is not sufficient. Beginning with personal choices in the creation of fictional characters, participants were invited to collaborate first in pairs and then as one group, with the dual objective of weaving dialogues and establishing a narrative context to embrace them.

2.3 Game Structure

"The Other Half” consists of four (4) stages, called "Episodes," which symbolize the journey from the individual to the collective. Each Episode presents players with its own task and set of rules. However, participants are allowed to modify any rule and/or goal they deem necessary, including the ones pertaining to the Episodes’ deliverables, as long as they agree to the required degree of majority. The purpose of this process is, on the creative level, to highlight the freedom and significance of adaptive thinking, as it is manifested through each choice made during the creative process; and on the reflective level, to emphasize the necessity, responsibility, and power of social commitment of the group that co-decides with a shared vision.

2.3.1 Episode 1

In the first Episode, players are presented with pairs of opposing characteristics, from which they must silently and without disclosing their choice select the pair that most captures their interest. Through an online application a virtual dice is rolled for each player to determine the order in which they will choose their preferred pair. When a pair is selected, it is removed from the virtual board and all remaining players must make their selection from the remaining options. The use of dice symbolizes the role of chance in an individual’s life and, by extension, in the society formed by individuals, as it can either facilitate or disrupt personal plans and shape social conditions. The authors have previously explored the concept of "disruption," its manifestations and implications, through the design, implementation, and evaluation of educational games (Rovithis et al., 2022).

After all players have chosen a pair of characteristics they have 12 minutes to compose a dialogue between two characters embodying the selected traits. Table 1 presents the pairs of characteristics that were available during the session discussed in this paper. The authors' rationale behind the selection of these specific dichotomies was to provide an overview of the diversity of human traits and behaviors that can possibly interact within a social collective. The sharp contrast in each pair reflects the heterogeneity that may occur within a group and account for divergence in ideas and attitudes. The deliverable for this Episode represents an understanding of this diversity through its artistic, narrative representation.

In this Episode, players work individually and are invited to explore the concept of opposition through the writing of a dialogue, embodying both extremes and developing empathy toward positions potentially unfamiliar or even opposed to their own. The only specification given by the instructors was that the dialogue should include a turning point—an instance where something changes dramatically. The interpretation of this turning point — as convergence, conflict, or otherwise— was left to the students’ discretion, with only request that they be able to justify their chosen interpretation.

Table 1: 16 pairs of contrasting character traits

Gullible	Skeptical
Organized	Chaotic
Realist	Visionary
Hard-working	Lazy
Content	Dissatisfied
Assertive	Modest
Changeable	Stable
Flatterer	Honest
Boastful	Humble

Conformist	Dissenter
Flawless	Imperfect
Proud	Servile
Superstitious	Rationalist
Brave	Coward
Arrogant	Insecure
Laconic	Expressive

2.3.2 Episode 2

In the second Episode, the transition is made from the individual to the most fundamental form of relationship: the pair. Players are divided into groups of two, and each team is isolated in a virtual room. Each member of the team must first decide to keep one of the two characters from their original dialogue and discard the other, and then together with the other team member compose a dialogue between the two retained characters. The exact way and criteria for selecting/rejecting the characters and composing the dialogue is up to each team to decide. For example, one approach would be that each team member makes their selection based on personal criteria before the dialogue's narrative framework is discussed, whereas another approach would be that the team members first agree on the context of their dialogue, which will then influence their character selection. The total time available is 15 minutes, and the only specification for the deliverable dialogue is that it must contain a turning point. The team members can communicate orally, unless they disturb other teams, in which case they must switch to written communication only.

The process of selecting and rejecting characters highlights the necessity and difficulty of decision-making, both within the intrinsic value of democratic procedures and in the creative process of any artistic composition. Moreover, the collaborative writing of a dialogue, starting out with at least equal responsibility for each co-creator and evolving through mutual compromises, reflects the negotiated yet productive interaction between the parts of a bilateral relationship, from interpersonal dynamics of individuals to bilateral agreements between states.

2.3.3 Episode 3

In the third Episode, each team is asked to compose yet another dialogue, this time between the characters that each team member had previously rejected. Again, the process lasts 15 minutes, and the dialogue must contain a turning point. Here, players are challenged to deal with the unexpected, as they had not known, when they previously rejected a character, that this character would later return to the game. The authors have previously explored the notion of "reversal" and highlighted the gravity of applying educational practices that prepare students for unexpected turns of events (Rovithis et al., 2022). On a creative level, this mechanic symbolizes the potential of previously dismissed ideas to re-enter and enrich later compositional processes, whereas in terms of reflection on Democracy, it highlights the necessity for active citizens to engage with voices that they themselves may have rejected and/or marginalized voices, which nevertheless assert their own positions and bring their own dynamics into the democratic dialogue.

2.3.4 Episode 4

In the fourth and final Episode, the game focuses on the concept of community and the rules and mechanisms that govern the democratic coexistence and interaction of its members. The virtual breakout rooms are dissolved, and all teams come together in a hybrid plenary session, combining in-person and online presence. The instructors announce the initial collective goal: the community must compose a work made up of selected dialogues, with the essential condition that a connection justifying these selections must exist, like for example a shared narrative framework or a common element in discrete narrative nodes. The community must select the dialogues through the following process.

Each team performs vocally its two dialogues without revealing which dialogue was created first or second (i.e. the one involving the initially preferred characters or the one involving the rejected ones). The community then approves by secret ballot one of the two. For the decision to be valid, at least 75% agreement is required. Abstentions and blank votes are not excluded but instead counted in the percentage calculation. Throughout the procedure, the team that wrote the dialogues remains silent. If a valid decision is not reached, the process

is repeated after two volunteer speakers, who support different decisions, openly defend their positions. Each speech has a maximum duration of 3 minutes. If no decision is reached again, the debate continues with new speakers. If no decision can be made, the game reaches a dead end and all players lose.

In the case that the community manages to reach a decision, it automatically gains the right to modify any game rule at will. This may be a percentage, a procedure, the final objective, or even the decision to end the game. The process of voting for a modification is public and unless modified requires 75% agreement. Any member of the community can propose a modification and argue in favour of its adoption. The vote on whether to adopt a modification can occur once in each round. If the required level of agreement is not reached, the game continues under the existing rules. The authors' intention is for the process to reflect the responsibility of individuals participating in democratic processes to pursue a collective goal through a form of synthesis rather than discord, guided by freedom and reasoning, while at the same time to allow for democratic mechanisms such as majority rule, public speaking, and voting to be empirically explored.

3. Evaluation Results

Twelve students took part in the game, thus forming six teams in the second Episode. The fourth Episode was interrupted, because the teaching session ended, and was resumed in the next week. After the game was completed, the class discussed about their experience. The following questions had been preselected by the instructors to stimulate the discussion:

- How did you find the experience?
- Mention, if any, one or more elements that you liked and/or did not like.
- How did the game impact your creative ability?
- Do you believe it helped you understand what determines the quality of democracy?
- Did it challenge or reinforce your views related to the power of the majority, participation, and dialogue?

The discussion was recorded, transcribed and analysed according to the thematic analysis methodology as described in (Caulfield, 2019; Maguire and Delahunt, 2017; Nowell et al., 2017). The inductive approach was followed allowing the coded data to determine the themes. The analysis resulted in 4 themes, namely "Game Mechanics", "Group Dynamics", "Hybrid Format", and "Potential Application in the Classroom". The "Game Mechanics" theme was broken down into 3 sub-themes, namely "Time Constraints", "System of Rules", and "Final Goal". The themes and corresponding codes are shown in Table 2 and analyzed further below.

Table 2: Themes, sub-themes, and corresponding codes

Theme: Game Mechanics		
Sub-theme: Time Constraints	**Sub-theme: System of Rules**	**Sub-theme: Final Goal**
Codes: pressing time limit, unfinished tasks, disconnection from game flow, safety, fun experience, suspense, need for closure	Codes: game alive and evolving, creative, confusion, more guidance, too open, need for clarity, to know rules better	Codes: lack of direction, no criteria for voting, unclear, seeking coherence, uncertainty, player-dependent
Theme: Group Dynamics	**Theme: Hybrid Format**	**Theme: Potential Application in the Classroom**
Codes: game fosters socialization, constructive teamwork, observing introverts and extroverts, uncomfortable with strangers	Codes: impersonal interaction, disconnection from game processes, face-to-face better for discussion, face-to-face makes participation easier, face-to-face expression more direct	Codes: democracy education, adaptability, creative activity for younger students

3.1 Theme: Game Mechanics – Sub-theme: Time Constraints

The participants were to a great extent concerned with the issue of time, and more specifically i) the time at their disposal to complete the solo and pair tasks (Episodes 1-3), and ii) the game's structure within the course of two teaching sessions. Regarding both issues, controversial opinions emerged from the discussion.

The amount of time available for delivering the dialogues had a positive impact on some participants and a negative impact on others. Some players reported that time was too limited for such a creative process. They also complained that they could not devote all the available time to the creative process as they had to process the game rules, which made the experience more stressful. Yet others reported that the specific time constraints made the experience more fun and suspenseful and had a positive impact on the creative process by establishing a concrete deadline for the goal to be achieved, which motivated especially persons with little experience in writing dialogues.

Regarding the game's structure in time, some participants found it difficult to reconnect with the plenary after it was interrupted, and would prefer a temporary closure after the game's first three Episodes that would allow them to enter the plenary for the first time in the second session. Others suggested the opposite, since knowing already how the plenary works made them feel safe the second time.

3.2 Theme: Game Mechanics – Sub-theme: System of Rules

Many participants appreciated the fact that the game rules were revealed step-by-step, and more importantly that all rules without exception were subject to change through the plenary sessions. This made them feel that the game was "alive" and constantly evolving, capable of being something entirely new every time, and that they can create order out of the initial chaos by voting to shape their own goal. Some argued that the voting process was their favourite and most creative part of the game. Yet, other participants found this freedom too much and would prefer to have a limited number of options to choose from.

In terms of clarity and presentation some participants mentioned that the game rules were complicated and had to be re-read several times. They also felt that as the game progressed and new rules emerged, keeping everything in mind was confusing and possibly led the group to forget some choices and miss some of the game's potential. Some participants made suggestions, such as having the total game instructions written in front of them all the time, or given to them beforehand, and asked for better explanation regarding the game's key issues.

3.3 Theme: Game Mechanics – Sub-theme: Final Goal

The participants were puzzled by the game's initial directive and found it too general. Confronted with having to figure out themselves what the final goal should be, they felt confused and without purpose. Not knowing the desired outcome resulted in lack of concrete criteria for voting for/against a dialogue, which hampered the voting process. Some felt reluctant to make decisions since no rule seemed permanent and no choice was guaranteed to prove itself useful in the end. They reported struggling to find a solid suggestion for a common goal to present and justify to the plenary. Thus, some asked for specific directions, such as a list of options to choose from. Yet, others argued that the goal of the game depends on the functional value that the users have agreed to bestow in the first place. Defining the game as primarily educational or creative can critically shift players' endgame approach.

3.4 Theme: Group Dynamics

Many participants stated that the game's collaborative tasks, namely creating dialogues in pairs and voting for dialogues as a group, were constructive and interesting experiences in terms of teamwork. Focusing on the plenary tasks some claimed that they aptly simulate the way a parliament operates, with others arguing that the plenary was their favourite part of the game, because one could observe how different characters, both introvert and extrovert, behave within a group. It was suggested that the game brings together different personalities and guides them explore how to work together even if they do not know each other. One participant though claimed that if she had not teamed up with a person she was familiar with, she would feel uncomfortable.

3.5 Theme: Hybrid Format

It was widely supported by the participants that the game's hybrid form with some players online and others physically present did not benefit the game process. This was reported by both people who were participating remotely and in person. Many felt that communication was impersonal especially when their peers had their cameras turned off. The lack in direct interaction weakened participation with people hesitating to raise their hand, wait for their turn and express themselves. Issues were not discussed thoroughly or even not discussed at all, resulting in the voting process being perceived as inefficient. All participants who shared the above opinions agreed that if they all played the game in person, such problems would be avoided.

3.6 Theme: Potential Application in the Classroom

Some participants were quite positive towards the game's application in the classroom. The most salient notion in that context was adaptability, which was reported to have two aspects. The one refers to the game's suitability to foster players' skill to adapt to the unknown, to randomness, to negotiation and compromise. Guided by the game's mechanics, which require their active participation, players must seek ways to integrate themselves in the collective in a fruitful and meaningful way. The other aspect of adaptability pertains to the game's flexibility in terms of rules and structure. Independent from a rigid system and open to constant change, the game can be adjusted to the specific learning needs of different target groups, subjects and tasks. The participants thought that younger students would be more interested in the game's creative tasks, whereas older students and adults more likely to engage more with the game's democratic processes.

4. Conclusion

Given the complexities of our time, which can potentially deal heavy blows to Democracy, the inclusion of lessons where dialogue is developed, decisions are made, and each of us transcends their own limiting horizon is essential. The goal is to think critically, without allowing things or situations to be processed for us, but rather by us. With the game "The Other Half", the authors try to encourage participants to express themselves creatively, while remaining open to co-authoring and negotiating towards a common goal, whose meaning they themselves collectively explore.

The game's evaluation suggests that the mechanics involved fostered creativity and communication on a personal and interpersonal level. The participants enjoyed especially the voting part and were inspired to reflect upon democratic notions and processes. However, some participants found the time constraints stressing and the game rules confusing. The game's hybrid form was also found to weaken participation. Moreover, participants felt overwhelmed by the freedom that was given to them and asked for a more restricted, unambiguous space of possibilities.

The authors suggest that the thought-provoking remarks regarding the game's rules and goal are mainly due to the game lacking a clearly opposing position to one's own. Students tended to seek out clear-cut distinctions that would provide specific options to select from. One of the major accomplishments of the game was that it enabled dialogue and reflection on the notion that, rather than starting from spontaneous disagreement and remaining within a framework of opposition and competition, players could move forward by opening spaces for doubt; passionately upholding the right to disagree in ways that ultimately lead to critical re-examination of one's own views. Future work will build upon these preliminary findings to further explore the affordances of Art education regarding active citizenship in the digital age.

Ethics Declaration

All participants signed a consent form, which complies with the Ionian University Ethics Committee regulations pertaining to the conduct of game-based qualitative research activities with human subjects.

AI Declaration

AI was employed i) as a support tool for translation, more specifically in the case of Democracy-related concepts that needed to be accurately and formally expressed in English, ii) in the transcription and translation of the recorded semi-structured discussion, iii) the design of the word cloud.

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A Scoping Review of Frameworks in Video Conferencing-Mediated Teaching: Enhancing Digital Competence for Educational Engagement

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Abstract: This scoping literature review synthesises existing digital competence frameworks relevant to teachers and students with a specific focus on their applicability within higher education and the effective, efficient, and pedagogically sound use of video conferencing (VC) systems. While numerous frameworks address digital literacy at the general or pre-tertiary level, few adequately capture the distinct demands of synchronous online teaching and learning in higher education contexts. The review highlights critical gaps between current frameworks and the specific digital competencies required for meaningful video conferencing use, including technical, pedagogical, and collaborative dimensions. Framed within the Erasmus+ KA2 project *"Portable Video Conferencing Toolkits and Online Applications for Engaging Learning Experience Design in Higher Education Classroom (EdViCon)"*, this study identifies core competencies, maps overlaps and distinctions across 10 frameworks, and argues for the development of a targeted competence matrix to guide training design and curriculum development for higher education. The findings offer a foundation for aligning digital skills training with the real-world needs of educators and learners engaged in video-mediated instruction.

Keywords: Review; Competence; Teachers; Students; High Education; Video Conference; Edvicon.

1. Introduction

In an era of increasing reliance on video conferencing (VC) technologies in education, the need to define and support digital competence specific to VC use in higher education remains both important and underexplored (Khalid, Tretow-Fish, & Parveen, 2023; Mansoor, Rozario, Kibria, & Khalid, 2024). While digital competence is widely recognized as critical to human development and intelligence (OECD, 2019), especially in the digital era (van Laar et al., 2017), much of the existing literature and frameworks focus on general digital literacy in primary and secondary education. This scoping review addresses the following research question: What existing digital competence frameworks are relevant for informing the development of targeted VC-related competencies among teachers and students in higher education? To answer this, the review synthesises peer-reviewed articles, institutional reports, and frameworks from national and international sources, with a focus on identifying and categorising digital competences essential for the effective, efficient, and pedagogically sound use of video conferencing systems in higher education teaching and learning. Key references include foundational documents such as the UNESCO Information, Communications and Technology (ICT) Competency Framework for Teachers, the European DigCompEdu model, SELFIEforTEACHERS, and the HeDiCom framework, among others. While overlaps exist, the digital competence needs of higher education teachers and students differ from those of the general public or K–12 educators. This review identifies these distinctions and evaluates how well current frameworks support VC-related practices in higher education contexts. Conducted as part of the Erasmus+ KA2 project "Portable Video Conferencing Toolkits and Online Applications for Engaging Learning Experience Design in Higher Education Classroom (EdViCon)," the review supports the broader goal of bridging the gap between theoretical models and applied pedagogical tools. It contributes to defining learning outcomes and training strategies for enhancing the quality of synchronous digital teaching and learning in higher education.

1.1 Digital Competence, Digital Literacy, and Digital Skills

Digital competence encompasses the set of knowledge, skills, and attitudes required to use ICT and digital media effectively, efficiently, critically, and ethically for a variety of purposes. It involves communication, collaboration, information management, problem-solving, content creation, and knowledge building across contexts such as work, learning, leisure, and civic engagement (Ferrari, 2012, p. 30). It goes beyond basic operational skills, encompassing the ability to communicate, evaluate information, and engage meaningfully with digital environments. A digitally competent individual must also understand legal and ethical implications, data privacy, and the societal impact of technology use. Janssen et al. (2013, p. 480) emphasize that responsible and healthy engagement with digital tools requires not only technical knowledge but also specific attitudes and values. Digital literacy, often used synonymously with digital competence, especially in educational contexts, involves the ability to confidently and autonomously learn, play, socialise, work, and participate civically in digital environments (Nascimbeni & Vosloo, 2019). Mattar et al. (2022) affirm that while these terms are closely related, their use may vary depending on context and audience. In the context of video conferencing (VC), digital competence must consider multiple dimensions: not only skills and literacy, but also the specific demands of online and hybrid learning environments. Both students and educators require tailored digital capacities for VC integration. Importantly, as Ferrari (2012) highlights, mastering tools or applications is only one part of digital competence, which also involves cognitive, ethical, and reflective dimensions. Newman (2008) further advocates for a view of digital literacy rooted in critical thinking. In his model, digital literacy is not just technical proficiency, but also a component of broader information literacy, where critical thinking plays a central role. Thus, meaningful engagement with digital tools, including video conferencing systems, demands more than just operational skills—it also requires analytical, evaluative, and ethical reasoning within a digital context.

2. Related Empirical Work on Competence Assessment

Yelubay et al. (2020) indicate that digital competence (DC) is one of the European Union's eight key competences for lifelong learning. Tretinjak and Anđelić (2016) conclude that there are five digital competence areas, including information, communication, security, problem solving, and content creation. All teachers should become familiar with them to make learning and teaching effective based on the six areas of Digital Competence of Educators (DigCompEdu) Framework (Redecker & Punie 2017). Muammar et al. (2023) adopted the DigCompEdu Framework to investigate the level of digital competences of educators in universities in UAE. In their findings, most faculties are digitally competent in all the six areas pertaining to professional engagement, digital resources, teaching and learning, assessment, learner empowerment, and learner facilitation which help to reflect the extent to which they interact with and use technology in different perspectives of teaching. Pedaste et al. (2023) develop an instrument for assessing Digital Competence for Learning (DCL) and psychometrically validated a DCL assessment test in primary and lower secondary schools, contributing to ongoing discussions about the dimensionality of digital competence (DC) and introducing ideas about reframing the dimensions of DC. They stated that DC is needed for carrying out effective learning and noted DCL as a specialised competence has not been widely studied and therefore relies on DC in the development of the concept and assessment of the instrument for DCL. Three challenges are highlighted in literature (Self-assessment based on Likert- type Scales)

- Students' self-reported levels of competence were not in line with their actual performance (Siddique et al. 2016).
- Educational context, confidence in one's digital abilities is only partially associated with students' actual performance of digital tasks (Porat et al. 2018)
- Trustworthiness of self-reports in information and communication technology (ICT) skills measurement that people with higher ICT skills are more likely to overreport having these skills but decreasing in age (Pałczyńska & Rynko 2021).

Jin et al. (2020) suggest that performance-based digital skills assessment would more likely provide accurate data since competences develop mostly through real-life experiences. Siddiq et al. (2016) and Reichert et al. (2020) conclude that the best way to assess them could be with the help of assignments drawn from real-life situations.

- Assessment of DC or DC on a group of people older than 16 students leaving out primary and lower secondary school students
- Focus on the assessment of only skills or abilities; whether the concept of DC or DCL is unidimensional or comprising several dimensions.

Pedaste et al. (2021) are initiating discussions for a more general discussion on the concept of competence. This can help educators put greater emphasis on areas where students need further improvement. Li (2016) classified digital competence into four levels: beginner, intermediate, higher, and advanced, and specified the ability level of each level in detail

3. Methods

This review was conducted as part of the EDVICON project, aiming to explore existing digital competence frameworks and assessment tools relevant to teachers and students, with a particular focus on competencies required for video conferencing contexts.

A systematic literature search was performed during the second week of January 2024 across multiple academic databases to ensure comprehensive coverage. The databases included IEEE Xplore, Scopus, Web of Science, ERIC, and Google Scholar. The search employed the keyword phrase “digital competence framework”, combined with additional terms such as “video conferencing”, “teacher digital skills”, and “digital literacy assessment” to refine the scope. The search was limited to peer-reviewed journal articles, conference papers, book chapters, and authoritative reports published between 2018 and 2023 to capture recent developments in digital competence.

Inclusion criteria were:

- Publications focused on digital competence frameworks or assessment tools relevant to education, particularly those addressing teacher and student competencies.
- Works that explicitly or implicitly addressed competencies related to synchronous digital communication technologies such as video conferencing.
- Publications available in English and accessible through institutional subscriptions or open access.

Exclusion criteria included:

- Studies primarily focused on general ICT infrastructure or non-educational digital skills.
- Publications without sufficient detail on framework structure or competency descriptions.
- Non-peer-reviewed opinion pieces or blog posts.

3.1 Screening and Selection

The initial search yielded 48 publications. After removing duplicates, two researchers independently screened the titles and abstracts to assess their relevance. Discrepancies were resolved through discussion until consensus was reached. This process resulted in a final set of 14 relevant sources from IEEE Xplore, along with additional key documents from other databases and institutional repositories.

3.2 Data Extraction and Analysis

Key information extracted from the selected documents included framework scope, structure, pedagogical foundations, and explicit or implicit references to video conferencing competencies. The approach aligns with the methodological framework proposed by Perifanou (2021), which emphasizes thematic analysis of assessment frameworks and tools related to digital competence in educational contexts. This analysis was integrated into the broader objectives of the EDVICON project, which aims to develop theoretical foundations and practical resources to support digital skill development in video conferencing environments. In this study, the terms framework, matrix, and tool are used with distinct meanings. A framework refers to a conceptual structure that outlines the domains and dimensions of digital competence. A matrix specifies levels or indicators within a framework, providing guidance for assessment or progression. A tool denotes a concrete instrument or application used to measure or support the development of competence. This distinction supports the study's aim to explore both theoretical models and practical instruments related to video conferencing competencies in educational contexts.

4. Analysis and Synthesis of Existing Competence Matrix for Educational Contexts

The various digital competence frameworks for teachers, students, and other educational roles and contexts were identified and reviewed in this section. At the end of the section, a framework is proposed by selecting and integrating key elements and concepts from the reviewed frameworks, specifically tailored to support the

efficient and effective use of video conferencing systems in live online and hybrid teaching scenarios. The section critically examines the various frameworks to inform this development.

4.1 UNESCO ICT in Education Curriculum for Schools and Programme of Teacher Development: Nine ICT Literacy Units

The UNESCO ICT in Education Curriculum for Schools and Programme of Teacher Development (2002) provides a foundational framework aimed at fostering ICT literacy among teachers through nine dedicated units. However, when evaluated through the lens of contemporary practices such as video conferencing for collaborative teaching and learning, the framework reveals notable limitations in both scope and pedagogical orientation. In terms of scope, the curriculum emphasizes general ICT integration rather than addressing the specific affordances of technologies such as video conferencing platforms. While this broad approach may have been appropriate in the early 2000s, it lacks the specificity needed to support synchronous digital collaboration tools that are now central to remote and hybrid pedagogies. Regarding structure, the framework adopts a linear, skill-based progression across its nine literacy units. Although comprehensive for its time, this structure does not sufficiently address the dynamic and multimodal nature of real-time video conferencing contexts, such as managing learner engagement, fostering co-presence, or ensuring inclusive participation across varying digital literacies. From a pedagogical perspective, the framework is underpinned in a transmissive model of ICT instruction—training teachers to use tools rather than -encouraging critical, reflective, and pedagogically grounded integration. This limits its relevance to practices where pedagogical design, social presence, and collaborative learning theories are the core principle in the effective use of video conferencing for education. In terms of relevance, while the curriculum was instrumental in laying early foundations, its dated conceptualization and lack of direct reference to synchronous online communication underscore the need for substantial revision. To remain applicable in today's educational landscape, the framework must evolve to reflect the demands and pedagogical opportunities presented by modern video conferencing environments.

4.2 The Digital Competence Framework for Primary and Secondary Schools in Europe

The Digital Competence Framework for Primary and Secondary Schools in Europe (Guitert et al., 2020) provides a structured and contemporary model organized around five key competence areas. Its broad scope aligns well with the goals of 21st-century digital education, explicitly encompassing Communication and Collaboration, which is directly relevant to video conferencing practices. In terms of structure, the framework balances technical and pedagogical dimensions, presenting a more integrated vision than earlier models. Pedagogically, it promotes active, participatory learning, aligning well with the collaborative affordances of video conferencing platforms. However, while the framework implicitly acknowledges the use of synchronous tools, it falls short of offering detailed guidance on the pedagogical integration of video conferencing.

4.3 European Framework for Digitally Competent Educational Organizations

The DigCompOrg Framework offers a systemic scope, targeting institutional development rather than individual digital competences. Its structure—composed of seven interrelated elements—supports strategic planning and policy alignment but is less directly applicable to classroom-level practices such as video conferencing. Pedagogically, the framework promotes self-reflection and organisational innovation, which can indirectly support the integration of tools like video conferencing. However, it lacks explicit guidance on synchronous teaching methods, limiting its immediate relevance to educators seeking practical strategies for collaborative, real-time digital learning environments.

4.4 The Digital Competence Framework

Janssen et al.'s (2013) Delphi-based framework presents a broad, cross-sectoral scope, identifying twelve essential elements of digital competence. Its structure, grounded in expert consensus, ensures a comprehensive yet generalized approach. Although pedagogically inclusive, the framework remains conceptual, and offers limited operational guidance for specific educational practices. Consequently, its relevance to video conferencing is indirect, highlighting foundational competencies but lacking concrete strategies for integrating synchronous, collaborative technologies into teaching and learning (Falloon, 2020).

4.5 Competency Framework for the University Bachelor of Technology

Georges and Poumay's (2020) framework, developed for the University Bachelor of Technology in French-speaking contexts, presents a detailed and context-sensitive structure for competency-based education. Its five-step design facilitates alignment between competency definition, authentic situations, and assessment. While the framework accommodates the integration of professional contexts—potentially including video conferencing scenarios—it does not explicitly address the pedagogical or technological specificities of synchronous digital environments. As such, its relevance to video conferencing depends on how educators contextualize the Learning and Assessment Situations to incorporate collaborative and real-time online interactions. In the absence of such specification, the framework offers limited direct guidance for designing or evaluating pedagogical practices based on video conferencing.

4.6 The Teacher Digital Competency (TDC) Framework

Falloon's (2020) TDC framework -adopts an interdisciplinary and holistic scope of digital competence, extending beyond technical skills to encompass ethical, pedagogical, and contextual dimensions. This broader perspective strengthens its relevance to complex practices such as video conferencing, which require not only technical fluency but also collaborative and reflective teaching strategies. The successful implementation of this approach relies on the collective engagement of all teaching faculties to ensure a shared understanding of the digital competencies across disciplines (Falloon, 2020). A unified, coordinated foundation for delivering the framework's goals can be achieved through a shift from the prevalent discipline-based models to a more collaborative and interdisciplinary approach, as advocated by Habowski and Mouza (2014). Structurally, the framework emphasises institution-wide faculty participation, promoting the consistent integration of digital competence across disciplines. Although it does not offer specific guidance on synchronous tools, its emphasis on faculty-wide collaboration and pedagogical coherence creates a strong foundation for integrating video conferencing into teacher education as a shared and reflective practice.

4.7 The HeDiCom Framework: Higher Education Teachers' Digital Competencies for the Future

The HeDiCom framework addresses a significant gap in the field by explicitly focusing on digital competencies for higher education teachers, rather than relying on adaptation from secondary education models. It's four dimensions—Teaching practice, Empowering students, Digital literacy, and Professional development—provide a comprehensive and contextually relevant structure that is both well-rounded and future-oriented. Particularly relevant to video conferencing are the emphasis on teaching practice and empowering students, which implicitly support synchronous and collaborative learning environments. However, while the framework accommodates the pedagogical integration of tools such as video conferencing, it lacks detailed, actionable strategies for their implementation. As such, its value offers a strong conceptual foundation that requires further operationalization through context-sensitive, practice-based guidance within higher education settings.

4.8 Self-reflection Tool Higher Education SELFIEforTEACHERS

The self-reflection tool is based on the European Framework for the Digital Competence of Educators (DigCompEdu, JRC 2017), which comprises 22 competences organised into six areas. The competences are described in six different levels of skills. Additionally, a seventh area—Open Education—has been incorporated, drawing from the OpenEdu Framework (JRC 2016, 2019). The complexity of response options is defined through two elements: (1) an adaptation of the Bloom's Digital taxonomy and (2) progression levels based on the complexity of the proposed activities. While the tool offers a broad and nuanced digital competency model, its direct applicability to synchronous teaching using video conferencing tools remains limited.

4.9 European Framework for the Digital Competence of Educators

The *European Framework for the Digital Competence of Educators* (DigCompEdu) (Redecker & Punie, 2017) offers a comprehensive and structured approach to digital competence, specifically for educators across all levels. Its scope encompasses six key competence areas—from professional engagement to facilitating learners' digital competence— addressing a broad spectrum of digital pedagogical needs. Structurally, DigCompEdu is organized into clear defined competence areas, each divided into progressive proficiency levels with detailed descriptors, enabling both self-assessment and targeted development. This level of granularity supports a nuanced understanding of digital competence that extends beyond technical skills to include pedagogical strategies. Pedagogically, the framework is rooted in constructivist, learner-centered principles, highlighting the

purposeful integration of digital tools to enhance teaching effectiveness, learner engagement, and assessment practices. This orientation is particularly relevant to video conferencing, as the framework explicitly recognizes the role of synchronous communication tools in promoting interaction, collaboration, and formative feedback in digital learning environments. In terms of relevance, DigCompEdu stands out as a highly applicable model for guiding educators in the effective use of video conferencing. It outlines practical competence areas such as managing digital resources, promoting collaborative learning, and ensuring inclusivity in synchronous settings, thus offering a strong foundation for the pedagogical use of video conferencing.

4.10 The DC4LT Assessment Framework (Perifanou, 2022)

The DC4LT Assessment Framework comprises six main categories, each with five concrete subcategories. The six main categories are: 1) Technology, 2) Pedagogy, 3) Assessment, 4) Content, 6) Professional development, and 7) Learners' support. Each category comprises a set of five (5) concrete subcategories. The first category, titled "Technology", outlines three levels of proficiency related to the efficient use of technology in the context of language education. Each level represents a different level of knowledge and skill that language teachers are expected to demonstrate across specific topics such as: 1) digital tools and devices; 2) tools for language education; 3) social media and collaboration platforms; 4) netiquette, and 5) security issues.

The thematic topics addressed across the six (6) DC4LT assessment framework's components are diverse and presented collectively in the following table. While the framework primarily focuses on general digital tools and pedagogical strategies, it does not explicitly address the unique demands of video conferencing (VC) environments. Although the inclusion of social media and collaboration platforms touches on some overlap with VC-related competencies, the framework lacks detailed attention to synchronous communication tools, such as managing virtual classrooms, breakout rooms, or integrating real-time feedback during video-based instruction.

5. Summary

In Table 1, a synthesis table is proposed to extract key insights patterns across the frameworks. The main dimensions discussed are:

- Scope Variation: Frameworks range from student-focused to teacher-focused and organizational/policy-focused. Few explicitly target higher education.
- Structural Complexity: Most frameworks use multi-dimensional structures with defined competence areas. Some provide progressive levels and detailed descriptors, while others remain conceptual or offer flexible guidelines.
- Pedagogical Emphasis: Many frameworks emphasize learner-centered, constructivist approaches, collaborative teaching, and professional development. However, few integrate detailed pedagogical strategies for synchronous tools.
- Video Conferencing Relevance: Explicit guidance on video conferencing is limited.

Table 1: Summary of Synthesis

Framework	Scope	Structure	Pedagogical Underpinnings	Relevance to Video Conferencing
UNESCO ICT Curriculum (2002)	Secondary education, teacher development	9 ICT literacy units, curriculum + PD program	Focus on curriculum alignment and teacher capacity building	Implicit; general e-learning and distance education, limited direct focus on video conferencing
Digital Competence Framework for Schools in Europe (Guitert et al., 2020)	Primary and secondary students	5 competence categories	Emphasizes active learning, communication, and collaboration	Includes communication/collaboration, indirectly supporting video conferencing
DigCompOrg Framework (Kampylis et al., 2015)	Educational organizations and policy	7 elements, 15 sub-elements, systemic	Organizational self-reflection and innovation	Supports digital integration broadly; no explicit focus on video conferencing

Framework	Scope	Structure	Pedagogical Underpinnings	Relevance to Video Conferencing
Janssen et al.'s Digital Competence Framework (2013)	Broad cross-sectoral	12 elements based on Delphi study	Conceptual, expert consensus	Foundational competences; no direct strategies for video conferencing
Competency Framework for Bachelor of Technology	Higher education, professional contexts	5-step competency drafting with learning/assessment situations	Contextual, authentic professional practice	Potential for inclusion of video conferencing via LAS; no explicit mention
Teacher Digital Competency Framework (Falloon, 2020)	Teacher education, interdisciplinary	Conceptual, faculty-wide engagement	Collaborative, interdisciplinary, ethical focus	Supports collaborative teaching; video conferencing relevance through pedagogical integration
HeDiCom Framework (Tondeur et al., 2023)	Higher education teachers	4 dimensions: teaching practice, empowerment, literacy, PD	Practice-focused, future-oriented	Implicitly supports synchronous tools; no detailed video conferencing guidance
SELFIE for Teachers (Higher Ed)	Self-reflection in higher education	Digital competence self-assessment tool	Emphasizes self-reflective practice and improvement	Indirect; supports evaluation of digital practices, possibly including video conferencing
European Framework for Digital Competence of Educators (DigCompEdu) (Redecker & Punie, 2017)	Educators at all levels	6 areas, progressive levels, detailed descriptors	Constructivist, learner-centered, pedagogical integration	Explicitly addresses video conferencing as a tool for collaboration and engagement
DC4LT Assessment Framework (Perifanou, 2022)	Learning technologies and training	6 areas	Focus on competence measurement and validation	No explicit focus, but applicable to digital teaching tools including video conferencing

Among the ten competence frameworks reviewed, the Digital Competence Framework for Primary and Secondary Schools (Guitert et al., 2020) provides a modern and relevant basis for integrating video conferencing systems in teaching and learning; however, it lacks explicit pedagogical strategies for effective implementation. The UNESCO (2002) framework remains historically significant but is now clearly outdated in addressing contemporary digital teaching needs. DigCompOrg and Janssen et al. (2013) offer valuable conceptual approaches but provide limited practical guidance for online teaching. The framework by Georges and Poumay presents a strong competency-based model but requires suitable adaptation to address the pedagogical and technological specificities of video conferencing systems. Notably, the DigCompEdu framework stands out as the most comprehensive and applicable for guiding the effective use of video conferencing. It directly addresses synchronous teaching, collaborative learning, inclusivity, and practical pedagogical strategies. The Teacher Digital Competency (TDC) and HeDiCom frameworks also offer theoretical and pedagogical foundations, particularly within higher education contexts, yet both require further operationalization to fully support synchronous, video-based learning environments. SELFIEforTEACHERS is well-suited for self-assessment and reflection but lacks actionable guidance, while DC4LT is obviously structured and context-specific for language education, though it does not sufficiently address the unique demands of video conferencing-based instruction.

6. Conclusion

Based on the documents highlighting the challenges and needs related to video conferencing skills for teachers, the study proposes a competence matrix specifically tailored for video conferencing. The researchers have developed a EDVICON framework (Campillo-Paquet, Impedovo, & El Hamaoui, 2024; Salha, Impedovo, & Khalid, 2025), structured in three main dimensions:

- **Technical Skills:** This competency refers to the educator's ability to proficiently operate, configure, and manage video conferencing platforms (e.g., Zoom, Microsoft Teams), tools, and supporting technologies. It covers not only basic platform navigation but also advanced features such as breakout room facilitation and interactive tool usage. Additionally, it includes the integration of

these skills into pedagogically sound practices that support online and hybrid learning environments.

- **Usage of Equipment and Applications in Video Conferencing.** This competence refers to the educator's ability to effectively operate and maintain essential hardware and software tools necessary for delivering high-quality synchronous online instruction via video conferencing platforms. It encompasses technical fluency in managing both the physical and digital tools for a virtual classroom environment.
- **Pedagogical Practices in Video Conferencing-Based Instruction**. This competency refers to the educator's ability to design and facilitate pedagogically grounded learning experiences using video conferencing tools. It involves the application of diverse educational approaches that harness the strengths of synchronous digital environments to promote engagement, collaboration, critical thinking, and learner autonomy.

Table 2 shows the competence framework proposed for a video conferencing system.

Table 2: Competence Framework for Video Conferencing System

Category	Competency	Description	Skills/Tools Required
Technical Skills	Platform Navigation	Proficiency in navigating video conferencing platforms.	Menu navigation, feature usage, settings adjustment
	Technical Setup	Setting up necessary technical components for video conferencing.	Microphone, camera, internet connection setup
	Distraction Management	Managing and eliminating distractions during video conferences.	Background control, muting participants, notifications management
	Background Management	Managing virtual backgrounds.	Uploading/selecting virtual backgrounds
	Breakout Room Management	Creating and managing breakout rooms.	Setting up and monitoring breakout rooms
Equipment Usage	Essential Hardware	Regular use and maintenance of necessary hardware.	Computer, microphone, webcam, external speaker
	Supporting Software	Proficiency in using supporting software for presentations and document sharing.	Microsoft PowerPoint, Word, Zoom, Webex, Google Meet
	Additional Tools	Use of additional tools to enhance video conferencing.	Auto-zoom cameras, extended screens, stylus pen
Pedagogical Practices	Constructivist Approach	Encouraging interactive and engaging activities for students to construct their own understanding.	Interactive activities, engagement strategies
	Collaborative Approach	Facilitating teamwork and collaborative projects.	Breakout rooms, group discussions
	Integrative Approach	Integrating multimedia resources and tools for comprehensive learning.	Multimedia integration, resource management
	Inquiry-Based Approach	Encouraging questions and research for deeper understanding.	Inquiry-based activities, research facilitation
	Reflective Approach	Providing opportunities for reflection on learning experiences and outcomes.	Reflective activities, feedback sessions

In conclusion, this document offers a comprehensive analysis of the challenges and needs related to the integration of video conferencing tools in teaching practices. The in-depth analysis of the study framework has highlighted the pressing need for a competency matrix to support the effective adoption of video conferencing tools, posing a major challenge for teachers in mastering the associated skills. Current practices often assume a baseline level of digital literacy among the teaching staff. However, the proliferation of competency frameworks in recent years indicates a growing recognition of the need for structured training, particularly for the optimal use of video conferencing in distance and hybrid learning environments. Importantly, self-directed exploration of these tools necessarily translates into the mastery required for effective pedagogical application, which underscoring the value of structured, targeted professional development. To foster this development, it is essential for teachers to be able to assess their current practices against the expectations outlined in a clearly

defined framework. In addition, the literature review reveals that existing institutional frameworks lack concrete, practical applications for educators. This disconnect calls for the operationalization of these frameworks in a way that directly supports teaching practice. In response, the development of a competency matrix specifically focused on video conferencing emerges as a relevant and timely initiative. Such a matrix can provide educators with a clearer understanding of the skill levels required. By embracing these tools, educational institutions can empower teachers to fully leverage video conferencing technologies in delivering high-quality, interactive, and engaging remote instruction.

Ethics Declaration

The ethical clearance was not required for the research.

AI Declaration

AI tools were not used the creation of this paper.

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AI Literacy in Preservice Teachers Preparation Programs: A Global Meta-Analysis

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Abstract: The rapid integration of Artificial Intelligence into education is reshaping how teaching and learning occur, prompting the need for pre-service teachers' programs to equip future educators with AI literacy. This systematic review, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocol, explores the role of AI literacy in pre-service teacher programs globally. The study examines how AI literacy is integrated into teacher preparation curricula to develop essential technological, pedagogical, and ethical competencies. The review focused on 79 studies published between 2020 and 2025, focusing on peer-reviewed journal articles, conference proceedings, and book chapters in English. The results reveal the growing importance of AI literacy, emphasising the integration of technological skills, ethical considerations, and pedagogical strategies. The study identifies key regional trends, with Western and Asian regions leading in AI literacy integration, while other regions remain at the entry of AI integration. The findings underscore the urgent need for teacher education institutions to prioritise AI literacy to foster innovation and the successful integration of AI. The review proposes a framework for enhancing AI literacy in pre-service teachers' programs, including recommendations for curriculum development.

Keywords: Artificial Intelligence (AI), AI Ethics in Education, AI Literacy, Digital Competency, Teacher Preparation Programs

1. Background

The rapid evolution of Artificial Intelligence (AI) is fundamentally reshaping education, making AI literacy a crucial and integrated competency for Pre-service teachers (PSTs). Beyond mere use of AI tools, this literacy empowers educators to be critical participants in an AI-driven world, encompassing technological knowledge, ethical awareness, and pedagogical application. While traditional teacher education focused on pedagogy and content, AI's ability to mimic human intelligence demands a new skill set. AI literacy is defined as the ability to understand AI's features, critique its biases, and assess its ethical impacts, including its potential for manipulation. Although frameworks like Technological Pedagogical and Content Knowledge (TPACK) help ensure effective use, significant disparities in adoption remain, particularly in the Global South, due to inadequate infrastructure and expertise. This fragmentation underscores the need for a unified approach combining technological, ethical, and pedagogical dimensions to inform future curriculum development.

2. Literature Review

2.1 The Need for AI Literacy in Teacher Education

The digital learning ecosystem is undergoing a massive transformation with the proliferation of Artificial Intelligence (AI) technologies. The potential of AI in improving pedagogy with regard to personalised learning, automated marking, and automation of administrative work has raised calls to incorporate AI literacy in educator training. Their research, which suggests a curriculum for developing AI literacy in primary schools (Kim et al., 2021), highlights the need for teachers to acquire an understanding of the technological, pedagogical, and ethical aspects of AI. Educator AI literacy is not just about being an end-user of AI systems. It involves critical skills that allow educators to determine if AI solutions are appropriate and effective for their specific classroom needs (Holmes et al., 2023). For instance, Holmes et al. (2023) argue that teachers should be trained in simplified AI algorithmic decision-making methods to identify any bias manifesting from such technologies and offer equitable learning experiences. Otherwise, teachers may adopt AI instruments lacking this literacy, thereby spreading societal bias or infringing on student privacy. Furthermore, Sunet al. (2023) emphasise that a lack of AI literacy hinders educators from realising the potential of AI ethically and responsibly. This entails a fundamental understanding of data privacy, knowledge of consent, and transparency of algorithms, fields whose integrity is persistently questioned as AI applications become institutionalised in education. Therefore, the development of AI literacy in teacher education is not just a matter of technological skill acquisition but also of developing ethical awareness, critical thinking, and proper use.

Studies suggest that the emergence of AI literacy is also aligned with more universal learning goals of forming digital citizenship and preparing educators to cope with a fast-changing landscape of data-driven decision-making (Althibyani & Al-Zahrani, 2023). Moreover, Jain and Singh (2023) propose incorporating AI literacy into key pedagogical skills, highlighting the latter's function in critically empowering educators to evaluate the pedagogic effectiveness and ethical considerations of AI tools. This perspective highlights that AI literacy supports teachers in using the benefits of AI and minimising risks.

2.2 Pedagogical Strategies towards AI Integration in PST Programs

Globally, the necessity of AI literacy in PSTs education is widely acknowledged, but its implementation is uneven and in its developmental stages. Technologically advanced regions like North America, Europe, and parts of Asia have integrated AI into digital literacy education and pedagogical frameworks supported by national policies and standards like ISTE (Kimm et al., 2020) and the European Framework for Digital Competence. Both technological AI abilities and pedagogical applications are areas of focus for these efforts.

In contrast, low-resource regions, including parts of Africa, Latin America, and Southeast Asia, are largely in the exploratory phase, with AI literacy limited to small-scale pilots or workshops due to infrastructural and capacity constraints. Recent models stress the need for holistic integration of AI literacy into established pedagogical frameworks like TPACK, Substitution, Augmentation, Modification and Redefinition (SAMR) and Digital Citizen (Ribble, 2017; Mishra & Koehler, 2006; Puentedura, 2009). Universities now offer specialised modules on AI ethics, data literacy, and instructional design. Ayyoub et al. (2025) highlight the efficacy of experiential learning approaches, such as simulations, project-based learning, and designing AI-supported lessons, which are proving effective in building practical AI competencies among PSTs. Despite these advances, there is a continued need for curriculum refinement, professional development, and alignment with broader teacher competency standards to ensure sustainable and scalable AI integration in teacher education.

2.3 Challenges and Barriers to Effective AI Literacy Development

Despite growing recognition of AI literacy's importance in PST education, widespread integration is hindered by several challenges. Key barriers include limited faculty expertise, resource constraints, and the absence of standardised instructional frameworks. Many teacher educators lack training in AI, and the rapid pace of technological change often outpaces curriculum updates, leading to what scholars describe as an “ontological lag.” Fragmented institutional strategies and inconsistent pedagogical approaches further weaken efforts to build scalable, replicable AI literacy programs. Financial limitations, especially in low-resource contexts, impede access to up-to-date tools and professional development. A shortage of faculty with both pedagogical and technological expertise exacerbates these challenges, reinforcing regional disparities.

The adoption of AI curriculum in education is progressing slowly. Jin et al. (2024) posit that there is institutional and cultural resistance to curriculum reform, coupled with a lack of prior assumption and limited familiarity with digital pedagogy, which directly hinders the implementation and adoption of new curricula. Overcoming these barriers requires a multifaceted approach. First, there must be coordinated policy action and sustained investment in both infrastructure and training. This includes the development of adaptable, contextually grounded resources and frameworks that can be implemented across diverse educational settings. Therefore, to prepare PSTs for an AI-driven future, the focus must shift towards developing a standardised curricula that seamlessly integrate technological, pedagogical and ethical characteristics of AI. This is a critical step to ensure a consistent and comprehensive level of training. Furthermore, cross-sector collaboration among educators, policymakers and industrial stakeholders is essential for creating inclusive and scalable models for AI literacy in the PST program. By working together, these groups can ensure that the next generation of teachers is not only competent but also ethically aware and ready to responsibly lead in an AI-powered world.

2.4 Conceptual Framework

Integrating AI literacy into teacher education is a multifaceted challenge that requires a holistic approach, which can be understood through key theoretical frameworks. The TPACK framework highlights the need for teachers to merge their subject knowledge and teaching methods with an understanding of AI tools. This ensures that AI is used to enhance learning, not just as a standalone gimmick. The SAMR model further evaluates this integration, encouraging a progression from simple AI substitution to the complete redefinition of learning experiences, empowering teachers to be innovators. Finally, the Unified Theory of Acceptance and Use of Technology (UTAUT) framework provides insight into why teachers adopt or resist new technologies, emphasising the importance of

institutional support and resources to overcome barriers to implementation. Together, these frameworks offer a comprehensive lens for designing effective and sustainable AI literacy programs that prepare future educators for a technology-driven world.

3. Methodology

3.1 Research Design

This study employs a systematic literature review, which is best suited to synthesise existing research and identify trends, gaps, and patterns in the literature. The systematic structure makes it possible to aggregate comprehensively relevant studies, and it provides an understanding of AI literacy in PST education across geographical contexts. By using a systematic review, the research is capable of addressing challenging questions with openness and stringency and of ascertaining that evidence pertinent to such questions is recorded in a systematic way. Bias is minimised, and conclusions arrived at from the review are assured of being derived from the best available evidence. In the interests of consistency and openness, the study followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines in its review. This systematic methodology offers a reproducible process for evaluating and synthesising existing research on AI literacy (Stracke et al., 2023). Applying such a methodological strategy makes it feasible for future researchers to replicate the study and utilise the findings accumulated in future investigations on the topic.

3.2 Literature Search Strategy

The literature search was designed to capture all relevant publications published between 2020 and 2025, a period purposely chosen to reflect the rapidly unfolding development of AI technologies and their applications in education. Extensive searching across five online academic databases: ERIC, Google Scholar, Scopus, JSTOR, and Mendeley was carried out. This multi-database approach was adopted for its comprehensiveness of peer review as well as grey literature. To maintain consistency and avoid language bias, the search was limited to English-language publications. Careful selection of search terms was made in order to yield extensive coverage of studies of AI literacy in PST education. Keywords utilised were "AI literacy", "PST education", "artificial intelligence in education", "AI tools in teaching", "digital literacy for teachers", "AI pedagogical integration", and "AI ethics in teacher education". Boolean operators (AND, OR) were utilised to limit the search in order to ensure that the retrieved studies conformed to the technological, pedagogical, and ethical specifications of AI literacy integration in teacher education.

3.2.1 Inclusion and Exclusion

To ensure the quality and relevance of the studies included in this systematic literature review, specific inclusion and exclusion criteria were applied. We included only peer-reviewed journal articles, conference proceedings, and book chapters published between 2020 and 2025 to capture the most recent developments in the field. The search adopted a global perspective, accepting studies from diverse geographical contexts, but required that their primary focus be on AI literacy as a core component of teacher preparation, encompassing technological, pedagogical, and ethical issues (Stracke et al., 2023). Conversely, studies were excluded if they lacked this specific focus or were not peer-reviewed, such as blog posts or opinion pieces, to maintain a high standard of academic rigour.

3.3 Data Extraction

The researcher developed a detailed data extraction on a table to systematically extract key information from each selected research study, with a uniform and organised method for review, in accordance with best practices in systematic reviews (Stracke et al., 2023). The structure was utilised to gather essential details, including study information like the author(s), publication year, study type, and geographic location. The researcher outlined specific information regarding the focus group of PSTs, aspects of AI literacy addressed in the study (technological, pedagogical, and ethical), and the theoretical framework and research methodology used. Finally, we integrated the most significant findings and suggestions of each study. Critical Appraisal Skills Programme (CASP) checklists were used to review the credibility, relevance and findings of studies (Critical Appraisal Skills Programme, 2023). This supported the researcher to gain insight into the validity and reliability of research, thereby establishing our review on a foundation of high-quality evidence. This systematic review provided a

structured overview of included research, and this was crucial in identifying the trends and gaps in integrating AI literacy in PST education.

3.4 Data Analysis

The systematic review was analysed using a thematic synthesis, a method which allows for identifying common patterns, trends, and gaps in the literature. By coding and clustering prominent themes in each study, the author was capable of isolating essential themes, such as the pedagogical approaches employed in AI literacy, the ethical issues contested, and the implementation recommendations. Through illustration of what the current building blocks under development are and where the underdevelopments and gaps are, the analysis provides a transparent, evidence-based roadmap for nurturing practical responses to address issues on AI literacy in PSTs' education. The purpose of the analysis was to provide actionable insights for educators and policymakers, ensuring that future teachers are not only technologically competent but also ethically aware and prepared to responsibly integrate AI into their classrooms.

4. Findings

The broad literature search across diverse publication types: journals, conference papers, and books, yielded a significant volume of records from key academic databases. The Mendeley contributed 3,609 articles, ERIC provided 2,200 articles, and 4250 Google Scholar articles, for a total of 10,059 articles added to the initial pool. After removing duplicates and the exclusion process, 2348 remained, and then the final process purposefully selected 79 articles for the study that closely aligned with the study goals.

4.1 AI Literacy in PSTs' Education

The results confirm that AI literacy is increasingly critical in PST education. The accelerating integration of AI tools in educational settings offers considerable transformative learning environments, enabling personalised learning experiences, automating teacher administrative tasks (Kalniņa et al., 2024). However, to fully realise these benefits, PSTs must be equipped with both technological knowledge of AI and pedagogical understanding of how to use it effectively and ethically (Holmes et al., 2019)

As the integration of AI tools into educational settings continues to accelerate, PSTs must be prepared to understand, evaluate, and integrate these tools into their teaching practices. AI holds great potential for determining education by providing personalised learning, enhancing students' engagement, and minimising administrative tasks (Kalniņa et al., 2024) However, to enjoy all the advantages of AI deployment, educators in the future must have technological competence in AI and pedagogical knowledge on how to implement it effectively and ethically (Holmes et al., 2019; Sun et al., 2023).

AI literacy entails awareness of AI concepts, application of AI tools in the classroom, and careful examination of their ethical aspects. This can be seen in the papers presented, which highlight the fact that in the absence of previous AI knowledge, PSTs cannot apply these tools in their classes (Abar et al., 2024; Kim & Kim, 2023). The outcomes of different research work recognise that teacher preparation programs must make AI literacy part of mainstream curricula (OECD, 2025) in order to provide PSTs with the capacity to leverage the challenges and potential provided by AI in the classroom.

4.2 Regional Differences in Integration of AI Literacy

Literature is characterised by a contrast of extreme proportions in adoption and utilisation. Western countries and Asian countries are leading the way, embedding AI literacy via specialised courses, workshops with specialised emphasis, and interdisciplinary programs. Studies carried out in Europe and North America (Lin et al., 2024; Hwang & Hwang, 2023; Al-Abdullatif, 2024) have incorporated AI modules in the curriculum to develop the technological competencies essential for AI tools so that they can be utilised optimally. Conversely, AI literacy in Latin America and Africa is underdeveloped, and studies indicate significant barriers in the guise of limited connectivity and sparse resources and an absence of qualified teachers (Cardon et al., 2023; Abar et al., 2024). National economic development and institutional resources have an immediate effect on its capacity to adopt new technologies and skills. In high-resource nations, they have created inclusive AI literacy courses for educators. This results in PSTs from the under-resourced not being able to feel comfortable applying AI within the classroom environment. For instance, many teacher training programs in Europe and North America have incorporated AI modules into broad digital literacy programs. This equips PSTs with the technological expertise

necessary to deploy AI tools in school settings. Institutions like Stanford University in the United States and the University of Cambridge in the United Kingdom have created comprehensive AI literacy programs specifically designed for teachers.

4.3 Pedagogical and Ethical Issues of AI Literacy

Studies indicate an increasing focus on the pedagogical and ethical issues of AI literacy. The majority of research underscored the importance of PSTs understanding the pedagogical application of AI tools, i.e., individualised learning, adaptive testing, and instant feedback mechanisms (Hwang & Hwang, 2023). The literature suggests that AI is capable of revolutionising classroom practice through tailored learning experiences that cater to various student needs. However, with these opportunities, there are ethical concerns about using AI in education. Concerns of privacy of data, bias in algorithms, and the potential for AI to compound educational inequalities have been brought up in various studies (Hwang & Hwang, 2023). Teacher education programs are becoming more aware of these issues. They are incorporating ethical dialogue into AI literacy courses so PSTs can become ready to address the ethical aspects of AI implementation in the classroom

4.4 Challenges and Barriers to AI Literacy Integration in PSTs Education

Although AI literacy is undoubtedly essential for PSTs, its integration in teacher preparation programs encounters various overarching challenges. The primary obstacle is that few qualified teacher educators are AI technology specialists. The Holmes et al. (2023) study highlighted that the majority of teacher educators lack the AI skills necessary to properly prepare PSTs. Such limited expertise limits the potential of a program to offer comprehensive AI literacy training, making future teachers ill-equipped. The second major challenge is the fast rate of AI development. Because AI technologies are evolving at such a high speed, the curricula of teacher education programs must be revised regularly to keep up with developments. In most cases, the programs cannot catch up. Southworth et al. (2023) noted that a lack of ability usually means curricula are out of date or of poor quality, failing to prepare PSTs for issues of the modern digital classroom.

The review also found that the unavailability of technology and resources is a major barrier, especially in low-resource settings. Ayyoub et al. (2025) established that where the availability of AI tools is scarce or non-existent, it's difficult for PSTs to gain experiential learning. The unavailability of access expands inequities in teacher training and does not prepare PSTs to implement AI tools in the classroom.

5. Discussion

This discussion section discusses how AI literacy is being integrated into PSTs' teacher education programs globally, the skills that PSTs are to develop, how these efforts vary by region, and the most effective pedagogies. By drawing on an interconnected conceptual framework, TPACK, SAMR and UTAUT, this systematic review offers a broad synthesis of global practices, challenges, and opportunities in teacher education AI literacy. The evidence identifies that effective integration of AI relies on something greater than tool availability; it has to be supported by deep pedagogical knowledge, transformative usage of AI, and facilitative institutional cultures.

5.1 AI Literacy in Global Teacher Education: A Growing Priority

There is a growing need in teacher education to bring AI literacy into PSTs’ preparation. While some regions are boldly charging forward with AI as a foundational competency, others have systemic barriers to overcome, which has given rise to a growing gap in preparing teachers for the digital and AI age.

In high-income countries, particularly across Western and Asian nations like China, Finland, the U.K., and the U.S., AI literacy has transitioned from a niche topic to a foundational element of teacher training. This progress is not accidental; it is often driven by national policies and institutional strategies that align with broader digital transformation agendas. These countries are not just introducing AI tools; they are building comprehensive frameworks. The TPACK model is a visible influence, with programs designed to connect AI technologies with specific content and pedagogical methods. This results in a multi-faceted approach, where PSTs don't just learn to use an AI tool but understand how to ethically integrate it to enhance learning outcomes.

Many countries in Africa, Latin America, and Southeast Asia face significant challenges that have hindered AI integration. The efforts that do exist are often fragmented, relying on small-scale, donor-funded pilot projects that lack the institutional backing to be scaled up. These conditions include reliable infrastructure, such as consistent internet access and adequate hardware, as well as a sufficient number of qualified teacher educators

who are themselves proficient in AI. Without these foundational elements, even highly motivated PSTs cannot effectively engage with AI technologies. The result is a cycle of limited exposure and a curriculum that often fails to systematically adopt emerging technologies. This leaves a new generation of teachers from these regions entering the workforce without the necessary skills to navigate and leverage AI tools, exacerbating existing inequalities and potentially limiting their students' future opportunities. The gap, therefore, is not just technological; it is one of educational equity.

5.2 Key Components of AI Literacy in Teacher Education

Four interrelated components of AI literacy emerged from the synthesis: conceptual understanding, practical competence, pedagogical integration, and ethical reflection. These dimensions align well with the TPACK model, which helps frame AI literacy as a blend of technology fluency, teaching expertise, and content alignment.

AI literacy for PSTs is built on four core pillars. First, conceptual understanding allows PSTs to grasp how AI works, which helps them avoid overreliance and misuse. This is paired with practical competence, which involves hands-on use of AI tools like ChatGPT for instruction, assessment, and classroom management. To ensure these tools are used effectively, pedagogical integration is essential; guided by frameworks like TPACK, this ensures AI is meaningfully embedded into lesson planning and practice. Finally, ethical reflection is a critical component, requiring PSTs to address concerns such as algorithmic bias, data privacy, and AI's potential to reinforce social inequalities. These elements are also linked to SAMR, which helps evaluate whether AI use simply substitutes traditional tools or redefines teaching and learning. High-impact programs use project-based, immersive activities to move PSTs from basic usage to transformative applications, enhancing both their competence and confidence (European Commission, 2024).

5.3 Regional Differences in AI Literacy Integration

The review found that regional disparities shape how AI literacy is approached. In North America and Europe, structured curricula, national frameworks, and clear assessment standards reflect advanced integration (Kimm et al., 2020). These regions also invest in faculty development, a critical enabler in UTAUT's facilitating conditions for successful technology use.

In Asia, particularly China and Singapore, AI is framed as a driver of innovation and economic development, with strong policy backing and institutional incentives (Kim & Kim, 2023). Here, a top-down approach has fast-tracked AI integration through state-led initiatives. Conversely, in Africa and Latin America, integration is often ad hoc, driven by external partners, and lacks long-term planning or systemic inclusion (Mpekoa, 2025). In many contexts, PSTs have high motivation but lack institutional support, relevant content, or infrastructure, highlighting UTAUT's value in diagnosing systemic challenges. These findings underscore the need to move beyond one-size-fits-all models. Local adaptations that respond to infrastructural realities, socio-cultural dynamics, and institutional readiness are essential for meaningful and equitable AI literacy development.

5.4 Pedagogical Strategies for Teaching AI Literacy

The most effective pedagogical strategies for AI literacy are those that are active, experiential, and reflective. Inquiry-based learning encourages PSTs to explore AI through real-world projects and creative experimentation. Case study analysis builds critical reasoning and ethical reflection, helping PSTs consider the broader social implications of AI in teaching (Holmes et al., 2019). Blended and experiential learning, including online modules, simulations, and hands-on tool engagement, enhances both technological fluency and teaching confidence (Al-Abdullatif, 2024).

These strategies directly support progress along the SAMR model from substitution to redefinition as PSTs evolve from basic AI use to innovative classroom transformation. However, a recurring barrier is the lack of faculty expertise in AI pedagogy. Many teacher educators are unfamiliar with emerging technologies, which limits their ability to model best practices. This gap reinforces the importance of faculty development, cross-disciplinary collaboration, and professional learning networks that promote TPACK-aligned pedagogy.

5.5 Implications for Teacher Preparation Programs

To advance AI literacy in pre-service teacher (PST) education, four key priorities must be addressed. First, curriculum integration is essential, moving AI from an optional topic to a core component embedded across subjects to build a holistic understanding. Second, faculty upskilling is crucial, as institutions need to invest in

continuous professional development to ensure teacher educators have the expertise to model effective and ethical AI use. Third, ethics and equity must be a central focus of the curriculum, empowering future teachers to critically evaluate AI's impact on all students, particularly those from marginalised communities. Finally, global collaboration is vital to bridge the disparities in AI adoption between high- and low-resource regions, sharing best practices and resources. These priorities, interpreted through an integrated framework of TPACK, SAMR, and UTAUT, provide a comprehensive roadmap for designing teacher education programs that are both technologically advanced and socially responsible.

6. Conclusion

This global meta-analysis highlights that while AI literacy is increasingly valued in PST education, its integration remains uneven. Institutions in developed regions such as North America, Europe, and parts of Asia have begun embedding AI through dedicated modules and pedagogical frameworks, recognising the need for both technological and ethical competence. In contrast, lower-resourced settings, particularly Africa and Latin America, face major barriers, including limited infrastructure, faculty expertise, and access to AI tools, leaving many PSTs unprepared for AI-integrated classrooms. The review emphasises that AI literacy must extend beyond consuming content to encompass ethical awareness, critical thinking, and inclusive pedagogical decision-making.

Ethical Declaration

This study did not involve human participants, personal data, or experimental interventions and therefore did not require formal ethical approval. The author declares no conflict of interest and assumes full responsibility for the content and conclusions of this work.

AI Declaration

AI tools were used to refine grammar, clarity, and coherence in early drafts. All analysis, synthesis, and final arguments were independently developed by the author. AI use was guided to support efficiency without compromising academic integrity. The author assumes full responsibility for the content.

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Enhancing Postgraduate Research Success via Co-Created e-Learning in Open University MBA Programs

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Abstract: Distance learning postgraduate programs continue to struggle with supporting research activities of their students. Geographical dispersion, limited contact, and diversified learners' needs tend to hamper research progress, increase completion time, and intensify student isolation. In response to these concerns, this research created, introduced, and assessed an innovative, collaboratively designed eLearning support program for an MBA program of a Thai open university. Guided by a user-centered design thinking methodology, the project facilitated active co-creation by students and faculty from the outset, including needs identification and iterative development. The resulting integrative system bridged formal academic support and informal peer education. The system integrates several key components: self-paced Moodle eLearning modules for core research topics, synchronous Microsoft Teams sessions for individual advisor guidance, and Line application-based peer mentoring. These elements collectively aim to foster collaboration and reduce student isolation. Pilot testing yielded strong initial results with substantially greater on-time graduation rates than prior cohorts and high student satisfaction levels. Qualitative results also showed more collaboration and less academic isolation; peer-to-peer communication through Line was particularly useful for building community. These results validate the utility of this student-centered, co-creative design thinking process for meeting student needs and creating a positive learning environment. This study provides a replicable and empirically validated model using linked, technology-facilitated methods to build research training and stimulate student success across a variety of distance learning environments.

Keywords: eLearning, Co-Creation, Design Thinking, Peer-to-Peer Coaching, Distance Education, Postgraduate Research

1. Introduction

Postgraduate work, particularly in distance learning, faces significant challenges in adequately supporting student research. These challenges arise from inherent constraints such as geographical distance, diverse student groups, and predominantly virtual interactions with teaching staff (Gregori, Martínez, & Moyano-Fernández, 2018; Lee, 2020). Research supervision in these environments demands customized strategies to reverse learner isolation and facilitate the timely completion of academic courses (Castillo-Merino & Serradell-López, 2014; Kebritchi, Lipschuetz, & Santiague, 2017). This was worsened during the Covid-19 pandemic because of technological constraints, issues in building useful student-advisor relationships, and issues to maintain research quality from afar across nations. (Suparman, 2021) Although eLearning has gained widespread acclaim as a reliable instrument in distance learning, maintaining effective research supervision is still an onerous responsibility, particularly when conducted exclusively through online channels (Garrison & Arbaugh, 2007). The literature identifies many critical factors influencing the success of postgraduate research in distance learning environments, including systematic and ongoing guidance, interactive communication platforms, and opportunities for peer collaboration (Kebritchi et al., 2017; Richardson, Maeda, Swan, & Caskurlu, 2017). However, despite technological advancements, the literature reports persistent issues concerning student isolation, lack of support mechanisms, and a lack of interactive and engaging learning spaces, which are considered major barriers to successful completion of research (Tait, 2018; Zawacki-Richter & Anderson, 2014). Hansen-Brown et al. (2022) and Chimbo et al. (2023) asserted that online remote learning under Covid-19 was often associated with higher levels of loneliness and lower levels of a sense of belonging to universities. This is due to the loss of informal and formal contact with lecturers and peers. This has led researchers to design learning interventions to mitigate loneliness and develop a sense of belonging in the online community via online interactive environment, peer interaction, and other educational support.

Open universities, which tend to attract students from a diverse range of educational and professional backgrounds, compound these challenges due to their special student body and entirely online instructional model (Lee, 2020; Simpson, 2013). Students in open university programs often have varying levels of competence in research methods, academic writing, and critical analysis. This variation requires personalized pedagogical methods that specifically target the special needs of each student, an aspect that is often lacking in traditional online courses (Simpson, 2013). Sukhothai Thammathirat Open University, the leading open university in Southeast Asia being examined in this research, postgraduate students studying the MBA program are from different geographic locations, both domestic and international. Supervisory relationships are established purely online, essentially via online communication platforms such as Microsoft Teams and Line, with very minimal face-

to-face contact. This flexible mode of teaching and mentoring, while having risks of delayed completion of research and graduation, has been reported to have annual late graduation rates following enrollment. Such delays not only affect student satisfaction but also institutional reputation and resource use efficiency. Breaking these systemic problems requires innovative solutions that integrate student-centered approaches and digital technologies to enhance the effectiveness of postgraduate research training. Design thinking, with its user-centered approach and iterative process of development, presents an effective model for tackling these challenges via co-creation in collaboration (Brown, 2009; Razzouk & Shute, 2012). By incorporating both teachers and students in the design and development phases, this method guarantees harmony with user needs and aspirations, enhancing engagement and advancing learning outcomes (Brown, 2009). Extending on the existing literature, this study designs and assesses a collaborative eLearning program to assist postgraduate research students pursuing the MBA program at Sukhothai Thammathirat Open University, an open university in Thailand. The program integrates extensive eLearning modules that are delivered via the Moodle platform and is supported by synchronous consultation and peer-to-peer mentoring carried out through Microsoft Teams and Line, respectively. This holistically framed approach is specifically designed to address the problems of isolation, multiple research backgrounds, and supervisory difficulties which are typical of open university settings. Therefore, this research aims to address a critical gap. It investigates the effectiveness of a collaboratively developed eLearning approach, guided by design thinking, in overcoming research completion challenges and enhancing student satisfaction. The study focuses on an unevenly distributed and heterogeneous group of postgraduate students. The findings emanating from this study not only add to the scholarship of distance learning but also offer applicable strategies that can be replicated in comparable educational institutions across the world. This research aims at attaining the following goals precisely

1. To assess how a co-designed, andragogy-based eLearning program, using project-based learning and peer-to-peer mentoring, impacts timely graduation rates of MBA learners in a distance learning setting.
2. To analyze the efficacy of peer-to-peer mentoring and synchronous advisor meetings in enhancing student engagement, reducing isolation, and optimizing collaborative research skills among geographically dispersed postgraduate students.

2. Theoretical Framework and Literature Review

This study is guided by several pertinent educational theories, such as andragogy, project-based learning, and peer-to-peer mentoring, that collectively guide the planning and deployment of a co-designed eLearning environment. Knowles' (1980) andragogy theory focuses on adult learners' unique traits, such as self-directedness, learning from experience, readiness to learn, and internal motivation. The application of this theoretical model in the context of postgraduate distance learning underscores the imperative of creating learning environments that acknowledge and leverage the existing knowledge, professional backgrounds, and self-directed learning inclinations of adult learners (Knowles, Holton, & Swanson, 2015). This approach is in complete alignment with the diverse backgrounds and self-directed learning imperatives typical of open university MBA students. Project-based learning (PBL) augments andragogical theory by providing structured, yet flexible, learning experiences through the resolution of real-world problems.

Project-based learning (PBL) builds deep understanding by involving students in projects that reflect actual professional practice. In the context of this research, building research skills through projects designed to match students' vocational contexts can build engagement, relevance, and successful transfer of research skills. PBL also naturally encourages ongoing reflection, critical analysis, and integration of new knowledge—primary skills needed for upper-level academic research. Peer coaching supplements this study's theoretical underpinning in fostering interactive and collaborative learning environments. Embedded in social constructivism, peer coaching leverages collaborative conversation and mutual support between learners, thus significantly enhancing engagement, confidence, and competence in complex research tasks (Topping, 2005; Ladyshewsky, 2017). This collaborative learning experience can mitigate the isolation distance learners may face by building meaningful and supportive peer relationships, hence fostering a vibrant learning community. Co-design of eLearning environments is also strongly informed by design thinking philosophies that espouse user-centered, iterative design processes (Brown, 2009).

Design thinking promotes engagement of the teachers and students actively in the process of development and implementation in such a way that the educational solutions directly match user needs and wants (Razzouk & Shute, 2012). This co-creative iterative process encourages continuous feedback, enhancing the effectiveness and relevance of the developed eLearning modules. Through the intertwining of these theoretical frameworks,

the co-designed eLearning solution of the present study addresses the special requirements of distance learning in postgraduate research environments. Arkadan and Kazemargi (2024) suggest that implementing a design thinking mindset is key to effectively reshaping the student learning experience in higher education. This approach is particularly relevant given the significant digital transformations and pedagogical innovations required by post-2020 conditions.

Peer coaching among graduate students has emerged as a prominent supportive mechanism for coping with the special demands of high-level scholarly work. Anchored in adult learning theory and social constructivist theory, this practice focuses on collaborative learning, support, and the cultivation of critical thinking. Ladyshewsky (2006) quoted that peer coaching raises self-esteem, boosts motivation, and facilitates personal development, which eventually results in improved academic performance. Current initiatives, as exemplified by the Graduate Student Coaching Program at MIT, have shown promise in utilizing organized peer coaching to build community integration, improve goal-setting competencies, and minimize perceptions of isolation for graduate students (Winn, 2023). Furthermore, online group coaching has been found to form connections among postgraduate students from various geographical locations, thereby inculcating a sense of belongingness and shared aspirations (Dumitru, et al., 2024; Nacif et al., 2023). These results highlight the value of peer coaching as a complementary instrument to conventional academic advising, leading to postgraduate students' personal and professional growth. Parmar et al. (2025) supported that peer coaching supported the social and emotional well-being of postgraduate students studying online during the pandemic.

The combination of andragogy, PBL, peer-to-peer coaching, and design thinking offers a strong theoretical basis to enhance student engagement, reduce isolation, and enhance research outcomes. The current body of research literature corroborates the effectiveness of such composite theoretical frameworks for augmenting the learning outcomes along with satisfaction among heterogeneous, geographically dispersed cohorts of students (Gregori et al., 2018; Kebritchi et al., 2017). Such a review herein therefore underscores the paramount importance of establishing an end-to-end theoretical framework for creating state-of-the-art, learner-centric eLearning tools. Furthermore, Fabriz et al. (2021) and Shoaib et al.(2023) proposed that both synchronous and asynchronous online learning and teaching experiences should be heightened during and post Covid-19 in the form of mentorship and peer support. By combining the strategic integration of andragogy, project-based learning, peer coaching, and design thinking practices, this study's co-designed eLearning program is well positioned to address the pressing needs and issues of open university MBA postgraduate students.

3. Methodology

The research and development framework for this research uses a qualitative R&D design, which is laid out in sequential steps as needs analysis, instructional development, successive prototyping, and pilot trials. The process aligns with qualitative research methods for education research and enables in-depth scrutiny and refinement of a novel eLearning intervention for postgraduate MBA students taking distance education courses within the context of an open university setting.

3.1 Phase 1: Qualitative Needs Assessment

The first phase consisted of gathering qualitative data through semi-structured interviews that were designed to ascertain research-related needs and problems faced by MBA students. A purposive sampling strategy was employed to recruit a total of 15 MBA students from a variety of geographic locations and educational backgrounds. The interviews were carried out online through Microsoft Teams and took about 45 minutes each. The interview timetable included questions that focused on students' views regarding existing supervision practices, difficulties encountered in their research work, desired approaches to online interaction, and recommendations on how to improve research support.

Data collected through these interviews were thematically analyzed, as set forth by Braun and Clarke (2006). Transcripts of all the interviews were carefully examined, coded, and arranged into distinct themes. These results significantly contributed to the instructional design phase by clearly illuminating the specific needs, desires, and problems experienced by students in the context of research supervision.

3.2 Phase 2: Instructional Design

Qualitative needs assessment findings informed the instructional design phase, which integrated fundamental principles of andragogy (Knowles, Holton, & Swanson, 2015), project-based learning (PBL), peer-to-peer coaching

(Topping, 2005; Ladyshewsky, 2017), and design thinking approaches (Brown, 2009; Razzouk & Shute, 2012). The instructional content was organized into self-contained, interactive modules covering critical research skills that included proposal development, literature review, methodology development, data analysis, and academic writing. The instructional design was based on the design thinking framework, which included recursive cycles of development, testing, and improvement. The modules included multimedia content, real-time consultation via Microsoft Teams, and systematic peer-to-peer coaching activities via the Line application, hence improving learners' engagement and fulfilling the established requirements in a relevant way.

3.3 Phase 3: Iterative Prototyping

In the phase of iterative prototyping, several cycles of module development and formative evaluations were conducted. Each cycle involved small groups consisting of instructional design experts, subject matter experts, and student representatives. Participants reviewed prototypes and provided extensive feedback through structured online surveys and online focus groups. Feedback was centered around topics such as instructional effectiveness, content clarity, usability, and quality of interaction within the online environment. Qualitative feedback obtained over these iterative cycles was examined using thematic analysis that allowed for refinement to instructional approaches, content delivery, user interface design, and effectiveness of interactive components. Ongoing, iterative refinement guaranteed the modules adequately addressed the varied needs of the intended student body.

3.4 Phase 4: Pilot Testing

The final phase involved extensive qualitative pilot testing with a small group of 20 MBA students at Sukhothai Thammathirat Open University. This group was selected using purposive sampling to provide representation of diverse student backgrounds and geographical locations. The pilot study was conducted during the period of one academic semester, during which participants were actively engaged with all created eLearning modules, participated in synchronous consultations, and were involved in peer-to-peer coaching activities. Upon completion of the pilot phase, data was collected through detailed virtual focus group discussions and open-ended qualitative questionnaires. The data collection methods used were aimed at exploring student experiences, perceptions of effectiveness, noted challenges, and suggestions for further improvement. The collected qualitative data were analyzed using thematic analysis. This analysis focused on understanding student experiences, satisfaction levels, and perceptions of learning engagement. It also assessed how well the initiative addressed the initial challenges of research supervision. The findings provided a detailed overview of the strengths and areas of possible improvement of the collaboratively created eLearning initiative.

The use of a qualitative research and development approach enabled an in-depth understanding of the specific contexts and requirements of distance learning MBA students. The methodology ensured exhaustive development, continuous improvement, and rigorous evaluation of the new, jointly developed eLearning solution specially tailored to the needs of postgraduate research students at open universities.

4. Results

4.1 Phase 1: Qualitative Needs Assessment

The qualitative data generated during interviews were subjected to thematic analysis, which revealed four broad themes that underlaid the students' experience and challenges. First, the students indicated intense feelings of isolation and disconnectedness from colleagues and advisers. Second, the participants indicated the desire for more structured guidelines for research procedures, which emanated from various previous experiences in academic research. Third, students expressed a desire for frequent, real-time interactions with advisors to allow for the resolution of ongoing questions and receive timely feedback. Lastly, students showed great interest in interactive learning modalities, including peer-to-peer interactions and collaborative activities, shown in table 1.

Table 1: Identified Themes from Qualitative Interviews

Theme	Frequency Mentioned
Student isolation	14
Structured research guidelines	12
Synchronous advisory sessions	11
Peer-to-peer interactions	13

4.2 Phase 2: Instructional Design

The instructional design stage leveraged learning accumulated in Phase 1 by employing a co-creation strategy founded on the principles of design thinking. The final education modules encompassed interactive video tutorials, in-depth research guides, live consultation sessions conducted through Microsoft Teams, and peer coaching sessions supported through Line. The central self-study eLearning modules covered major postgraduate obligations at the university. These included submission dates for each semester, institutional review board (IRB) requirements, research publication expectations, examiners' criteria, and documentation needs from proposal to final thesis. The modules also offered step-by-step, in-depth instruction on the research process, along with illustrative walk-throughs for analyzing data. They also offered access to crucial resources like a model template for research reports, a reference guide in accordance with APA 7th edition requirements, plagiarism detection software, and a repository of research studies both on and off the university network. The students were advised to work through all eLearning modules before attending the synchronous online coaching webinars. They could also revisit the modules at any time and from any location, enabling flexible, self-paced learning at their convenience. The eLearning was supplemented with weekly online coachings, held through Microsoft Teams, by the academic advisors. These coachings were intended to enable regular feedback on research updates, project reviews and comments, and avenues for peer-to-peer discussion. Students who were ahead were invited to act as unofficial peer coaches, modeling by providing best practices and giving others advice on how to steer clear of typical pitfalls. This created a collaborative learning environment whereby students were able to gain advantage not just from advisor feedback but also from constructive criticism provided by others in the class. The students were urged to work with fellow classmates who had allied research interests to promote collaborative idea generation and informal peer review. This not only helped in the refinement of research competencies but also promoted deeper interpersonal relationships and a spirit of intellectual camaraderie among the student body. Besides, a Line group, which is Thailand's most used social media platform, akin to WhatsApp, was created as an open online community for use in sharing brief updates, questions, suggestions, and motivational messages. Microsoft Teams and the Line group together acted as a complete learning space with the purpose of assisting students during their research work. Following a number of rounds of iteration, the design was progressively refined based on continuous feedback from subject matter experts as well as students. Interestingly, peer-to-peer mentoring and weekly virtual coaching were emphasized due to students' high preference for more interactive and collaborative learning experiences.

4.3 Phase 3: Iterative Prototyping

Iterative prototyping involved three cycles of participant feedback on module usability, clarity of content, and interactivity functionality. Feedback from these iterative cycles pinpointed significant improvements in module clarity, ease of user interface, and comprehensiveness of content. Usability feedback led to streamlined navigation pathways within the Moodle environment, while content feedback prompted additional explanatory examples and more concise explanations for complex research concepts, as shown in table 2.

Table 2: Summary of Improvements in Iterative Prototyping

Iteration	Major Improvements
1	Enhanced clarity of module objectives
2	Improved user-interface and navigation design
3	Added detailed examples for research concepts

4.4 Phase 4: Pilot Testing

Qualitative data analysis of the pilot test indicated some significant findings. Firstly, the students cited significant decreases in feelings of isolation due to regular contact through synchronous consultations and peer-to-peer coaching. Secondly, the research modules with structure significantly increased students' levels of confidence in conducting research responsibilities, as brought out through focus group discussions. Finally, students greatly preferred the interactive learning elements, which promoted a collaborative learning environment, as evidenced by numerous positive comments in qualitative feedback sessions, shown in table 3. As a result of this testing, the graduation rate increased significantly from an average of 65-75% in previous cohorts to 85% in pilot cohort with this co-created eLearning initiative. Students reported a substantially higher satisfaction rate of 4.8 out of 5.0, +0.6 vs. previous cohorts.

Table 3: Student Feedback Highlights from Pilot Testing

Feedback Category	Representative Quote
Reduction of isolation	"The regular meetings made me feel less isolated and more connected."
Increased research confidence	"Clear instructions and examples boosted my confidence tremendously."
Value of peer interaction	"Peer coaching provided invaluable support and fresh insights."

In summary, these findings highlight the efficacy of a qualitative and iterative method to the design of a bespoke eLearning intervention. The eLearning programme that was developed effectively remedied the original problems established under the qualitative needs analysis in terms of improved student interest, self-confidence, and team working amongst MBA students in an open university distance learning environment. As a result of this finding, the triangle of research support was proposed, show in Figure 1.

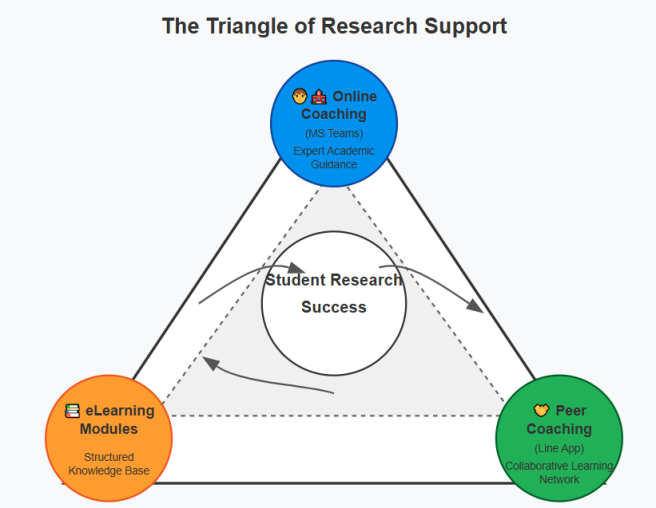


Figure 1: The Triangle of Research Support for Postgraduate Students

5. Discussion

The qualitative results of this research are aligned with earlier academic work that stresses the pivotal role of social contact, organized support, and cooperative peer-to-peer engagement in online postgraduate learning. The significant decrease in student loneliness reported throughout the pilot phase corroborates earlier work by Kebritchi et al. (2017) and Topping (2005), thereby underlining the value of active and cooperative learning spaces in distance learning. In support of the adult learning theory posited by Knowles et al. (2015), the results of this research highlight the importance of structured, yet flexible, learning experiences that leverage learners' self-direction and prior professional experiences. Further, the high level of preference for regular synchronous advisory interactions aligns with previous literature that argues ongoing, real-time communication with coaches enhances learner engagement and enables prompt feedback (Richardson, Maeda, Swan, & Caskurlu, 2017). Good acceptance of peer-to-peer mentoring programs also resonates with Ladyshewsky's (2017) reasoning on peer coaching efficacy in enhancing student confidence and learning performance. Iterative design and prototyping also evidently showed the benefit of using design thinking practices (Brown, 2009; Razzouk & Shute, 2012) in educational settings. Ongoing iteration driven by user feedback resulted in substantial improvements in

teaching material, usability, and overall student satisfaction. These results highlight the triumph of taking an iterative, co-creative stance in creating personalized learning solutions that meet the needs of students and improve postgraduate research skills. In summary, this research provides compelling evidence that integrating adult learning theory, peer coaching, and design thinking can effectively address typical problems in postgraduate distance education. Specifically, this approach helped build community, alleviate isolation, and develop students' research confidence and abilities.

6. Theoretical and Practical Implications

The theoretical contributions of the current research highlight the applicability and viability of using adult learning frameworks, specifically andragogy (Knowles, Holton, & Swanson, 2015) and peer-to-peer coaching (Topping, 2005; Ladyshewsky, 2017), in the context of online learning spaces. The results indicate that adult learners reap substantial advantages from learning modules that are both structured and flexible, allowing for the integration of their varied existing knowledge and professional experience. This study focuses on the important role of developing interactive and collaborative learning environments that significantly enhance learner engagement while reducing feelings of isolation. Theoretically, the research also validates the utility of design thinking (Brown, 2009; Razzouk & Shute, 2012) as a process to undertake education innovation, especially in complicated and geographically distributed learning contexts. The recursive, social processes embedded in design thinking promoted ongoing adherence to the needs of learners and hence exhibited the appropriateness of approaching the sophisticated education problems experienced by distance learners. This study offers definitive recommendations for instructional designers and administrators involved in distance education initiatives. The focus on synchronous advisory consultations and framed peer-to-peer interaction as integral elements of instructional design responds pragmatically to prevalent problems in online learning, including student disconnection and inadequate feedback. Colleges and universities can use these findings to develop more effective, nurturing, and community-based learning environments. In addition, the intensive iterative prototyping model presented in this research provides a template that can be replicated in creating and iterating eLearning content. Teachers can initiate comparable iterative feedback loops to make instructional resources adaptive to both student feedback and the changing needs of learning. Organized integration of peer coaching into instructional frameworks also provides tangible avenues for building student self-efficacy, research proficiency, and teamwork skills that are requisite in graduate education. In conclusion, the theoretical frameworks and practical strategies presented in this study can make a valuable contribution to future teaching practice, more specifically the development and presentation of effective, interactive, and student-centered online postgraduate degree courses.

Ethics Declaration

Ethical clearance was not required for this study, as it involved routine educational practice conducted as part of regular instructional improvement activities within the university's MBA program. All participants voluntarily engaged in the activities and provided informed consent to participate in feedback sessions. Participants were assured of confidentiality, informed about their right to withdraw at any time without any negative consequences, and data were handled securely to protect participant privacy, with personal identifiers removed from all research outputs.

AI Declaration

In the preparation of this manuscript, AI tools were utilized to assist with limited aspects of the writing process, specifically for language editing, grammar checking, and formatting suggestions.

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Hybrid Learning Through the Eyes of Current Lower Secondary School Teachers: A Pilot Study

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Abstract: Hybrid learning is a revolution in education that combines the best of face-to-face and online learning, offering students greater flexibility and personalisation. This dynamic approach not only enhances the quality of education but also reflects the changing needs of society. Therefore, the hybrid form of learning deserves intensive research to reveal its full potential and help to further improve it. The aim of this pilot research was to test the suitability of the main research methodology focusing on the views, attitudes and experiences of current lower secondary school teachers with hybrid learning. The pilot phase focused on testing a semi-structured interview with an emphasis on the clarity of the questions, the relevance of themes and the overall effectiveness of the data collection. Five teachers with varying levels of experience working with digital technologies, online teaching, and varying lengths of experience participated in the research. The purpose of this pilot research was also to obtain current lower secondary school teachers' perspectives on hybrid learning in the form of preliminary findings. A qualitative research design was chosen for this pilot research. A semi-structured interview was used as the research instrument. The research investigation was carried out in a face-to-face meeting with five teachers of a lower secondary school in the Czech Republic. The results of the pilot research helped to verify the functionality of the proposed research tool and to choose an appropriate direction for further research. The pilot research confirmed the suitability of the proposed questions for the semi-structured interview. The data obtained showed the lack of experience of the selected lower secondary school teachers with hybrid teaching, but at the same time these teachers had a lot of experience in using digital learning resources in face-to-face teaching. The results of the pilot research showed that the methodology was workable and no major modifications to the research design were necessary. These preliminary findings suggest key themes for the main research in which the sample will be expanded to include additional respondents. The data obtained outlined the views of lower secondary school teachers and how hybrid teaching could be organised.

Keywords: Pilot Research, Hybrid Teaching, Lower Secondary School Teachers, Semi-structured Interview, Covid-19.

1. Introduction

At a time when technology is becoming an integral part of everyone's life, it is common to harness its potential in the field of education. Online learning is now a well-known concept that almost everyone is familiar with, and in the wake of the Covid-19 pandemic, most teachers and learners across all levels of the education system have tried it. Hybrid learning is a slightly younger concept that has started to spread rapidly in the last few years, and therefore the benefits and effects on learning outcomes or learner motivation are beginning to be discussed.

The area of hybrid learning from the students' perspective has been addressed in several studies, but the perspective of lower secondary school teachers on this form of learning remains largely unknown and needs to be addressed. It is the teachers on whom the successful implementation of hybrid learning and learners' satisfaction with this form of learning and the realisation of its full potential depend. Therefore, it is crucial to understand the perception of hybrid learning from the perspective of current teachers to find the best way of implementing it that would suit teachers and at the same time contribute to greater learners' motivation and easier learning. To date, there is no qualitative study focusing on this topic, especially at the lower secondary school level, so this study seeks to fill this research gap and contribute to mapping this area.

The pilot phase of the research was primarily conducted to test the clarity and functionality of the proposed methodology for collecting qualitative data through semi-structured interviews with lower secondary school teachers. Another aim of the pilot research was to obtain preliminary results of these interviews on teachers' attitudes towards hybrid learning. The chosen research strategy focused on exploring teachers' views and attitudes towards hybrid learning, with the expectation that their insights would help to identify areas key to the proper implementation of hybrid learning with a view to maximising its potential and making it easy and effortless to prepare and implement in lower secondary school classrooms.

1.1 Hybrid Learning

Different authors explain the terms hybrid and blended learning in different ways. For example, Meeprom & Fakfare (2023) state that the terms are identical and that they are a way of teaching where elements of online learning are merely added to face-to-face learning. However, more common are definitions where the two terms are perceived differently, and each refers to a different form of learning. For example, authors Baker & Spencely (2023); Usher & Hershkovitz (2024) and Fabian et al. (2024) define the differences between the different forms of learning.

In this context, we will not confuse the term hybrid learning with terms such as blended learning, because the hybrid form has its own specificities. We talk about hybrid learning when learning is done in two ways simultaneously: some learners are physically present in the school together with the teacher, while other learners join the same lesson remotely via video chat. Simply put, it is a parallel combination of face-to-face and online learning, where both take place simultaneously in real time (Pramila-Savukoski et al., 2023; Baker & Spencely, 2023; Usher & Hershkovitz, 2024; Fabian et al., 2024). See Table 1 for the main comparison of the two forms of learning. However, to successfully manage this form of learning requires careful planning and organization to ensure that activities are appropriately distributed between learners in the classroom and those participating remotely (Rijst et al., 2023; Ahlgren et al., 2020). In contrast to the hybrid model, blended learning involves a gradual alternation of online and face-to-face learning, but never both forms occur simultaneously (Stoloff et al., 2022).

Table 1: Comparison of hybrid and blended learning

Criterion	Hybrid Learning	Combined Learning
Definitions	Simultaneous real-time engagement of face-to-face and online participants	Alternation of full-time and distance learning in separate blocks
Form of teaching	Synchronous - teaching takes place at the same time for all students (online and face-to-face)	Asynchronous - parts of the teaching are scheduled (e.g. a week online, a week face-to-face)
Technological requirements	High - need for quality audiovisual equipment, stable connection	Lower - need for digital platforms for the online part, but not necessarily in real time
Student interaction	Can be uneven (e.g. online students have less access to communication)	More even - each student participates in both forms at different times
Organizational complexity	High - coordination of two groups simultaneously	Medium - clearly separated parts, planning of rotation
Applicability	Where it is necessary to provide access to remote students at the same time	Where teaching can be divided into phases and the advantages of both forms combined

Hybrid learning therefore takes advantage of both forms (face-to-face and online learning) and combines them into one functional system. This model is often preferred abroad due to its flexibility and the possibility to adapt teaching to the individual needs of students (Rijst et al., 2023). In order to achieve a higher quality of learning, improve learners' performance and increase learners' motivation, it is crucial to make the most of the strengths of both modalities while eliminating their weaknesses. Moreover, according to Gamage et al. (2022), both learners and teachers express support for a gradual transition to hybrid learning. Restricting learners strictly to online instruction can lead to feelings of inferiority, but the choice of learning form offered by hybrid learning can ensure that all learners are satisfied and feel like full participants in the learning experience (Fabian et al., 2024).

There is already some research abroad on hybrid learning (e.g. Kee et al. (2024); Usher & Hershkovitz (2024); Fabian et al. (2024)), but to a lesser extent than that of online learning. For example, some studies have focused on factors that influence the effective organisation of this form of learning (Ahlgren et al., 2020). Unlike abroad, this topic has not received sufficient professional attention in the Czech Republic. As a result, there is a lack of uniform terminology and ambiguous definitions of key terms, which often leads to confusion in their use in practice.

The main benefit of hybrid learning is most often cited as its flexibility, which supports an individual approach to learning (Gamage et al., 2022). Interactivity is also an important element of hybrid learning, which helps to activate learners. In addition, one of the earlier international studies pointed out that learners' preferences for

different forms of learning and their performance in a hybrid environment can be influenced by their individual learning styles (Lin, 2008). Other research points out that the quality of hybrid learning and the satisfaction of all participants, is closely related to the level of Internet connectivity, the technologies used and the students' ability to use these tools (Martin-Nunez et al., 2022). Other research suggests that hybrid learning could be a suitable form for education in which, collaborative learning could be used as a method to facilitate interaction between learners and allow them to build their competencies together (Pramila-Savukoski et al., 2023). Hybrid learning can promote learners' autonomy and increase learners' satisfaction and learning outcomes, but it all depends on many different factors (Fabian et al., 2024).

On the other hand, Baker & Spencely (2023) concluded that learners were not actively engaged in learning through MS Teams when this platform replaced or supplemented face-to-face learning. Rather, the introduction of MS Teams represented a simple technological intervention without a deeper curricular innovation. At the same time, the authors point out the false assumption that young people are automatically technologically literate. In fact, they often lack the skills needed to use technology effectively for learning. Building on the experience of emergency online learning, it is therefore important to critically evaluate which technological interventions make sense and which do not. For digital learning resources (DLRs) to be truly beneficial, the purpose of their use needs to be clear, and appropriate training needs to be provided. Simply replacing face-to-face learning with online tools will not lead to the same result without a well-developed hybrid learning plan (Rath et al., 2019).

Hybrid learning cannot be seen as an isolated concept, as its nature is based on the interconnection with e-learning, online learning, but above all with various digital learning resources. It is the combination of online and face-to-face elements that forms the basis of this teaching strategy, which combines the advantages of both approaches and opens up new possibilities for individualisation and flexibility of learning. For this reason, one part of the developed interview questions focuses on online learning and another part on the use of digital learning resources in traditional face-to-face learning.

2. Methodology

The qualitative research method, namely semi-structured interview, was chosen for the pilot research. For the purpose of the semi-structured interview, 20 questions were developed. The first two questions were introductory and served to get to know the interviewee (subjects taught along with the reason for their selection and length of teaching experience). The main part of the interview was divided into three sub-areas. The first area mapped the experience of online learning during the Covid-19 pandemic. The second area built on this theme and explored the current state of the use of digital learning resources in teaching. The last area covered the whole interview on the topic of hybrid learning and sought teachers' opinions, ideas, recommendations and concerns about the possible implementation of this form of learning.

This interview has so far been piloted with a sample of five participants. The research investigation was carried out in a face-to-face meeting with teachers of a lower secondary school in the Czech Republic. The results of the pilot research helped to verify the functionality of the proposed research instrument, and it was not necessary to make major changes in the composition and wording of the questions in the semi-structured interview for further research. The data collected from the pilot research outlined the views of lower secondary school teachers on hybrid learning, how hybrid learning could be organised and the main issues that could arise.

For the purposes of this research, five teacher participants were selected with different lengths of experience, different subject areas, which may influence the diversity of backgrounds for working with digital learning resources, and all of these participants must have had experience of online learning during the Covid-19 pandemic. In the pilot phase of the research, responses were obtained from three men and two women, but gender was not a parameter for the selection of participants. The disciplines taught by these participants differed and overlapped. The subjects were physics, music education, civic education, and foreign languages. For further research, this research sample will be expanded to include additional teachers from this lower secondary school (to include teachers from other subject areas) as well as from at least one other lower secondary school that varies in location, size, and digital technology equipment until the research sample is saturated.

For the semi-structured interviews, the main research question was set: How do lower secondary school teachers perceive the opportunities and challenges associated with the implementation of hybrid learning? Each of the three parts of this interview then answered one of the sub-research questions: How has the Covid-19 pandemic affected lower secondary school teachers' teaching? How do lower secondary school teachers

integrate digital learning resources into their teaching? What problems/obstacles do teachers expect when implementing hybrid learning?

3. Results

Experiences with online learning during the Covid-19 pandemic varied considerably among the selected teachers. While some teachers experienced conventional synchronous online learning, others used an asynchronous form of online learning, and there was also a case where a given teacher implemented hybrid learning. All participants in the pilot research perceived online learning as useful in times of crisis. For some it was a challenging experience, but one that influenced their face-to-face learning. In the beginning of the pandemic, they were mainly faced with technical problems and uncertainty about how to structure the teaching in a new way. However, all teachers described that after some time they improved and became familiar with the Google Classroom platform, streamlined assignments and started to make better use of the DLRs. One participant stated "I think as a school we were well prepared technically. The first Covid period was without online learning, we just sent them *(learners)* some materials and they submitted some assignments. I was grateful when both my children saw the teacher and she explained it to them, and I was grateful that I could do it *(online teaching)*."

Based on their experiences with online learning, all participants have started to use DLRs in face-to-face learning. At the same time, they all agreed on the benefits that these DLRs have. Specifically, they stated, “They are meaningful, effective, they help the kid understand it better”; “It definitely improves teaching, otherwise I wouldn't use it.”

However, a major problem with online learning for all participants remains the unstable internet connection and the passivity of some learners. One participant commented: “It's the age of the kids...” and stated that younger learners try to engage more in online learning than older ones. Similarly, another participant responded: "Of course they had things on at it (e.g. games), but they were trying their best, of course. There was a need to ensure the children's attention, so they weren't distracted by something else. Trying to keep them interested somehow. It was more tiring, both for me and for the kids."

The advantages and disadvantages of online learning mentioned by the teachers interviewed are consistent with the results of previous research. The positive side of online learning for some participants is the possibility of joining the class from the comfort of their home, the possibility of using a wide range of online tools, and above all the possibility of holding classes even in a crisis situation when face-to-face learning cannot be implemented. "They can work from home. It's taught me a lot, like *(using)* online tests." In addition, participants reported that the use of visual aids such as interactive whiteboards, visualizer, graphic tablet or screen sharing proved useful to help online learners to visually see the teacher's activity and better understand the interpretation of the material. One participant noted: “What I wrote, they saw immediately...”

Preliminary results of the pilot interviews showed that most teachers are prepared for the potential hybrid learning and are not worried about its implementation. However, teachers perceive this form of learning almost identically to online learning, along with its shortcomings and advantages. A participant who has already had experience with hybrid learning described his experience by saying: "I had my laptop open, and we were just going and occasionally I would hit someone who was online, I would turn it on *(if they were paying attention)*. When someone from online was talking, I turned on the microphone and the class *(in attendance)* could hear it too. It wasn't that much of a cowboy thing, I just went to class and took the laptop with me."

All teachers interviewed agreed that they would implement hybrid learning in the same way as face-to-face learning, in which they all already use DLRs in different ways, mainly as a result of their experience with online learning. “I have started to incorporate that online practice much more often in that *(face-to-face)* learning.” They would stick to proven teaching methods and ways of organisation, the only difference being the synchronous (video)call through which some learners would be connected online. Although most of the participants had no experience with hybrid learning, they were all familiar with this form of learning and shared a number of specific recommendations and suggestions that they found useful for the successful implementation of this form of learning. They repeatedly mentioned the importance of thorough lesson preparation and the ability to keep track of two groups of learners (physically present in the classroom and connected online). They considered a clear lesson structure and regular alternation of attention between the two groups to be essential.

Respondents' views on hybrid learning were neutral to slightly critical. Although they recognized the benefits of the hybrid model in terms of maintaining instruction in the absence of some of the learners, “I was grateful that the kids had that option.” They considered this mode of teaching inappropriate for mainstream use in lower secondary schools. At the end of the interviews, participants emphasised that they saw hybrid learning as an emergency solution rather than a permanent model and considered it important that it should only be used when justified. “I see it as such an emergency option.” All participants described that coordinating learning for two groups of learners at the same time requires significantly more focus and preparation than traditional face-to-face learning, e.g., one participant stated: “It's challenging to combine, but the option, why not.” Despite this, all participants indicated that they felt prepared for the potential hybrid learning and could manage its implementation.

Preliminary findings from the pilot study confirm that the chosen method of semi-structured interviews is a suitable tool for capturing teachers' individual experiences and reflections on hybrid learning and the use of DLRs in face-to-face learning. The content of the interviews also indicated practical aspects of organizing hybrid learning.

These results of the pilot phase are presented in general terms without detailed analysis and interpretation and will therefore be further developed in the main phase of the research with a wider sample of interviewees. The pilot interviews will remain part of the data set as they meet the requirements for content and methodological relevance.

4. Conclusion

The results of the pilot research confirmed the appropriateness of the chosen research method and the semi-structured interview questions. The overall length of the interviews fulfilled the requirements for a quality interview providing sufficiently saturated answers to the research questions of the whole research, as stated e.g. by Švaříček et al. (2007).

The preliminary results of the pilot interviews confirm the findings of Usher & Hershkovitz (2024). Teachers in hybrid learning must make a greater effort to provide an equivalent learning environment and experience for online and face-to-face learners and therefore must sufficiently rotate their attention between the two groups of learners involved. Teachers, and probably learners, have learned to make more use of digital learning resources in face-to-face learning, to work with digital technologies, but above all to develop their digital competences through online teaching, as confirmed by e.g. the results of Bickle et al. (2019); Gamage et al. (2022); Stoloff et al. (2022). The participants in this research, like the authors Moise et al. (2021) or Yuhanna et al. (2020), agree that the biggest advantage of online learning is the ability to join the class from the comfort of home. At the same time, all participants agreed that the possibility of implementing online and hybrid learning is a great solution in times of crisis when learners cannot attend classes in person.

The pilot study involved five participants with different lengths of teaching experience, disciplinary focus and experience with online or hybrid learning. The interviews not only provided validation of the chosen research methodology but also outlined important areas that may be crucial for the implementation of hybrid learning in lower secondary schools. The chosen methodology allows the area of hybrid learning to be explored in depth, and thus to gain a comprehensive picture of how lower secondary school teachers perceive the opportunities and challenges associated with the implementation of hybrid learning. This pilot research now needs to be expanded to include a larger research sample until saturation occurs and the answers obtained no longer provide new information. Then, the data collected, i.e. the interview transcripts in text form, will be further processed and analysed in detail systematically through the method of response coding, thematic analysis and subsequent interpretation. The main output of the follow-up research will be a set of recommendations and guidelines for working in hybrid learning for current lower secondary school teachers, and at the same time a learning content for future teachers will be obtained, i.e. content for a subject to be taught at universities in preparation for teaching practice.

Ethics Declaration

Informed consent was obtained from all subjects involved in the research.

AI Declaration

The authors state that they did not use artificial intelligence tools to generate the text in this paper.

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Artificial Intelligence in E-Assessment: Tools and Action Research in Mathematics

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Abstract: The rapid advancement of artificial intelligence (AI) has led to significant transformations in educational assessment practices. AI-supported electronic testing (e-assessment) is gaining attention for its potential to enhance automation, adaptivity, and efficiency in both formative and summative evaluation processes. This study combines a comparative analysis of selected online platforms that utilize AI for e-assessment with the outcomes of action research implemented in real-life school settings. In the first phase, we conducted a functional and pedagogical analysis of various AI-based e-testing tools, focusing on their capabilities for automatic question generation, adaptive item sequencing, and real-time feedback. Special attention was given to the field of mathematics education at the primary level, where accurate knowledge verification and differentiation are essential. In the second phase, we carried out action research at the lower secondary level (ISCED 2) of a primary school, investigating the implementation of AI-generated e-tests in regular mathematics instruction. The study examined not only the cognitive and motivational responses of students to AI-driven assessment but also teachers' reflections on the practical integration of such tools in their instructional routines. The results indicate that AI-enhanced e-testing offers multiple pedagogical benefits, including increased student engagement, personalization of learning, and more efficient data-driven feedback. However, several limitations were identified, such as technological constraints, challenges in interpreting open-ended responses, and the need for teacher mediation in adapting AI outputs to classroom realities. This research contributes to the ongoing discourse on educational technology by providing empirical evidence and critical reflection on the meaningful integration of AI in assessment. It underscores the importance of equipping educators with both digital and pedagogical competencies to ensure responsible and effective use of AI tools in primary and lower secondary education.

Keywords: Artificial Intelligence, E-Assessment, Mathematics Education, Primary School

1. Introduction

Over the past ten years, the landscape of teaching and student assessment has undergone profound transformation across all educational levels. The widespread adoption of digital technologies has fundamentally changed not only how instruction is delivered, but also how learners are assessed. A growing number of electronic tools are now being incorporated into classroom practice, enabling more interactive, engaging, and adaptive forms of teaching and providing teachers with faster, data-informed feedback. Among these tools, electronic testing (e-testing) has emerged as a particularly promising method. E-testing brings numerous advantages—not only in terms of efficiency and time-saving capabilities, but also in its potential to support individualized learning pathways, offering tailored questions and differentiated levels of difficulty (Andriaputra, Resmana, Marzuki, & Rangkuti 2022). In parallel with the evolution of e-testing tools, significant strides have also been made in the field of artificial intelligence (AI), which is increasingly being harnessed to enhance educational processes. Within the context of primary and secondary education, AI technologies are now being used for tasks that were previously difficult or highly time-consuming. These include the automatic generation of test questions, adaptive sequencing based on student responses, automated evaluation of open-ended items, and the provision of real-time, personalized feedback (Luckin et al. 2016; Abdelmagid et al. 2024). Such innovations not only support more dynamic assessment practices, but also open new possibilities for addressing individual student needs. In the specific context of mathematics education at the lower secondary level, the integration of AI into e-assessment has the potential to deliver significant benefits. Mathematics is a discipline that demands precision, systematic problem-solving, and repeated practice. Teachers often face challenges such as preparing exercises that suit different ability levels, adapting instruction for diverse learners, and spending large amounts of time manually grading assignments. AI-powered e-testing tools can help automate many of these processes while maintaining assessment quality and increasing student motivation through interactivity and instant results (Vilček 2024). The purpose of this article is to present and critically examine several selected online platforms that incorporate artificial intelligence into the design and delivery of electronic tests, with a particular emphasis on their application in lower secondary mathematics education. In addition to conducting a comparative analysis of these AI-enhanced platforms, the study also includes an action research component, carried out in real classroom settings at the ISCED 2 level. This practical phase explored how AI-generated e-tests function in regular instruction, focusing on students' cognitive performance and

motivational engagement, as well as on teachers' reflections regarding the feasibility and value of integrating AI tools into their everyday teaching practice.

2. Research Design

This study addresses the insufficient empirical evidence on the use of AI-generated e-tests in primary school mathematics education. The research aims to investigate their impact on students' cognitive performance, motivation, and teachers' practical experiences with the implementation of these tools compared to traditional assessment methods.

The research design is based on a mixed-method approach combining a comparative analysis of selected AI-supported e-assessment tools with an action research component conducted in authentic classroom settings. This design enabled linking theoretical knowledge of AI functionalities in e-testing with practical experiences in real-life school environments.

Research questions:

1. What is the impact of AI-generated e-tests on students' cognitive performance in mathematics?
2. How do AI-supported e-assessment tools influence students' motivation and engagement in solving mathematical tasks?
3. What are teachers' experiences and perceptions of the benefits and limitations of implementing AI-based e-testing tools?

Participants: The study involved 37 students from grades 6 and 7 (ISCED 2) and two mathematics teachers. The tools tested were Quizizz and Edpuzzle, selected for their AI-driven features such as automatic question generation, instant feedback, and result tracking.

Data collection methods included:

- Observation of classroom interactions and engagement levels.
- Analysis of test results (success rates, types of errors, time to solve tasks).
- Short post-lesson questionnaires for students focusing on motivation and perceived usefulness.
- Semi-structured interviews with teachers to gather their reflections on the implementation process.

Data analysis combined quantitative indicators (test scores, error distribution) with qualitative coding of student and teacher comments. This allowed a multi-faceted understanding of how AI tools influence both cognitive and affective aspects of learning, as well as their practical applicability in mathematics education.

The research design of this study combines comparative analysis with elements of action research. The aim was not only to describe and compare the functions of selected online tools using artificial intelligence in e-testing, but also to verify their practical use in teaching mathematics at the second level of primary school. This mixed approach allows to link theoretical knowledge about the possibilities of AI tools with concrete experiences from real school environments. The research was conducted in two follow-up phases. The first phase focused on a systematic analysis of the features of the three selected applications, with an emphasis on their applicability to the development of e-tests in mathematics. The second phase took the form of an action research in which these tools were tested in regular classrooms, and students' reactions and teachers' reflections were observed. The following subsections describe in detail the procedure and methods used in both parts of the research.

2.1 Phase 1 - Comparative Analysis of Educational Applications

In the first phase of the research, a comparative analysis of three online educational tools that combine traditional e-testing environments with elements of artificial intelligence was conducted. Kahoot!, Edpuzzle and Quizizz were included in the selection process and were chosen based on several criteria: availability of a free version, degree of integration of AI features, intuitiveness of the interface for teachers, feedback options and ability to work with mathematical content. For each of the apps, specific AI-powered features were looked at, the automatic generation of questions based on a given topic, text, link or PDF document, the adaptive nature of the testing, and the options for scoring answers, including open-ended tasks. The analysis also focused on the practical applicability of the tools in the development of tests in mathematics at the second level of primary school, noting their advantages and limitations in terms of pedagogical use. For example, Kahoot! offers the generation of test problems from text-based materials or web pages and high student motivation due to its game-like format. Edpuzzle enables interactive video work and uses AI to generate questions and automatically score open-ended answers. Quizizz features a wide range of question generation options and clear result

scoring. The output of this phase was a systematic characterisation of each tool and its suitability for use in mathematics education.

2.1.1 Rationale for Excluding Kahoot! from the Action Research

Although Kahoot! scored highly in terms of student motivation thanks to its game-based design, its limited capacity to support more complex mathematical problems and reliance predominantly on multiple-choice formats made it less suitable for the objectives of this research. In contrast, Quizizz and Edpuzzle provided more flexible options for generating and assessing mathematics tasks, including open-ended responses and adaptive question formats. These features better aligned with the study's aim to examine not only engagement but also deeper cognitive understanding in mathematics education.

Table 1 Comparison of AI-supported e-testing tools (Kahoot!, Edpuzzle, Quizizz).

Criterion	Kahoot!	Edpuzzle	Quizizz
AI Question Generation	From text, PDF, or website	From video content	From topic, text, or website
Mathematical Suitability	Less suitable for complex problems	Supports conceptual understanding	Strong support incl. math notation
Feedback Quality	Immediate, mostly multiple-choice	Detailed, incl. open-ended answers	Provides instant feedback with detailed tracking
Motivation/Engagement	High (game-based)	Moderate to high (video-based)	High (gamified quizzes)
Teacher Workload	Requires review/editing	Saves time via auto-grading	Reduces workload with AI-assisted customization
Free Version Limitations	Some advanced features restricted	Some features limited	Limited access to certain features

2.2 Phase 2 - Action research in school environment

In the second phase of the research, action research was carried out to test the possibilities of using electronic tests generated by artificial intelligence in regular mathematics teaching. Action research, first conceptualized by German American psychologist Kurt Lewin in the 1940s, is a cyclical and reflective process in which researchers and practitioners collaboratively identify a problem, plan and implement interventions, observe the outcomes, and reflect on the results to improve practice. In educational contexts, this methodology is widely used to enhance teaching and learning in authentic classroom settings, as it allows for a dynamic interplay between research and practice.

In this study, the action research was conducted during two consecutive lessons in the second level of primary school (ISCED 2), specifically in grades 6 and 7, with the participation of a total of 37 pupils. The Quizizz and Edpuzzle applications were used during the lessons, with an emphasis on the use of their AI features for automatic test problem generation, feedback, and result tracking. The research focused on three main areas: (1) students' cognitive response, i.e., level of understanding of the task and success in solving the tasks; (2) motivational aspects, such as engagement in the activity and preference for the tools; and (3) teachers' reflection, including practical experiences with the implementation of the tools in the classroom, their perceived benefits, and limitations. Data were collected through classroom observations, semi-structured interviews with teachers, and analysis of test results (including success rates, types of errors, and solution time).

3. Review of Selected Educational Apps

Given the growing potential of using artificial intelligence (AI) in education, new tools are emerging that can significantly save teacher's time while also making learning more engaging for students. One area where AI is increasingly being applied is in the creation of electronic tests—not only in generating questions but also in evaluating responses and providing feedback. For the purposes of this article, three online tools were selected that combine traditional testing environments with AI elements and have proven effective in teaching mathematics at the lower secondary school level. The selection criteria focused primarily on the availability of a free version, the extent of AI integration, the intuitiveness of the teacher interface, feedback options, and the ability to handle mathematical content. This section will present and compare the following applications in more detail: Kahoot! Edpuz285zle, and Quizizz. The emphasis will be on describing specific AI-powered features, the advantages and limitations of each tool, and their practical application in the creation of e-tests in primary school settings.

3.1 Kahoot!

Kahoot! is a very popular tool among pupils due to its game-based approach to testing and strong visual appeal. Recently, Kahoot! has implemented several AI-powered features that significantly speed up content creation and save teacher's time. One of the key features is the ability to automatically generate questions based on a given topic—for example, by entering the term *"geometry,"* the system creates related questions along with possible answers. This feature supports more than 50 languages, including Czech, and allows users to choose the difficulty level of the questions. Another useful function is the ability to generate a quiz from an uploaded PDF document, such as a worksheet or a teaching text. The AI can extract key information from the document and create relevant questions. Similarly, quizzes can also be generated from a provided website link—for instance, inserting a link to a Wikipedia article prompts the system to automatically create questions based on the page's content. These tools allow for a very efficient transformation of study materials into an interactive format without the need for manual rewriting. However, it's important to note that AI-generated content may not always be accurate or fully appropriate for specific learning objectives. Therefore, teachers should carefully review and, if necessary, edit the AI outputs to ensure they meet the instructional goals and the age level of the pupils.

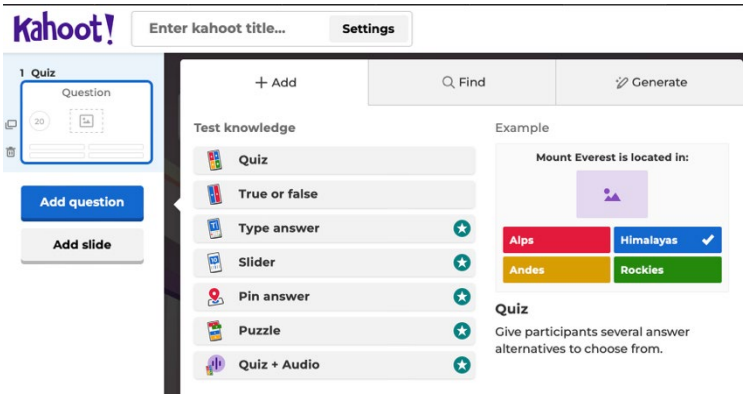


Figure 1 app Kahoot!

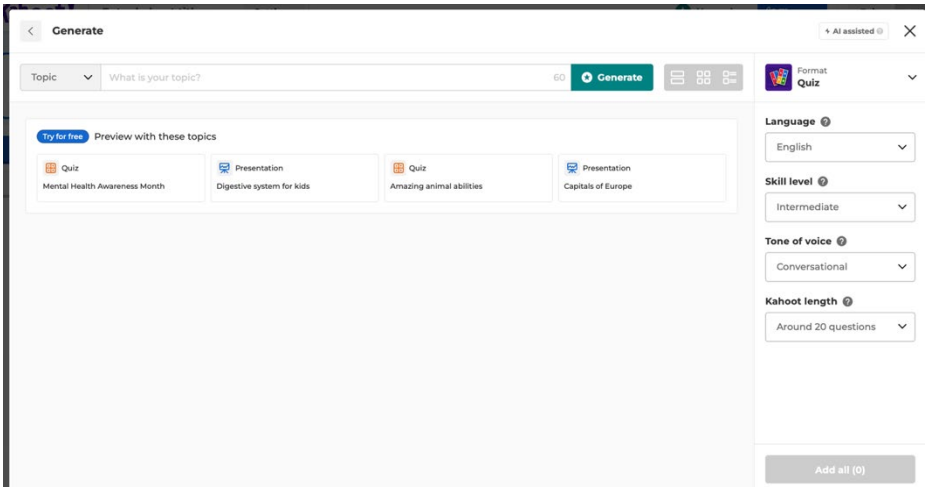


Figure 2 app Kahoot! - AI generator

Advantages of Kahoot!:

- High pupil motivation thanks to the game-based format
- Fast question creation using AI
- Ability to generate quizzes from PDFs or websites
- Support for the Czech language
- Clear evaluation of responses

Disadvantages of Kahoot!:

- AI-generated content is not always accurate – teacher review and correction is necessary
- Limited options for more complex math problems
- More suitable for review than for deeper assessment of understanding
- Some advanced features are only available in the paid version

3.2 Edpuzzle

Edpuzzle is an interactive learning platform that allows teachers to take any video from the internet (such as YouTube, Khan Academy, or their own recordings) and enhance it with interactive elements—specifically questions, notes, or comments. This transforms ordinary passive video watching into an active learning experience that increases student engagement and allows teachers to monitor understanding throughout the video.

As students watch the video, they are prompted to respond to embedded questions (such as multiple choice, short answer, or fill-in-the-blank). This enables the teacher to see exactly who answered what and when, and to adjust instruction accordingly. For example, if most students struggled with a particular section, the teacher can revisit it during class.

Newer versions of Edpuzzle include tools powered by artificial intelligence (AI), grouped under the Teacher Assist feature set. These AI tools are designed to save teachers time and support more efficient lesson planning and assessment:

- Autograde: This feature automatically evaluates open-ended responses by comparing student answers to an ideal response provided by the teacher. It saves time on manual grading and delivers prompt feedback to students.
- Question Generator: AI analyses the content of the selected video and automatically suggests relevant questions that can be embedded directly into the video. Teachers can either use these questions as-is or modify them to better suit their instructional goals. This greatly simplifies the preparation of interactive lessons.

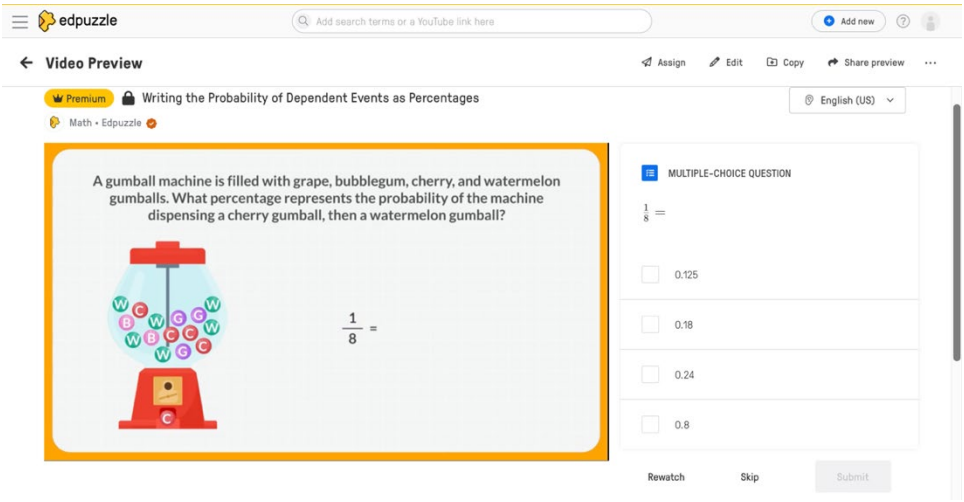


Figure 3 app Edpuzzle

Advantages of Edpuzzle:

- Automated grading of open-ended questions using AI
- Question generation based on video content
- Ability to customize questions to meet specific instructional needs

Disadvantages of Edpuzzle:

- Automatic grading may be less accurate for complex answers
- Generated questions may not always match the desired difficulty level
- Some features may be limited in the free version

3.3 Quizizz

Quizizz is a modern platform for creating quizzes and e-tests, popular among both teachers and pupils for its interactive and playful environment. Compared to traditional quiz tools, it has taken a step further thanks to the integration of artificial intelligence (AI), which enables fast and efficient generation of test questions. The Quizizz AI feature offers several ways to automatically generate questions based on the teacher's needs.

The most used function is Generate with AI, where the user simply enters a topic (e.g., *fractions*, *equations*, *probability*), and the AI automatically creates a set of questions with answer options. The teacher can choose the language (Czech is supported), the number of questions, and their difficulty level. Alternatively, the Generate from Text function allows the creation of questions based on an inserted text (e.g., a textbook excerpt or explanation), generating questions that match the content precisely. Quizizz also enables question generation from a website or by entering key terms.

In mathematics education, Quizizz is highly applicable—it supports not only multiple-choice questions but also fill-in-the-blank answers and working with mathematical expressions. The platform allows teachers to easily track pupil results, assign homework, or create competitions that motivate pupils to review the material.

Advantages of Quizizz:

- Quick question generation using AI
- Generation from a topic, text, or website
- Support for Czech and various difficulty levels
- Engaging environment for pupils, including game elements
- Ability to track results and repeat tests

Disadvantages of Quizizz:

- AI-generated questions need review—they are sometimes too general or too simple
- Open-ended or multi-step math problems are limited
- Some features and advanced analytics are only available in the paid version

4. Research Findings

This section presents the main outcomes of the conducted action research on the use of AI-supported e-assessment tools in mathematics education. The findings are based on data collected from two classes (6th and 7th grade), where Quizizz and Edpuzzle were implemented during regular lessons. The results highlight both cognitive aspects of student performance and the motivational impact of using these tools. The following subsections provide a detailed overview of the quantitative results and students' feedback on their learning experience.

4.1 Quantitative Findings

The quantitative analysis of the collected data revealed high success rates among students when using AI-generated e-tests. In Grade 6, where the focus was on the properties of triangles, the average success rate reached 97%. Despite this overall high performance, several recurring mistakes were identified. The most frequent errors included confusion between equilateral and isosceles triangles, incorrect identification of obtuse angles within triangle contexts, and difficulties in determining the type of triangle based on given side lengths. In Grade 7, where the topic of percentages was addressed, the average success rate was slightly lower, at 94%. Commonly observed mistakes included confusion about identifying the correct base value in percentage calculations, mixing up decimal and percentage forms (for example, interpreting 0.25 as 25% or vice versa), and omitting essential steps when solving word problems. These findings suggest that, while students generally performed well using AI-supported e-assessment tools, specific conceptual misunderstandings persist in both geometry and percentage calculations.

4.2 Qualitative Findings

The findings indicate that the use of AI-based assessment tools had a positive effect on student motivation and overall engagement during mathematics lessons. Many students reported that completing tasks through these digital platforms was significantly more enjoyable than traditional paper-based tests. In particular, the game-like format of Quizizz was highlighted as highly engaging, fostering a sense of competition and encouraging students to perform better. They appreciated the opportunity to receive immediate feedback on their answers, which allowed them to correct mistakes and improve their understanding on the spot. The feedback on Edpuzzle was more varied. While some students valued the use of instructional videos and considered them helpful for

understanding the topic, others expressed a preference for the faster-paced, interactive quizzes provided by Quizizz. This suggests that different students may respond differently to various AI-supported tools, with gamified approaches generally perceived as more appealing. Selected student comments illustrate these perceptions:

- "This was way better than a regular test."
- "I scored higher than last time—happy about that!"
- "The video was okay, but I like quizzes more."

Overall, the integration of AI tools appeared to enhance student motivation, making the learning process more dynamic, interactive, and enjoyable compared to traditional testing methods.



Figure 4 Children making Quizizz

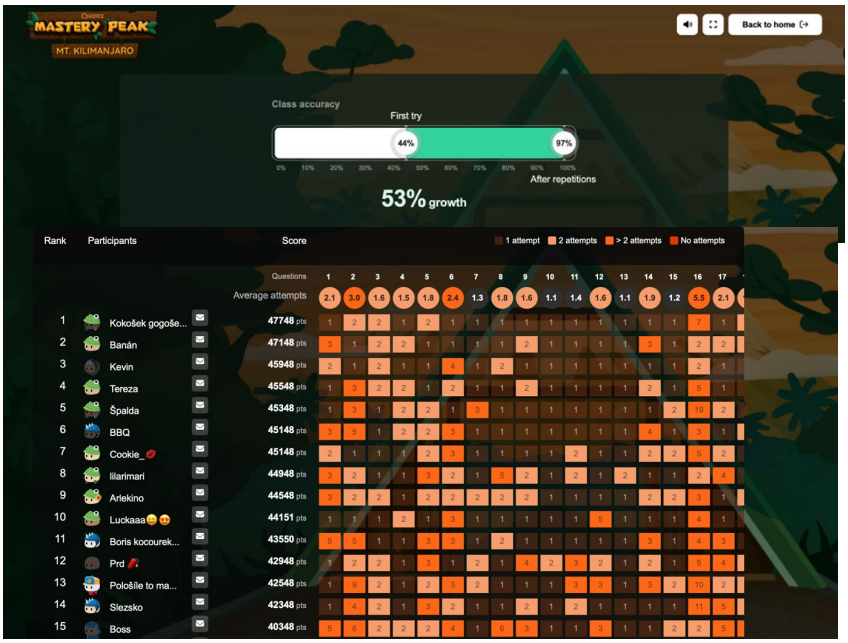


Figure 5 Quizizz results

5. Conclusion

This research confirmed that AI-supported e-assessment tools can significantly enhance formative assessment practices in mathematics education at both the primary and lower secondary levels. The tested applications, Quizizz and Edpuzzle, enabled teachers to quickly generate tests using AI features, provided students with instant feedback, and increased their motivation through interactive and game-like elements. The action

research conducted in two classes (6th and 7th grade) demonstrated that students responded positively to this type of assessment, actively engaged in learning activities, and generally achieved high success rates. Despite these benefits, some challenges were observed. The study highlighted the need for teacher oversight to ensure the accuracy, appropriateness, and difficulty level of AI-generated questions. While AI tools effectively support content review and quick diagnostics of student understanding, their ability to handle complex, multi-step problems remains limited. Additionally, successful implementation depends on adequate technical infrastructure and teachers' digital literacy, as well as their ability to pedagogically adapt the generated content to students' needs. Feedback on Edpuzzle showed that while video-based questions can support understanding, many students preferred the more dynamic quiz format. From a practical perspective, AI-driven e-assessment tools have strong potential to complement traditional evaluation methods by making the learning process more engaging, adaptive, and efficient. Teachers who wish to integrate these tools should critically review AI-generated content for accuracy, tailor it to individual learners, and ensure equitable access to technology. Future research should investigate the long-term effects of AI-supported assessment on learning outcomes, its potential to create personalized learning pathways, and its applicability across broader mathematical topics and other school subjects. With proper implementation and teacher guidance, AI-driven e-assessment can significantly enrich mathematics education and contribute to more dynamic, data-informed, and student-centered learning environments.

Ethics declaration

This study did not require formal ethical clearance, as it was conducted within the standard framework of regular classroom instruction and involved no collection of sensitive personal data. Participation was entirely voluntary, and the students' responses and results were anonymized. The research was carried out with the informed consent of the participating teachers. No identifiable information about students was recorded or reported.

Declaration on the Use of AI Tools

In the preparation of this work, the authors made use of the ChatGPT language model developed by OpenAI, primarily for academic language editing and refinement of the English text. All content generated with the assistance of this tool has been carefully reviewed, revised, and edited by the authors, who assume full responsibility for the final version and overall content of the article.

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Enhancing Higher Education Learning through Blackboard: Impact on Student Learning and Diversity

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Abstract: The increasing reliance on digital learning platforms in higher education necessitates an exploration of how Learning Management Systems (LMS) like Blackboard influence student learning experiences and accommodate learning diversity. This study examines the effectiveness of Blackboard in promoting inclusive and engaging learning experiences at the University of Fort Hare. The purpose of this research was to investigate how students interact with Blackboard, the challenges they face, and the extent to which the platform supports diverse learning needs. This study is guided by the Community of Inquiry (CoI) framework, which examines cognitive, social, and teaching presence in online learning. By applying this framework, the research evaluates how Blackboard fosters meaningful engagement, supports diverse learning needs, and enhances instructional effectiveness, contributing to a more inclusive and student-centered digital learning environment. This study adopts a mixed-methods approach. This methodology allows for a comprehensive analysis of students' perceptions, engagement levels, and barriers to the optimal use of Blackboard. The findings indicate that while Blackboard enhances accessibility to learning materials and fosters asynchronous engagement, students encounter challenges related to digital literacy, navigation complexities, and limited interactive elements. Additionally, variations in students' technological proficiency and learning preferences highlight the need for adaptive instructional strategies. The above findings indicate the importance of integrating student centered design principles into Blackboard's usage, ensuring that learning experiences cater to diverse student backgrounds. Providing training for both students and lecturers is important in addressing technical challenges, improving digital literacy, and ensuring seamless navigation of Blackboard. The study's relevance lies in informing institutional strategies for improving Blackboard's pedagogical effectiveness, fostering student engagement, and promoting digital inclusivity. By addressing these concerns, the University of Fort hare can enhance student learning experiences and bridge digital disparities, ultimately contributing to a more equitable and responsive higher education environment.

Keywords: Blackboard, Learning Management System, Student Engagement, Learning Diversity

1. Introduction and Background

In recent years, universities have made a big shift towards using online learning tools to support teaching and learning. At the University of Fort Hare (UFH). Blackboard is the Learning Management System (LMS) used to give students access to learning materials, sharing of announcements, and allowing interaction between students and lecturers. This shift has been especially important during and after the COVID-19 pandemic, which pushed many institutions to rely more on digital platforms , (Czerniewicz at el, 2020). While Blackboard makes it easier for students to access learning content at any time, it also comes with practical challenges that affect how students learn and engage with their studies (Uziak,at et, 2018). Many UFH students come from disadvantaged backgrounds, and not all of them have the same level of digital skills. Some students struggle to use Blackboard because they are not familiar with technology, while others face problems like poor internet connection or difficulty in navigating the system. Alokluk (2018) states that effective implementation of Blackboard must address a number of barriers, including institutional culture, pedagogical and technical support, teacher's familiarity with technology and pedagogical content knowledge, students' technical knowledge, and resources. These challenges make it hard for all students to benefit equally from online learning. Some also find the content on Blackboard not interactive enough, which can make learning feel lonely or boring.

The central problem addressed in this study is the disconnect between the intended functionality of Blackboard as an inclusive learning platform and the actual experiences of students at UFH. While Blackboard is designed to support a wide range of learning needs through its digital tools and flexible content delivery mechanisms, in practice, it does not always meet the diverse requirements of all students. According to Yu at el (2024) many students encounter barriers such as limited digital literacy, inconsistent access to reliable devices or internet connectivity, and difficulties in navigating the platform's interface. Additionally, the way in which learning content is structured and delivered on Blackboard often fails to consider students' varied learning preferences, linguistic backgrounds, and levels of prior exposure to digital learning environments (Raza at el, 2022). These challenges contribute to unequal learning experiences and hinder full participation in the academic process for some students.

At UFH, first-year students are supported through structured Blackboard training sessions designed to introduce them to the platform's key features, including course navigation, accessing learning materials, submitting assignments, and participating in online discussions. These trainings are conducted during the first week of the academic year as part of the student orientation programme. The training runs over a full week, with two sessions held daily, each lasting two hours. Following the initial training week, additional refresher sessions are scheduled every Wednesday for the first term to reinforce learning and address any challenges students may encounter as they begin engaging with their online courses.The TeL Student Assistants play an important role in providing hands on guidance, answering student queries, and offering one-on-one consultations to ensure that first-year students develop the digital skills needed to effectively engage with their courses on Blackboard. This support system is crucial in helping new students transition into the digital learning environment with confidence.

2. Literature Review

2.1 The Role of Learning Management Systems in Higher Education

The LMS play an important role in higher education by enhancing teaching and learning processes. These platforms facilitate the creation, delivery, and management of educational content, making learning materials easily accessible to students (Thangavel, 2024). In addition to supporting academic delivery, LMS streamline administrative functions such as documentation storage and report generation, thus improving institutional efficiency (Madyatmadja et al., 2023). The integration of LMS into higher education institutions has transformed traditional educational practices, supporting more organized, centralized, and efficient workflows.

The LMS also contributes significantly to teaching and learning by promoting student engagement and supporting a variety of learning preferences. The LMS faciliatates the creation of interactive learning environments that encourage active participation, leading to improved student satisfaction and learning outcomes (Madyatmadja et al., 2023). Moreover, LMS offer flexible and accessible learning opportunities, allowing students to learn at their own pace and from any location (Ebbini, 2023). By accommodating various pedagogical approaches, these systems help lecturers address diverse learning needs and styles, ultimately enriching the overall educational experience.

Despite their numerous advantages, the implementation of the LMS is not without challenges. Issues such as system complexity, infrastructure limitations, and the need for skilled personnel can hinder effective integration (David et al., 2022). Nevertheless, the transformative potential of LMS in higher education remains substantial. Continued investment in training, system development, and technological innovation is essential to fully leverage the benefits of the LMS and ensure they contribute meaningfully to the advancement of teaching, learning, and institutional effectiveness.

2.2 Digital Literacy and Access in the South African Higher Education Context

Digital literacy and access in South African higher education are pressing concerns, shaped by persistent socio-economic disparities and rapid technological advancements. While the integration of digital tools has the potential to enrich learning experiences, many students continue to face significant obstacles in both access and skill development. Research shows that a considerable number of students lack the digital and information literacy skills necessary for academic success and meaningful participation in the digital world (Shibambu & Mojapelo, 2024). As the demands of the Fourth Industrial Revolution grow, there is a rising need for inclusive digital practices, especially in multilingual educational settings where technology can serve as a tool to improve learning outcomes (Ndebele, 2022).

Despite efforts to promote digital inclusion, many students still experience inconsistent access to digital resources. This tension is often felt as students navigate between technologically enriched environments and under-resourced ones, reflecting broader inequalities in the South African education system (Kajee & Balfour, 2011). The digital divide in this context is not simply about having or lacking technology, but rather about the quality, consistency, and context of access. As such, it is important to move beyond simplistic understandings of digital inequality and recognize the nuanced, uneven experiences of students across different institutions and communities (Liebenberg et al., 2012).

The educational implications of these disparities are significant. Multimodal pedagogies offer a promising response, allowing lectures to tap into the diverse resources that students bring with them and to create more inclusive learning environments (Archer, 2016). At the same time, there is a growing recognition of the need for curricula to incorporate digital competencies to better prepare students for the evolving demands of the digital age (Shibambu & Mojapelo, 2024). Although the challenges remain considerable, there are ongoing efforts

through policy, pedagogy, and institutional reform to bridge digital gaps and promote greater equity in South African higher education.

2.3 Theoretical framework

The study employs the Community of Inquiry (CoI) framework developed by Garrison, Anderson, and Archer (2000). This model guides the design of effective online and blended learning environments by emphasizing the interplay of three core elements: cognitive presence, social presence, and teaching presence. Below on figure 1 is the Community of Inquiry framework diagram that illustrates the interrelatedness of the three elements of the framework.

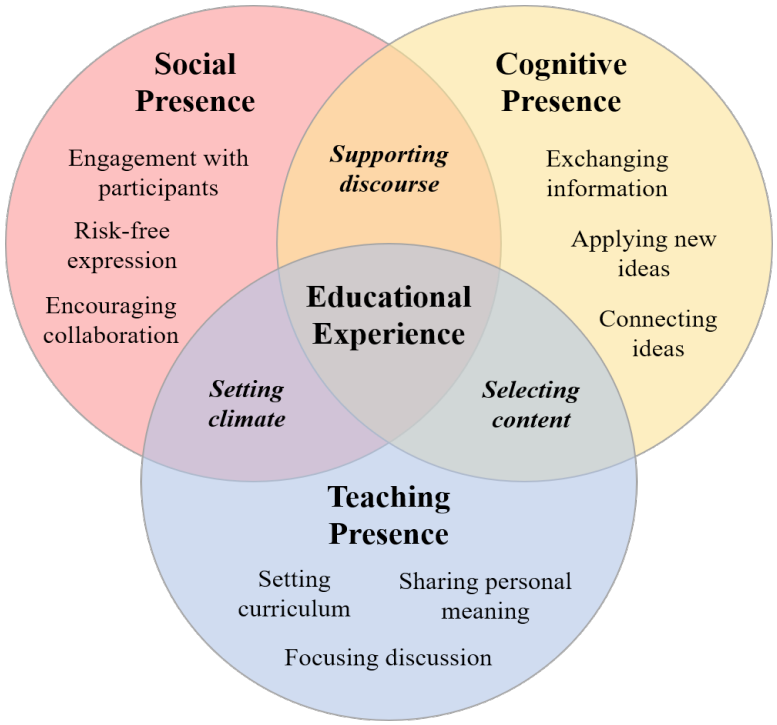


Figure 1: Community of Inquiry framework.

The framework looks at three key areas: cognitive presence (how students make sense of the content), social presence (how students connect with others), and teaching presence (how lecturers guide the learning process). The study explores how well these areas are working on Blackboard and what can be improved. The aim is to help the university make better decisions about how to use Blackboard in ways that support all students, especially those with limited digital access or learning support.

3. Methodology

3.1 Research Design

The parallel mixed-methods design was employed in the study to effectively capture undergraduate students' perceptions, engagement levels, and barriers to using Blackboard. In this approach, quantitative data was collected through structured surveys, allowing for statistical analysis of students' usage patterns, satisfaction levels, and technical challenges. At the same time, qualitative data was gathered using open-ended survey questions, providing deeper insight into students' personal experiences and contextual factors influencing their use of the LMS. The data from both strands were collected independently but analyzed together to draw comprehensive conclusions. As Hashemi et al (2013) highlight, this concurrent design ensured that both numeric trends and individual voices were equally considered. The combination of closed- and open-ended items strengthened the study's validity, offering both breadth and depth in understanding students' interactions with Blackboard. This design is particularly useful in educational research where multiple forms of evidence enrich interpretation and application (Mislevy,, Behrens, Dicerbo,& Levy, 2012).

3.2 Sampling

In this study, one academic bootcamp was conducted for the faculty of Social Sciences first year students in UFH. The bootcamp aimed to support students' transition into university learning by covering key academic and digital skills, including a dedicated session on digital literacy, which focused on effective use of Blackboard and other

online learning tools. It is mandatory for all students to attend from the faculty of Social Sciences. Following the academic boot camp, a questionnaire was distributed to the students through Google forms to collect their responses and perceptive. Out of 650 students who attended the bootcamp, 276 students completed and submitted the questionnaire. This resulted in a response rate of approximately 42%. The collected responses were then used to anaylse the effectiveness of Blackboard in promoting inclusive and engaging learning experiences at the university.

3.3 Data Collection

In this study, the data collection process used both quantitative and qualitative methods to capture a comprehensive set of responses from participants. Quantitative data were gathered through numerical responses, which involved the use of surveys with closed- ended questions and rating scales. This type of data provides measurable results that facilitate the identification of trends, patterns, and correlations within the dataset.

In addition, qualitative data was collected through narrative responses, which involved open ended questions with prompts that encouraged participants. This approach captures the experiences, opinions, and insights offering context and elaborating beyond numerical scores. Participants shared their personal reflections on the effectiveness of Blackboard in promoting inclusive and engaging learning.

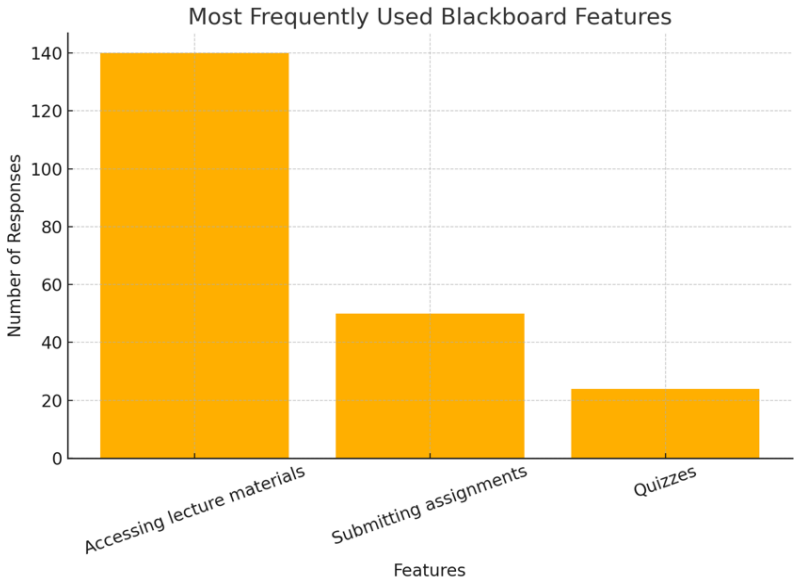
3.4 Data Analysis

The analysis is structured using the Community of Inquiry (CoI) framework, which evaluates the learning environment through three key presences: Cognitive, Social, and Teaching. The goal is to identify strengths and areas of improvement in Blackboard usage to support all students, especially those with limited digital access or learning support.

4. Results and Discussion

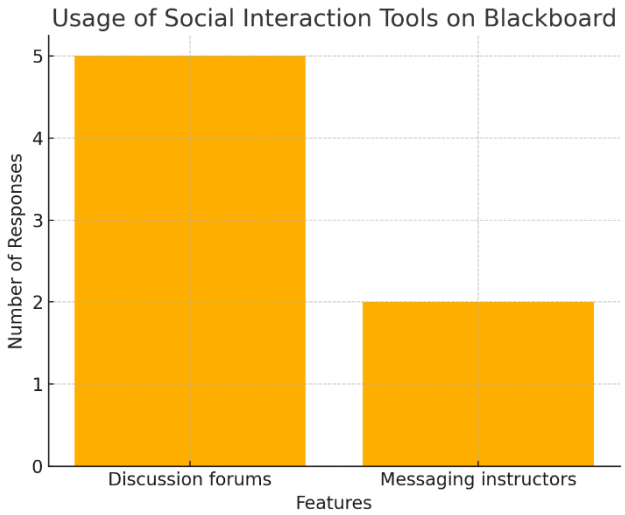
4.1 Cognitive Presence Analysis

Cognitive presence refers to the extent to which students can construct and confirm meaning through sustained reflection and discourse. Within the Blackboard learning environment, it is demonstrated by how students engage with academic content, particularly in ways that support understanding, inquiry, and knowledge building. Based on the survey data, the most frequently used feature was accessing lecture materials, which received the highest number of responses (140), indicating its central role in students' use of the platform. This was followed by submitting assignments, with 50 responses, highlighting its importance in managing coursework. Quizzes were also commonly utilized, with 24 responses, suggesting that they are a valued tool for assessment and engagement in the learning process. These findings indicate that students are consistently using Blackboard to engage in academic activities that foster independent learning and understanding of course content. The high usage of content delivery and assessment features shows that students are utilizing Blackboard not just for administrative tasks but as a core component of their academic learning.



4.2 Social Presence Analysis

Social presence involves the ability of students to project themselves socially and emotionally within a digital learning environment. In the context of Blackboard, this presence is fostered through tools that enable interaction, collaboration, and communication among students and lecturers. Based on the survey data collected, discussion forums were used by only 5 respondents, indicating limited engagement with peer-to-peer interaction features. Similarly, messaging lecturers was the least utilized feature, with only 2 respondents reporting its use, suggesting minimal direct communication between students and lecturers through the platform. These low usage numbers suggest that Blackboard's interactive features are underutilized for fostering community and connection. This minimal engagement indicates a gap in peer-to-peer and student instructor interaction, which can negatively impact students' sense of belonging and engagement. There is a clear need for targeted interventions to encourage and support meaningful online interactions through these tools to build a more connected and supportive learning community.

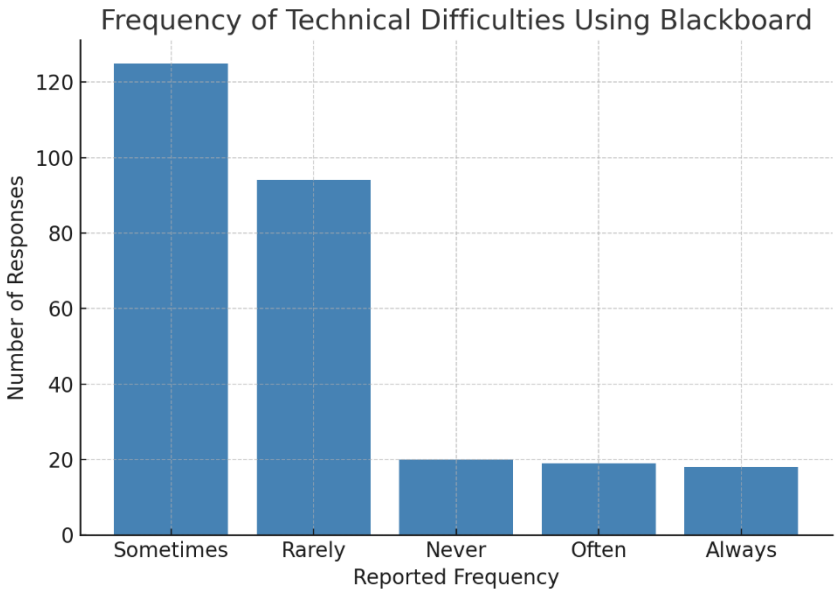


4.3 Teaching Presence Analysis

Teaching presence refers to the design, facilitation, and direction of cognitive and social processes to realize meaningful learning outcomes. Within the Blackboard platform, teaching presence is reflected in how well the platform is structured, how clearly course instructions are communicated, and the degree to which lecturers guide and support students through their learning journey. Based on the survey results, students expressed a high level of satisfaction with their learning experience, as reflected in the following, the average score for confidence in using Blackboard for academic activities was approximately 4.1 out of 5. The average score for ease of navigation on the platform was approximately 4.2 out of 5. These results suggest that the instructional design within Blackboard is generally well executed. The high ease of use scores implies that course structures, learning paths, and access to academic resources are automatically laid out. Similarly, the high confidence levels indicate that students feel adequately prepared and supported when engaging with Blackboard’s academic tools.

4.4 Barriers and Challenges

Technical difficulties emerged as a significant barrier to effective engagement with the Blackboard platform. When asked about the frequency of these issues, most students indicated they experienced them sometimes (19% responses), followed by rarely (14% responses), suggesting that while not constant, technical problems were a recurring concern. A smaller number of students reported never encountering issues (20), while others experienced them more frequently, with often (19) and always (18) responses, highlighting that for a subset of students, technical challenges were persistent and potentially disruptive. This distribution shows that while a considerable number of students face occasional issues, technical barriers are a consistent concern for a large portion of users. Such interruptions can affect students’ ability to attend classes, complete assessments, or access materials on time Open-ended responses revealed specific challenges such as poor internet connectivity, difficulty logging into the system, and problems with accessing or submitting online tests. These technical limitations disproportionately affect students with limited digital infrastructure and undermine the overall effectiveness of Blackboard as a learning tool.



5. Conclusion

This study has demonstrated that Blackboard plays an important role in enhancing access to learning content and promoting independent academic engagement among students at the University of Fort Hare. Guided by the Community of Inquiry (CoI) framework, the research revealed strong cognitive and teaching presences on the platform, particularly in terms of content accessibility, assignment submission, and course navigation. However, social presence remains significantly underdeveloped, with limited use of discussion forums and communication tools, thereby weakening the potential for peer collaboration and community building. Challenges such as inconsistent digital literacy, unreliable internet access, and technical glitches disproportionately affect students from disadvantaged backgrounds, undermining the inclusive potential of Blackboard. While training interventions such as bootcamps and the support of TeL Assistants have begun to address these gaps, sustained institutional efforts are needed to optimize Blackboard's pedagogical impact. Ultimately, the findings emphasize the importance of responsive digital learning environments that are not only technologically functional but also pedagogically inclusive. Addressing the structural and technical barriers identified in this study will be crucial to ensuring that Blackboard truly supports diverse learning needs and contributes meaningfully to equitable and transformative higher education in South Africa.

6. Recommendation

Based on the study's findings, it is recommended that the University of Fort Hare strengthen digital literacy support for both students and lecturers through continuous training and expanded access to TeL Assistants. Greater emphasis should be placed on enhancing social presence by encouraging the use of interactive features such as discussion forums and peer collaboration tools within Blackboard. To improve accessibility and user experience, the university should address technical issues related to platform reliability and ensure offline or low-bandwidth alternatives for students with limited connectivity. Furthermore, institutional policies should prioritize digital inclusion by aligning resources toward device provision, internet access, and pedagogical innovation. Ongoing monitoring and student feedback mechanisms are essential to ensure that Blackboard continues to meet the diverse and evolving needs of the student body.

Ethics Declaration

This research was carried out in line with established ethical standards and institutional protocols governing studies involving human participants. Approval for the study was granted by the Inter-Faculty Human Research Ethics Committee (Reference Number: IFHREC-25/08/0008). Participants were provided with full information regarding the study's purpose and procedures, and their voluntary involvement was obtained through signed informed consent. Measures were taken to safeguard participants' privacy, confidentiality, and anonymity, with all data managed in accordance with relevant data protection requirements.

AI Declaration

This paper was prepared with the assistance of artificial intelligence tools, namely ChatGPT (OpenAI), which was used to improve language clarity and support the development and refinement of ideas during the writing

process. The author remains fully responsible for all critical analysis, content decisions, and the overall structure of the work. The use of AI was conducted in alignment with relevant ethical and institutional guidelines.

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PhD Research Papers

Affective Artificial Intelligence in E-Learning: Towards Emotion-Aware Educational Technologies for Mental Wellbeing and Inclusion

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Abstract: Emotion-aware technologies are increasingly shaping the future of digital education. This study explores the potential of affective artificial intelligence (AI) to recognize and respond to learners' emotional states in online learning environments. While such systems promise more inclusive, supportive, and responsive digital classrooms, their design in addition raises important ethical and psychosocial concerns. Drawing from affective computing, digital empathy, and inclusive pedagogy, this conceptual study examines how AI can be used not only to monitor engagement however in addition to promote emotional wellbeing and learner autonomy, especially for students at risk of emotional distress, disconnection, or exclusion. Through analysis of existing technologies and case-informed reflections, the paper identifies both the opportunities and the limitations of affective systems in e-learning. A preliminary framework for ethically aligned emotional AI is proposed, emphasizing transparency, user agency, and safeguards against bias and manipulation. These insights aim to inform educators, designers, and policymakers working toward more humane, equitable, and emotionally intelligent uses of AI in lifelong learning.

1. Introduction

Artificial intelligence (AI) is changing the way we design, access, and experience education. One of the most fascinating and in addition controversial, developments in this space is affective computing: technology that can sense and respond to human emotions. In digital learning environments, this has given rise to emotion-aware systems that aim to make learning more personalized, engaging, and emotionally supportive. (European Commission, 2017; Cummings, 2018; Picard, 1997; D'Mello and Graesser, 2015).

But while the possibilities are exciting, they in addition come with important questions. Can a system truly understand how a learner feels? What happens when students are emotionally profiled, tracked, or nudged based on their data? And how can we make sure that emotional information is used in ways that support, rather than harm, those who may already be struggling? (Zuboff, 2019; Floridi and Cowls, 2019; Cheong, 2024; Koene et al., 2021).

This study takes a closer look at these issues by focusing on affective AI in e-learning. The goal is to understand how these technologies might help or hurt learners, especially those who feel emotionally disconnected or isolated. Special attention is given to students who experience stress, disengagement, or who are neurodivergent and may express emotions differently.

By offering a conceptual framework and reflecting on real-world cases, this study contributes to the growing conversation about how AI can be used in education with care and responsibility. It suggests that emotion-aware technologies shouldn't just make learning smarter, they should in addition make it kinder and more human.

2. Theoretical Background

The integration of affective computing into digital education is shaped by ideas and approaches from several fields, including artificial intelligence, psychology, pedagogy, and ethics. This section outlines the core concepts that support the development of emotion-aware learning environments, with a particular focus on digital empathy, learner diversity, and bioethical concerns.

2.1 Affective Computing and Emotion-Aware AI

Existing work on affect-aware learning technologies is increasingly complemented by studies that explore multi-modal sensing and adaptive feedback in real-world learning contexts. Recent research shows how emotion recognition can be integrated into robotic tutoring or multi-agent environments to enhance engagement and personalization (Fung et al., 2025). At the same time, emerging literature on accountability in AI stresses that affective systems need to be evaluated not only for their technical accuracy but also for their transparency and

responsibility toward learners (Nove, Taddeo and Floridi, 2023). In line with this, Seremeti (2023) emphasizes that affective educational technologies must be interpreted through socio-cultural lenses, cautioning against the adoption of universal models of emotional expression that ignore contextual diversity. These developments highlight that affective computing in education is no longer limited to theoretical exploration but is gradually entering applied pedagogical settings, accompanied by pressing ethical debates.

2.2 Digital Empathy in Online Learning

In addition to traditional concerns around the authenticity of empathy in human–computer interaction, new perspectives have linked digital empathy to issues of children's rights, psychological safety, and the socio-emotional climate of online classrooms. For example, Risser and Bottoms (2020) argue that the use of emotion-recognition AI in contexts involving young or vulnerable learners requires careful safeguards to avoid exploitation or undue influence. More recent dialogic approaches suggest that empathy-driven systems can play a constructive role when designed to enhance mutual understanding rather than to simulate care superficially (Slade, Prinsloo and Khalil, 2019). Complementing these perspectives, Anastasiadou et al. (2022) stress that educational applications of affective AI must be aligned with learner autonomy, ensuring that emotional nudges do not compromise the integrity of pedagogical relationships.

2.3 Inclusion and Neurodiversity in E-Learning

International frameworks have increasingly emphasized the importance of inclusion when deploying AI in education. The UNESCO report on AI and inclusion (2022) stresses that emotion-aware systems must be aligned with principles of equity and non-discrimination, ensuring that neurodiverse learners or those from underrepresented cultural backgrounds are not misclassified. Greek research has similarly highlighted these risks: Souravlas et al. (2021) show how algorithmic personalization may unintentionally reinforce bias in digital platforms, while Robertson and Ne'eman (2008) warn that rigid affective models' risk pathologizing neurodiverse emotional expressions. Together, these insights underscore the need for inclusive design principles that recognize diversity rather than impose uniformity

2.4 Ethical Frameworks and Bio-Psycho-Social Implications

A bioethical lens reminds us that emotions are not merely data points to be captured, but are deeply personal and connected to identity, privacy, and trust. As Anastasiadou et al. (2024) argue, it is crucial to balance technological innovation with care and respect for learners' emotional integrity. At the same time, the ethical discourse around affective AI has intensified in recent years with the publication of the European Union's AI Act and parallel critiques of its limitations. Wachter (2024) identifies significant loopholes in the legislation that directly affect how emotional data may be collected, processed, and governed. Similarly, Robles and Mallinson (2023) highlight the lack of cohesion in global AI governance frameworks, underlining the risk that affective systems may advance faster than regulatory mechanisms. Building on these debates, Kontis et al. (2025) introduce the concept of legal entropy to describe the uncertainty and fluidity of AI regulation, an idea with particular resonance for emotion-aware systems where ethical and legal boundaries remain unsettled.

2.5 Cultural and Socio-Psychological Perspectives on Affective AI

Cultural background, social context, and lived experience all shape how people express and interpret emotions, and these dimensions strongly influence the design and application of affective AI in education. Seremeti (2023) highlights the risks of adopting universal emotion models that disregard cultural diversity, calling instead for culturally sensitive approaches to affective modelling. This concern is echoed in work by Anastasiadou et al. (2022), who underline the ethical risks of using AI to "read" emotions without safeguarding learner autonomy. Building on these perspectives, Souravlas et al. (2021) show how algorithmic personalization can unintentionally reinforce bias in digital platforms, further illustrating the dangers of misclassifying emotional behaviour. More recent European research situates affective AI within wider socio-cultural and workforce transformations: Kalogera et al. (2025) link emotional dimensions of technology to the emerging notion of a "digital DNA" shaping modern labour markets, while Anastasiadou (2026) applies advanced statistical techniques to explore ethical perceptions of AI in educational contexts. Complementing these analyses, Kontis et al. (2025) introduce the concept of legal entropy to capture the uncertainty and fluidity of the regulatory environment in which affective educational technologies operate. Taken together, these contributions underscore that emotion-aware systems

cannot be reduced to technical artefacts; they must be understood as phenomena embedded in cultural, social, and ethical contexts that shape both their potential and their risks.

3. Methodology

The study is based on a structured review of the literature, combined with a thematic analysis of the material identified. The purpose of this approach was to develop a comprehensive and conceptually robust account of how emotion-aware artificial intelligence is being explored in educational contexts, while at the same time ensuring that the process of selecting and interpreting studies was systematic and transparent.

The search drew on major academic databases, including Scopus, Web of Science, IEEE Xplore, ERIC, and Google Scholar, and covered publications from 2010 to 2025. A set of targeted keyword combinations guided the process, with terms relating to affective computing, learning analytics, digital empathy, inclusion, and neurodiversity. To capture influential contributions that might not emerge directly from database searches, additional sources were located through citation tracking of seminal works in the field.

The studies retained for analysis were those that connected artificial intelligence with affective or emotional aspects of education, either through empirical investigations, conceptual models, or ethical and policy discussions. Purely technical articles without educational relevance and non-English texts were not included. After initial screening, the material was gradually refined to a core body of work that could support a deeper analysis. A flow diagram is provided to illustrate the selection path from the initial pool of results to the final dataset.

The corpus was examined through thematic analysis following established qualitative research practice. In line with Braun and Clarke's well-recognized framework (2006, 2019), this process involved a gradual progression from familiarization with the material to the generation of initial codes, the search and refinement of candidate themes, and the definition and naming of thematic categories. The analysis converged around three broad dimensions: the technological capacities of emotion-aware systems, their pedagogical and psychosocial implications, and the ethical or inclusion-related challenges they pose. These dimensions were subsequently aligned with the guiding research objectives of the paper, forming the basis for the synthesis and framework presented in the following sections.

4. Findings and Discussion

Since this paper does not include original empirical data, the findings are based on a combination of literature analysis, conceptual synthesis, and reflection on existing use cases. Three main insights emerge from this process: (1) the emotional gap in online learning, (2) the dual-use dilemma of affective AI, and (3) the need for ethically grounded and inclusive design.

4.1 The Emotional Gap in Digital Learning

Even though e-learning technologies have grown rapidly in recent years, most of them remain emotionally neutral, they aren't designed to recognize or respond to how learners feel. This lack of emotional awareness can make learning feel distant or disconnected. It may in addition lead to frustration, mental fatigue, and even isolation (D'Mello and Graesser, 2015; Wegerif, 2020).

Emotion-aware systems are seen as a potential solution to this problem. By using tools like facial expression analysis, tone of voice, or physiological sensors, these systems try to "read" the learner's emotional state and respond accordingly. But in practice, such tools are still rare in mainstream education, mainly because of technical limitations and concerns about privacy, ethics, and pedagogy.

4.2 The Dual-Use Dilemma of Affective AI

Affective AI holds great promise, but it in addition comes with risks. On one hand, it can help educators better understand students, support their wellbeing, and make learning more empathetic. On the other hand, it can easily be misused. Systems that collect emotional data might be used to monitor, categorize, or even manipulate students (Zuboff, 2019; Cowie et al., 2013).

There's in addition the risk of bias. Many affective systems are trained on emotional expressions that reflect dominant cultural norms. This means they might misinterpret or mislabel emotions that don't "fit the model", especially in the case of neurodiverse learners (Robertson and Ne'eman, 2008). In an educational setting, this

can have serious consequences: students may be nudged in certain directions, or misunderstood, based on faulty assumptions about what they feel.

4.3 Towards Inclusive and Ethically Aligned Design

Designing affective AI for education means shifting the focus from simply predicting emotions to genuinely caring about how learners feel and respond. This requires systems that recognize emotional diversity, respect learner autonomy, and include safeguards grounded in bioethics (Anastasiadou et al., 2024; Seremeti, 2023).

Emotion-sensitive technologies must be transparent, respectful, and flexible, especially when used with students who are neurodivergent, emotionally vulnerable, or experiencing digital overload. They should support learners, not control them.

Ongoing European discussions, such as the AI Act and UNESCO's AI ethics framework, stress the importance of emotionally intelligent systems that enhance human decision-making rather than replace it. These systems should include clear mechanisms for consent, transparency, and emotional data governance (Souravlas et al., 2021).

To synthesize the thematic findings presented above and link them explicitly to the research objectives of the study, Table 1 provides an overview of how objectives, identified themes, key insights, and indicative references are aligned.

Table 1: Mapping of Research Objectives, Themes, Key Insights and References

Research Objective	Themes Identified	Key Insights	Indicative References
Explore the theoretical foundations of affective AI and its potential role in online education	**The Emotional Gap in Digital Learning**	Most current e-learning systems remain emotionally neutral; this lack of affective responsiveness contributes to frustration, disengagement, and isolation.	D'Mello & Graesser (2015); Wegerif (2020); Fung et al. (2025)
Examine how emotion-aware systems are currently applied	**The Dual-Use Dilemma of Affective AI**	Affective technologies can both enhance empathy and wellbeing or lead to manipulation, profiling, and bias, especially when trained on narrow cultural or neurotypical models.	Zuboff (2019); Robertson & Ne'eman (2008); Seremeti (2023)
Highlight key ethical, psychosocial, and inclusion-related challenges	**Towards Inclusive and Ethically Aligned Design**	Emotion-sensitive systems must respect learner autonomy, safeguard diversity, and embed transparency and accountability. Ethical risks intensify with weak regulation and uncertain legal boundaries.	Floridi & Cowls (2019); Wachter (2024); Anastasiadou et al. (2022); Kontis et al. (2025)
Suggest a practical framework for responsible integration	**Human-Centered Framework for Affective AI**	Four guiding pillars emerge: Emotional Transparency, Learner Autonomy, Cultural/Neurodiversity Sensitivity, and Ethical Oversight. These provide a foundation for future pilot studies in professional and lifelong learning.	Anastasiadou (2026); UNESCO (2022); Souravlas et al. (2021); Kalogera et al. (2025)

Towards a Human-Centered Framework

Building on the discussion above, this study proposes a preliminary framework for the responsible use of affective AI in education. The framework is structured around four guiding pillars (Floridi and Cowls, 2019; Robertson and Ne'eman, 2008; Anastasiadou, 2026):

- Emotional Transparency

Learners should always be clearly informed about what emotional data is collected and how it is being used.

- Learner Autonomy

Emotional nudging or manipulation must be avoided; learners' freedom of choice should remain intact.

- Cultural and Neurodiversity Sensitivity

Systems should respect diversity in emotional expression and avoid enforcing a single emotional model as a standard.

- Ethical Oversight

Institutions bear the responsibility to ensure affective data is collected, interpreted, and applied with accountability and fairness.

This framework provides a foundation for future pilot studies, particularly in lifelong learning programs designed to promote emotional wellbeing, such as initiatives in maternal digital care and professional upskilling.

5. Ethical Declaration

This research did not involve direct experimentation with human participants. It is based solely on secondary sources, published case studies, and conceptual analysis. No personal or biometric data were collected, stored, or processed in the preparation of this paper.

All ethical considerations were guided by European and institutional frameworks on AI in education and digital wellbeing. Any future empirical applications of the proposed framework will be subject to formal ethics review and informed consent procedures.

6. Conflict of Interest Statement

The author declares no conflict of interest regarding the content, funding, or institutional affiliations of this paper. The research was conducted independently as part of an ongoing PhD project and does not reflect the views of any commercial or political entity.

7. Conclusion

Integrating affective artificial intelligence into digital education opens promising opportunities, but it also raises critical concerns. Emotion-aware systems have the potential to enhance student engagement, foster inclusion, and support emotional wellbeing. This is especially valuable for learners who may feel isolated or overwhelmed in online environments where human presence is limited (Robertson and Ne'eman, 2008; Risser and Bottoms, 2020; Whittlestone et al., 2019; Kontis et al., 2025).

At the same time, the use of emotional data in education must be approached with caution. Risks such as emotional profiling, biased interpretations, or loss of learner agency cannot be overlooked. As this study has shown, there is a clear need for frameworks that place ethics, empathy, and inclusion at the center of design.

The reflections presented here are part of an ongoing PhD project. The next step will be to pilot the proposed framework in real-world educational settings, particularly in professional training and digital care. The ultimate goal is not only to design smarter systems, but to build thoughtful systems that support, rather than replace, the emotional connection between people and learning.

AI Declaration

No generative artificial intelligence (AI) or automated tools were used in the creation of the content of this paper. Any assistance with spelling, grammar, or formatting was conducted using standard software tools, and the intellectual content is entirely the responsibility of the authors.

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Digital Formative Assessment and Motivation in Initial Teacher Education: Findings from the REFRESH Project

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Abstract: This study investigates the potential of digitally mediated formative assessment to influence the performance motivation of higher vocational school students preparing for the teaching profession in pre-school and after-school education. The research is carried out within the framework of doctoral studies at the Faculty of Education of the University of Ostrava and linked to the REFRESH - Centre for Research on Energy and Social Change project (CZ.10.03.01/00/22_003/0000048). The research population consisted of 136 students from four classes. Three groups were taught using digital formative tools (Microsoft Forms, Mentimeter, self-assessment forms, peer feedback), while the control group was taught in a traditional way. Achievement motivation was assessed using the School Performance Motivation Questionnaire (Hrabal & Pavelková, 2011), which takes into account the tendency to succeed (NFA) and the avoidance of failure (NAF). The results show an increase in NfA and a decrease in NAF for students involved in formative assessment. There was also a shift in the typology of performance motivation towards a performance-oriented type. These findings confirm the findings of previous studies on the benefits of formative assessment in developing student motivation (Black & Wiliam, 2009; Brophy, 2004) and underscore the importance of feedback and active student engagement in the professional preparation of teachers. The findings offer actionable insights for educators, researchers, and educational policy makers seeking to develop technology-supported feedback environments in teacher preparation.

Keywords: Formative Assessment, Digital Feedback Tools, Pre-service Teacher Education, Achievement Motivation, Vocational Education, Educational Technology, REFRESH Project

1. Introduction

Contemporary vocational education faces the challenge of effectively supporting not only the development of professional knowledge, but also students' motivation to learn, self-regulation and career orientation. Particularly in the preparation of future pre-school and after-school teachers, it is crucial to foster performance motivation, which significantly influences their attitudes towards learning and subsequent teaching practice (Eccles & Wigfield, 2002).

One promising tool for the development of intrinsic motivation is formative assessment, which in recent years has been profiled as a key component of modern teaching. In the literature, it is understood as a process of collecting, interpreting and using information about student progress in order to adjust teaching and support learning (Black & Wiliam, 2009). The introduction of digital technologies into this process brings new opportunities for interactivity, personalisation and immediate feedback (Carless & Boud, 2018; Nicol, 2020).

Despite the growing interest in digital formative tools, the use of these approaches in vocational education, and especially in higher education settings, remains under-researched. Working with heterogeneous groups of students, some of whom come from socially disadvantaged backgrounds where performance motivation may be impaired by, for example, fear of failure or low self-concept, is also a specific challenge (Hrabal & Pavelková, 2011; Deci & Ryan, 2000).

This study responds to the aforementioned challenges and explores how digitally mediated formative assessment can influence the performance motivation of higher education students in the context of their career preparation. The research is carried out as part of a PhD study at the Faculty of Education, University of Ostrava and is linked to the REFRESH - Centre for Research on Energy and Social Change project, which involves the development of innovative educational strategies reflecting the needs of a changing society.

2. Research Design and Hypotheses

The aim of this study is to analyse the impact of digitally mediated formative feedback on the school performance motivation of higher education students in the context of vocational education. The research also focuses on a specific subgroup of students coming from a mining background in order to identify possible differences in the changes in their motivational characteristics.

2.1 Research Questions

1. What is the impact of formative assessment on changes in the performance motivation of students in vocational education?
2. Does students' performance motivation differ between groups with and without formative intervention?
3. What is the baseline typology of students' performance motivation and how does it change after the intervention?
4. Are there differences in performance motivation between students from mining backgrounds and others?

2.2 Hypotheses

- **H1:** Students in the experimental groups (classes A, B, 2nd year) will show a higher need for successful performance (NfA) and a lower need for avoiding failure (NAF) after the intervention than before the intervention.
- **H2:** Students in class C (no intervention) show no significant change in performance motivation.
- **H3:** The proportion of positive performance motivated types (Type 1) will be higher in the posttest for the experimental group than for the control group.
- **H4:** Students from mining backgrounds will have higher NAF and lower NfA than the others in the pretest, but their performance motivation will improve comparably or more than in the other students in the posttest.

3. Theoretical Background

Initial teacher education in vocational and technical schools represents a specific learning environment in which the key professional and learning competencies of future teachers are formed. This environment is influenced not only by curricular and institutional factors, but also by the personal characteristics of learners, especially their performance motivation. As stated by Näsström et al. (2021), motivation is an essential prerequisite for effective learning and formative assessment can contribute significantly to both behavioural engagement and the development of both autonomous and controlled components of learners' motivation.

Performance motivation, according to Hrabal and Pavelková (2011), is made up of two basic components - the need for successful performance (NfA) and the need to avoid failure (NAF). The ratio between these components influences how students approach challenging learning tasks and how they respond to assessment situations. When the NFA component predominates, the student tends to actively engage and overcome challenges, whereas the dominance of the NAF may lead to anxiety or avoidance behaviour.

In the context of Society 4.0, which emphasises digital competence, adaptability, reflectivity and autonomous decision-making, the form of assessment in education takes on a new dimension. Current conceptions of digital literacy include not only technical skills but also the ability to critically evaluate information, collaborate, share content and manage one's own learning (Ala-Mutka, 2011; Carretero et al., 2017). These skills are crucial in the use of digital formative feedback tools that can enhance learners' self-regulation and create space for a reflective approach to learning.

Formative assessment is defined in the literature as the process of continuously collecting and interpreting information about learners' progress in order to adjust instruction to benefit student learning (Black & Wiliam, 2009). This process can be teacher-driven or actively mediated by learners through self- or peer-assessment and feedback (Nicol & Macfarlane-Dick, 2006). The authors emphasize that the effectiveness of formative assessment increases with the degree of student involvement in clarifying learning goals, self-reflection, and understanding of performance criteria.

Palmberg et al. (2024, p. 4) state in their case study that, "Such comprehensive multi-approach formative assessment practices may consist of the teachers working with the students to attain a shared understanding of the learning goals [...] and the teachers supporting the students in carrying out peer-assessment and [...] self-assessment." In their research, the combination of multiple approaches proved to be an effective way of activating learning motivation and promoting a deeper understanding of the curriculum.

The importance of this approach is also supported by a randomized study by Lichtenberger et al. (2025), who found that a combination of feedback, conceptual question work, and teacher reflection yielded significant

improvements in curricular understanding. The use of digital tools in this type of assessment contributes to greater interactivity and transparency of the whole learning process.

Muho and Taraj (2022) identified the most significant motivational effect for strategic questions asked by the teacher, followed by self-assessment, peer assessment and student portfolios. The results of their study show that the combination of different forms of formative assessment positively influences intrinsic motivation and active student engagement: "The factor that had the greatest impact on motivation for learning were strategic questions used by the teacher during formative assessment, followed by self-assessment, peer assessment and student's portfolios" (Muho & Taraj, 2022, p. 31).

All of these findings are consistent with the research focus of this study, which aims to investigate how digitally mediated formative feedback affects the performance motivation of college students preparing to become preservice and inservice teachers. Special attention is also paid to a subgroup of students from mining backgrounds, whose motivation is examined in relation to possible specificities of the socio-economic context. Thus, the study contributes to the discussion on the transformations of assessment in vocational education and its role in enhancing the career orientation and intrinsic motivation of future teachers.

Summarizing the theoretical underpinnings above, it can be concluded that formative assessment - especially in digital form - has the potential to support students' performance motivation through fostering a sense of competence, autonomy and meaningfulness (Deci & Ryan, 2000; Brophy, 2013; Nicol & Macfarlane-Dick, 2006). Effective feedback, active student involvement in assessment, and transparent criteria are factors that the authors suggest contribute to self-regulation and greater willingness to take risks in learning, which is particularly important for students with a tendency to avoid failure. Therefore, the research design of this study deliberately integrates these approaches to investigate whether the students experience a change in performance adjustment - in particular, a decrease in performance strain (NAF) and a shift towards a positive performance type (Type 1 according to Hrabal and Pavelková, 2011). Thus, the theoretical frameworks directly shape the research assumptions and provide the interpretive basis for subsequent analysis of the results.

4. Methodology

The research was conducted at a Czech higher vocational school within a three-year study programme aimed at preparing future teachers of pre-school and out-of-school pedagogy. The research population consisted of a total of 136 students from four classes: A (n = 37), B (n = 41), C (n = 29) and 2nd year (n = 26). Classes A and B were assigned to the experimental group, which received instruction with targeted use of formative assessment supported by digital tools. The intervention took place over the course of one academic year. Class C was defined as the control group and received instruction without intervention. The Year 2 class represented a special case as the formative approach had been applied to this group for two years. For this reason, it is analysed separately in the results section with emphasis on its long-term experience with formative strategies.

To measure performance motivation, the standardized diagnostic instrument "School Performance Motivation of Students" (Hrabal & Pavelková, 2011) was used. The questionnaire contains two scales - the need for successful performance (NfA) and the need to avoid failure (NAF). The resulting scores of both scales were converted into a five-point standardized scale, which allowed not only a quantitative comparison of baseline and outcome values, but also the classification of individual students into typological categories of performance motivation according to the authors of the instrument.

The formative intervention was integrated into regular teaching and included regular use of digital feedback tools, particularly Microsoft Forms and Mentimeter. These tools allowed to obtain up-to-date information on students' progress and to adapt the teaching to their needs. The intervention also included the use of self-assessment forms, peer assessment and targeted pedagogical interviews. The teacher set clear assessment criteria, defined deadlines for outcomes, and actively involved the students in the evaluation process. The teaching structure thus created space for reflection, development of self-regulation and strengthening of intrinsic motivation. The way digital tools were used was based, among other things, on international research confirming the benefits of immediate feedback for adaptive learning management (Näsström et al., 2021).

The control group received instruction without the use of digital tools and without targeted formative intervention. The assessment in this group was mainly implemented through traditional, summative methods. This contrast allowed for a comparison of differences in performance motivation between the groups exposed to formative intervention and the group exposed to the traditional approach.

Particular attention was paid to a subgroup of 18 students coming from families of mining industry employees (e.g. OKD and partner companies). These students were evenly distributed among the classes studied and their performance motivation was analysed separately. The aim of this analysis was to test whether digitally mediated formative assessment can be an effective tool also in socially disadvantaged groups.

The collected data was subjected to descriptive analysis, including the calculation of the mean values of the two dimensions studied. Subsequently, it was converted into standardized scores and individual students were classified into five types of performance motivation according to Hrabal and Pavelková. The results of the pretest and posttest were compared between the classes as well as between the experimental and control groups. Separately, the trajectory of performance motivation of students from mining backgrounds was also examined.

5. Results

5.1 Impact of Formative Assessment on the Students' Performance Motivation (RQ1, H1)

The results of the entry and exit measures show (see Table 1, Figure 1) that for the classes targeted by the formative intervention (Classes A, B and Year 2), there was an increase in the need for successful performance (NfA) and a concomitant decrease in the need to avoid failure (NAF). In Class A, there was a shift from a mixed type of performance motivation (Type C) to a clearly performance-oriented profile (Type A) (see Table 1). A similar trend was also evident fo students in Class B (see Table 1). For the students in the 2nd year, the values of the NfA remained relatively stable, but the NAF showed a slight decrease (see Table 1, Figure 2). In contrast, Class C, which served as the control group, showed a significant increase in NfA values at posttest (see Figure 1), but without a corresponding decrease in NAF (see Figure 2), which may indicate a one-sided shift without a comprehensive improvement in motivational profile. An overview comparison of the mean values for each class in the pretest and posttest is presented in Table 1. The observed values are further illustrated in the form of Figure 1, which shows the evolution of NfA over time and across classes.

Table 1 shows the evolution of the mean values of the need for successful performance (NfA) and the need to avoid failure (NAF) between pretest and posttest across the observed classes. Classes A, B, and year 2 underwent the formative intervention, while Class C served as the control group without intervention.

Table 1: Trends in the mean values of need for successful performance (NfA) and need to avoid failure (NAF)

Class	Stage	NfA(mean)	NAF (mean)
A	Pretest	21.53	21.02
A	Posttest	22.83	19.43
B	Pretest	21.51	20.60
B	Posttest	22.11	18.86
C	Pretest	20.40	21.62
C	Posttest	22.70	21.20
2nd year	Pretest	21.69	19.80
2nd year	Posttest	21.74	18.86

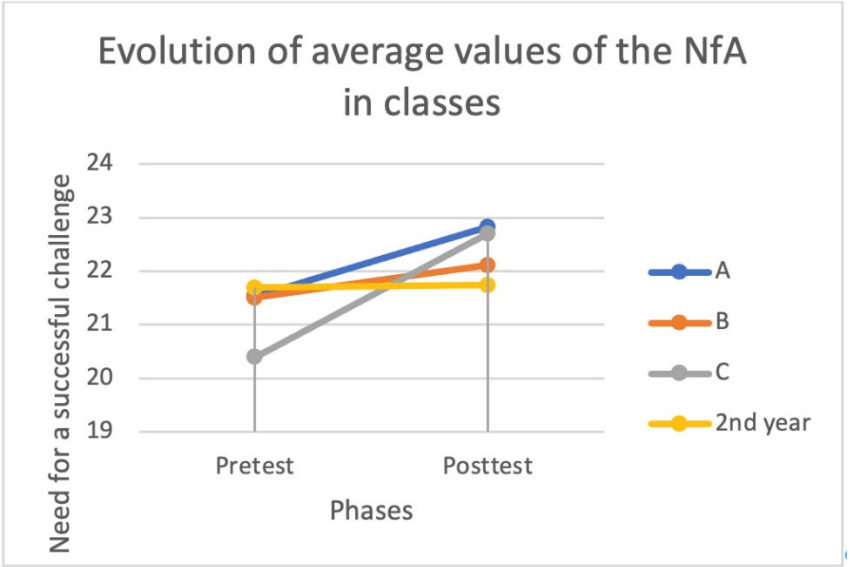


Figure 1: Evolution of average NfA values in classes

Source: own elaboration 2025

The evolution of the mean values of the need for successful performance (NfA) in the studied classes between pretest and posttest. The graph *shows* the change in the performance orientation of the students depending on the type of instruction. For classes A and B which were exposed to formative assessment, there was an increase in the values of NfA. In the 2nd year, where the intervention was applied for a long period of time, the NfA values remained stable. The significant increase in control class C (no intervention) is noteworthy and requires interpretation in a broader pedagogical context.

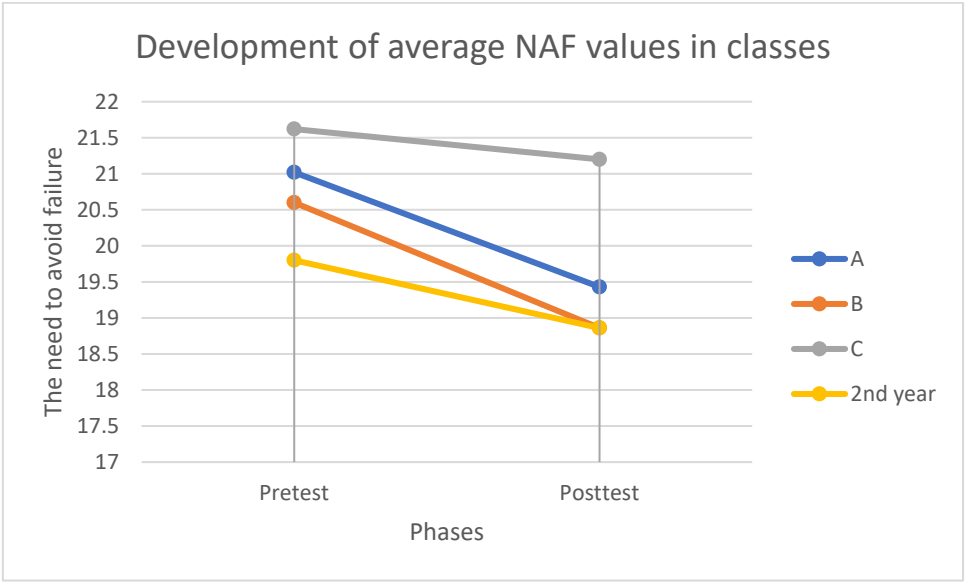


Figure 2: Evolution of average NAF values in the classes

Source: own elaboration 2025

Evolution of the mean values of the need to avoid failure (NAF) in the treatment classes between pretest and posttest. The graph shows the evolution of students' performance strain in relation to the application of the formative approach. The most significant decrease in NAF was observed in classes A and B, confirming the positive impact of regular feedback and active participation in the classroom. In Year 2, the decrease is moderate and may be related to the stabilisation of attitudes. For Class C, the change in NAF was minimal, which is consistent with the absence of intervention.

5.2 Typology of Performance Motivation According to Hrabal and Pavelková (RQ3, H3)

Based on the standardised scores, the students were classified into five typological categories of performance motivation according to Hrabal and Pavelková's (2011) model, which works with a combination of the need for successful performance (NfA) and the need to avoid failure (NAF) measures. The most represented type was Type 5 - undefined motivation, characterized by fluctuating or intermediate values of both dimensions. This type was identified in more than 70% of all students, indicating a predominant absence of a distinct performance focus in the baseline measure.

Following the implementation of the formative intervention, there was a significant shift towards a positive performance type (Type 1) in experimental classes A and B, confirming the effect of the digital feedback-based interventions. In contrast, in Class C, which was not exposed to the formative intervention, the motivational typology remained virtually unchanged. The distribution of the different types across the whole population is shown in Table 2 and visualized in Figure 3. A synthetic overview of these data is visualized in Figure 3.

Table 2 shows the distribution of the students according to Hrabal and Pavelková's typology of performance motivation. Type 5 - undefined motivation was the most frequent, while the positively performance-oriented Type 1 was the least represented.

Table 2: Distribution of types of performance motivation across the research population

Type	Description	Number of Students	Percentage (%)
1	High NfA, low NAF (Positive performance)	7	5.2 %
2	Low NfA, high NAF (Anxious type)	19	14.1 %
3	High NfA, high NAF (Conflict type)	5	3.7 %
4	Low NfA, low NAF (Unmotivated)	4	3.0 %
5	Medium/unstable values (Undifferentiated	100	74.1 %

Source: own elaboration 2025

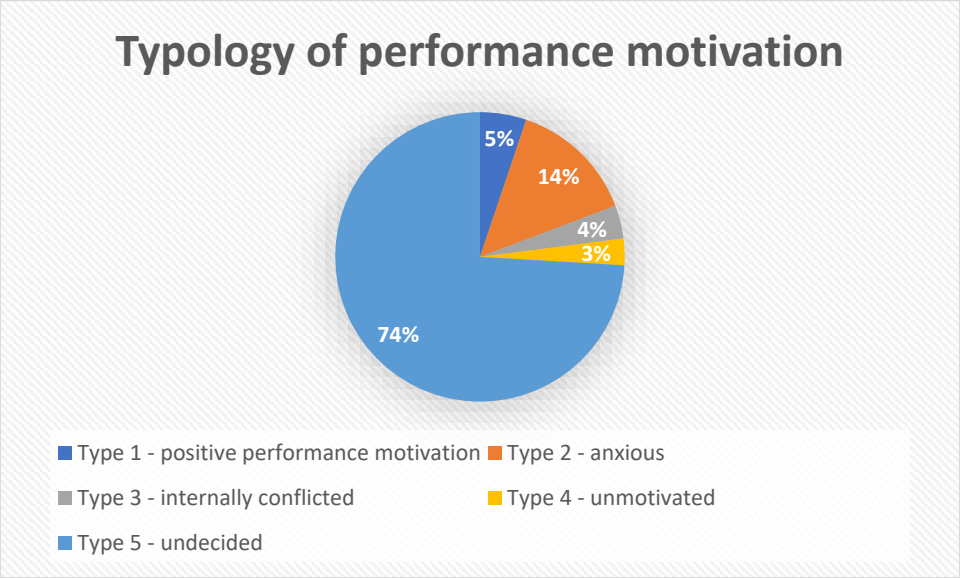


Figure 3: Typology of performance motivation according to Hrabal and Pavelková

Source: own elaboration 2025

Typology of performance motivation according to Hrabal and Pavelková - number of students by motivation types. The dominance of the undefined type (Type 5) confirms the need for systematic support of performance orientation in the educational process. The shift towards positive performance profiles (Type 1) after the intervention was observed mainly in the experimental classes.

5.3 Comparison of Groups with and without Intervention (RQ2, H2)

When comparing the performance motivation between the groups with the formative intervention and the group without intervention (Class C), it was found that although Class C showed a slight improvement in NfA values, the NAF remained almost unchanged. Typologically, this group continues to correspond to the mixed type (Type C). The results support hypothesis H2 that there was no significant change in performance motivation in the control group without intervention.

5.4 Performance Motivation of Students from Mining Backgrounds (RQ4, H4)

For the subgrouCp of 18 students coming from families of employees in the mining industry, a lower value of NfA (21.22) and a concomitantly increased value of NAF (21.16) were observed in the pretest, corresponding to increased performance strain and lower levels of self-confident achievement orientation. After the implementation of the intervention, an increase in NfA (22.88) and a concomitant slight increase in NAF (22.50) were noted (see Table 3). These results support hypothesis H4, which states that the performance motivation of this subgroup improved comparably or even more than that of the other students, although the increased performance strain persists.

Table 3 shows the evolution of the mean values of need for successful performance (NfA) and need to avoid failure (NAF) for the students from mining backgrounds between pretest and posttest. An increase in NfA indicates a positive impact of the intervention on performance ambition, although an increased NAF indicates persistent performance strain.

Table 3: Trends in the mean values of NfA and NAF for students from a mining background.

Phase	NfA (mean)	NAF (mean)
Pretest	21.22	21.16
Posttest	22.88	22.50

Source own elaboration 2025

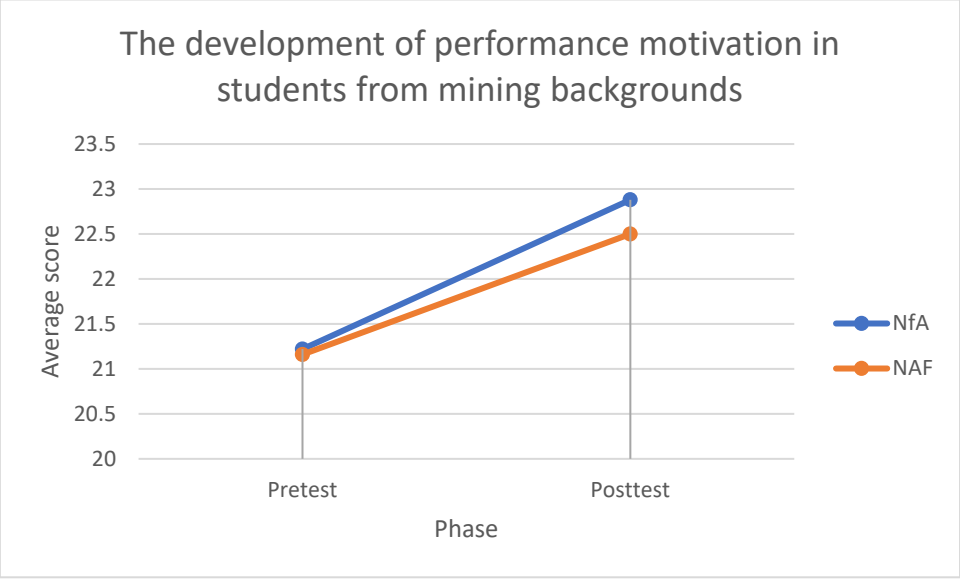


Figure 4: Development of performance motivation in students from mining background

Source own elaboration 2025

Development of performance motivation in students from mining background between pretest and posttest (see Table 3 and Figure 4). While the NfA shows a significant increase, the NAF values have slightly increased. The results suggest a positive impact of formative assessment on ambition even in the socially disadvantaged group, with increased strain persisting.

6. Discussion

The data obtained confirm that digitally mediated formative assessment is an effective tool for promoting students' performance motivation in vocational education. In the experimental groups, an increase in the need for successful performance (NfA) was observed along with a decrease in the need to avoid failure (NAF), which can be interpreted as a shift from passive to anxious motivation to autonomous performance settings. This development corresponds with Hrabal and Pavelková's (2011) model of performance motivation, who state that "performance motivation is not only a matter of ambition, but also of the balance between the expectation of success and the fear of failure" (p. 22).

Positive changes were also noted in the typology of executive motivation, as illustrated by the results in Table 2 and Figure 3. In the experimental classes, there was a shift away from the undefined and anxious types toward a positive performance orientation (see Table 2 and Figure 3). This result can be linked to the comprehensive implementation of a formative approach including feedback, self-assessment and clear assessment criteria. Nicol and Macfarlane-Dick (2006) emphasize that "feedback is effective when the student understands the learning objectives, has access to assessment standards, and is able to reflect on his or her performance against these benchmarks" (p. 205). In the control group, which received instruction in a traditional manner, the typological profile of performance motivation remained virtually unchanged, highlighting the limitations of a conventional instructional approach without formative assessment elements.

This development is consistent not only with Hrabal and Pavelková's (2011) model of performance motivation, but also with broader findings from research on motivation in education. Brophy (2004) highlights that motivation to learn is strongly influenced by whether the learning environment provides students with a sense of meaning, autonomy and competence. According to him, "students feel motivated if they believe they understand the expectations, are likely to succeed, and perceive the learning as valuable" (p. 20). It is the formative approach, which links feedback, self-assessment and transparent criteria, that creates such conditions and thus can fundamentally transform learning attitudes.

Specific attention was paid to a subgroup of students from families of employees in the mining industry. These students showed lower levels of performance ambition (NfA) and higher performance strain (NAF) in the pretest, which may be related to the overall setting of expectations and self-concept in the context of socioeconomic disadvantage. However, there was an increase in performance orientation following the implementation of digital feedback (see Figure 4), suggesting that a comprehensible and supportive learning environment can contribute significantly to performance confidence. According to Näsström et al. (2021), "formative assessment can promote behavioural engagement while stimulating both autonomous and controlled components of motivation" (p. 1). However, the persistence of higher NAF in this group also highlights the need for long-term and sensitive work with fear of failure and performance uncertainty.

The results of the study support the need to systematically incorporate formative assessment into vocational education. Formative strategies based on regular feedback, active student participation, and a transparent assessment structure are consistent with the principles as defined by Black and Wiliam (2009), who view formative assessment as "a process in which teachers and students use information about learning to modify teaching and learning" (p. 5). In our research, a combination of tools (e.g., Microsoft Forms, Mentimeter) and strategies (e.g., self-assessment, layered feedback) were implemented, which is consistent with the findings of Palmberg et al. (2024) who state that "comprehensive multi-approach formative assessment practices may consist of the teachers working with the students to attain a shared understanding of the learning goals, [...] and the teachers supporting the students in carrying out peer-assessment and [...] self-assessment" (p. 4).

This strategy is also consistent with the cyclical model of feedback as presented by Carless and Boud (2018), who suggest that "feedback is only meaningful if it stimulates student action" (p. 1313). Learning then becomes not a one-off response to assessment, but a continuous process of self-regulation and competence development.

The study's findings are also in line with the results of an intervention study by Lichtenberger et al. (2025), which shows that "the mere inclusion of conceptual questions is not enough; integration with other formative assessment strategies is key" (p. 27). It also points out that even short-term targeted professional learning for teachers can make a significant difference in the effectiveness of assessment and its impact on student achievement. These findings underscore the importance of professional preparation for future teachers specifically in the area of feedback and evidence-based decision making.

Other research (Boud & Molloy, 2013; Muho & Taraj, 2022) highlights the importance of combining different forms of formative assessment. Boud and Molloy (2013) state that "the effectiveness of feedback is contingent

on its active reception and integration into student learning behaviours" (p. 703). Based on a quantitative investigation, Muho and Taraj (2022) report that "the factor that had the greatest impact on motivation for learning were strategic questions used by the teacher during formative assessment, followed by self-assessment, peer assessment and student's portfolio" (p. 31).

Given that a significant portion of the research sample exhibited an undefined type of performance motivation, it seems appropriate to focus on individual work with students' motivational profiles in the future and to further develop differentiated formative assessment strategies in teacher training. Further research should explore the long-term effect of these approaches across educational contexts and analyse the influence of social and personal factors on the development of performance motivation**.**

7. Conclusion

The present study has demonstrated that the targeted use of digital formative assessment tools has a positive impact on student teachers' performance motivation in initial teacher education. The formative intervention led to an increase in performance ambition while contributing to a reduction in fear of failure. These changes are particularly important in the context of promoting self-regulation and an active approach to learning, which are key to the professional growth of future teachers.

A significant finding is the identification of the prevalence of the undefined motivational type in the pretest and its transformation towards positive performance profiles as a result of targeted formative interventions. Particular attention to students from mining backgrounds has shown that a supportive and comprehensible learning environment has the potential to compensate for initial disadvantages and contribute to increased self-confidence even in socially disadvantaged groups. Yet the results also highlight the need for long-term work to address performance strain, particularly in students at risk of academic failure.

The findings of the study support the broader thesis that digital formative assessment is not just an assessment tool, but a means of building autonomy, responsibility and a reflective relationship with learning. In pedagogical practice, the emphasis should be on systematically involving learners in the feedback process, on transparently setting assessment criteria and on promoting metacognitive strategies during the learning process. Experience gained during the teaching of vocational courses also shows that the meaningful use of digital applications (e.g. Microsoft Forms, Mentimeter, Nearpod, Canva) can increase not only the level of learners' active engagement, but also their ability to plan their own learning, assess progress and work with learning objectives.

Based on the findings, several recommendations for pedagogical practice can be formulated. The use of digital tools for regular feedback appears to be an effective means of developing performance motivation. Incorporating self- and peer-assessment into teaching should be considered as a standard part of a formative approach. Transparently establishing assessment criteria and structure early in the course helps to reduce performance uncertainty. Long-term work to address fears of failure is also important, particularly for students from higher-risk backgrounds. Individualising feedback and monitoring its impact on the development of performance motivation should be an integral part of the evaluation of teaching.

The findings can serve as inspiration for teachers, didacts and educational policy makers in designing inclusive, digitally supported learning environments aimed at developing students' motivation, self-regulation and career readiness in vocational education.

Ethics Declaration

This study did not require formal ethical approval. Participation was voluntary, data were anonymised, and no sensitive personal information was collected.

AI Declaration

AI tools (ChatGPT by OpenAI) were used to support language refinement and structure. All outputs were critically reviewed and edited by the author.

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Iva: A Playful Humanoid Robot with Educational Flare for Little Patients

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Abstract: Traditional child patient care needs human workers, who are limited due wage shortage and other factors. Using technologies such as robotics may be a viable alternative as a care assistant to improve child patients' wellbeing, especially when the UK government is encouraging robotics and artificial intelligence innovation. Literature found positive implications for the use of robotics for child patients, such as social humanoid robots providing emotional support and helping child patients reduce pain, which allows for more possibilities of using social humanoid robots to explore serving child patients. This research aims to develop an effective solution to entertain and comfort child patients who have been negatively impacted by the threatened and declining social care sector. The researchers introduced a new design of the robot - Iva: a playful humanoid robot with educational flare for little patients. Iva is based on the NAO robot's hardware and equipped with various sensors and abilities, such as tactile sensors, facial detection and speech and object recognition, enabling it to interact with children through interactive activities. Iva can perform conversation, games, shows, exercises and more activities, based on the thinking of the child patients' needs and preferences, forms of expression and programming workflow. The whole process emphasised user friendliness and ethical considerations, including data privacy and informed consent. The design, development and testing have been conducted in the novel EUREKA Tokku Zone to ensure ethical integrity. Preliminary testing in a laboratory setting shows all the functions of Iva work correctly for providing multiple interesting activities to let child patients play and relax. In terms of Iva's performance, she is a meaningful robot that contributes to a more positive and supportive environment for children during hospitalisation. Future work contains improvements of Iva's program for a more accessible experience, and the test in the real hospital setting within the Tokku Zones in Wales.

Keywords: Child Patients, Child-Robot Interaction, Hospital Robots, Healthcare Robot, Social Robots, Robot Programming

1. Introduction and Background

In recent years, the use of robotics in healthcare and social environments has grown steadily, with humanoid robots becoming more common in roles that support interaction, learning, and new types of user experiences (Broadbent, Stafford and MacDonald, 2009; Belpaeme et al., 2018). These technologies can offer fresh ways to share information, promote engagement, and encourage participation especially in situations where more traditional approaches may not be as effective or appealing (Mubin et al., 2013). One such example is Iva, a humanoid robot designed with a playful and educational approach, created to offer engaging and accessible social experiences. Aimed at a wide range of users, including young adults, Iva provides a unique platform for informal learning and interaction (Tanaka and Matsuzoe, 2012). While interest in social robots continues to expand, there is still relatively little research on how people respond to these technologies and how well they can support meaningful engagement (De Graaf, Allouch and Klamer, 2015). This study looks at how users initially react to Iva, with a focus on their sense of engagement, perceived usefulness, and the potential value of the robot in informal educational settings.

1.1 Research Aim and Objectives

This research aims to create a supportive and enjoyable way to entertain and comfort child patients, particularly those affected by the strain on the social care sector. This research has the following objectives:

- Build rationale and gauge a deeper understanding of the robotic intervention to yield appropriate methods to entertain and educate child patients.
- Plan and delegate tasks and workflow effectively based on the functions and methods to be used in this research.
- Design, implement and test the program of the robot.
- Summarise findings and reflections and conclude the work.

1.2 Traditional Care Situations for Child Patients

Child patients are traditionally entertained and comforted by social care workers, who have had their sector under impact for decades. A 2019 UNISON conference claimed that "A decade of austerity has ravaged social care", reporting that its workforce is "almost universally underpaid, largely undervalued and often exposed to exploitation" (UNISON, 2019). Thomas et al. (2025) showed that the nursing shortages are becoming a serious problem in the UK. As of September 2023, there was a shortage of 42,000 social care workers in the UK's National Health Service (NHS) (Bazeer, Kelly and Buchan, 2024). With the waiting lists reaching a record 4.46M as of November 2020 and almost 200,000 patients having to wait longer than 52 weeks for routine treatment (Perry, 2021). Focus is being drifted elsewhere than on the entertainment and comfort of child patients, care that is a part of an already struggling sector, comes as no surprise. McLaughlin et al. (2024) got the result that the salary is the most important factor for child and family social workers to work on this, while England is facing labour shortages in social work for children and families. From this, it is evident that there is an urgent need for greater solutions than the traditional method to protect the well-being of child patients now more than ever, which has prompted the perfect opportunity for robotic intervention.

1.3 How Robots Help with Child Patients

Robotics and Artificial Intelligence (AI) are becoming more advanced and helping in healthcare scenarios, especially for elderly people and children (Carpenter, Sharma and Sengupta, 2024). The 2019 Remote Applications in Challenging Environments (RACE) report unveiled the recent change in perception and openness to investment in robotics. The report claims a lack of robotic investment has even been "acknowledged by the UK Government in their Made Smarter Review and the next few years will see significant investment in robotics" (Department for International Trade, 2019). The UK Research and Innovation (UKRI) invests and supports robotics and AI, partnered with the Engineering and Physical Sciences Research Council (EPSRC), illustrating great opportunity to develop solutions whilst backed by government funding and the UKRI Challenge Fund has provided £45.5 million to support hubs in robotics and AI (UKRI, 2025). Or, Ng and Goh (2025) described that the social robots are doing great work on reducing children's pressure and anxiety in hospitals when they are undergoing medical procedures. These robots can be programmed to perform actions and interact with children. To deepen understanding of the international horizon, existing solutions with use cases relative to this project's research problem have been analysed below. Robin is a humanoid robot which can give lovely facial expressions (Paplu et al., 2023). Robin was piloted at three Armenian hospitals to over 100 children with a self-report questionnaire finding that "joyfulness" was increased by more than 26% whilst stress was reduced by 34% (Kart, 2020), indicating strong positive reception. MEDi is a humanoid robot helping children in hospitals (Onuoha et al., 2024), created and programmed on a SoftBank NAO robot (SoftBank Robotics, 2021). MEDi can be programmed to teach child patients (Lee-Krueger et al., 2021) and reduce children's pain and fear (Farrier, Pearson and Beran, 2020). Nishat et al. (2025) used the same type of the robot to entertain children before doing surgeries. This showed these kinds of robots can reduce children's pain in hospitals. In Dubai, researchers also showed these robots can entertain children (United Arab Emirates University, 2022). Alhashmi et al. (2021) found that Students felt comfortable interacting with the robot and wanted the robot for fun activities. Huggable is a robot which can be hugged, as its name and was developed by the Massachusetts Institute of Technology (MIT). It was piloted at Boston Children's Hospital, improving the experience of the hospital and addressing child patients' emotional needs (Logan et al., 2019). Akiyoshi et al. (2024) built an autonomous dialogue system using the hug functions and showed that it can reduce people's negative thoughts. Humanoids UK Government consulted the national experts to produce the Rapid Technology Assessment guide for trends, risks and future directions for researchers to address the current gaps (UK Government, 2025).

2. Methods

2.1 Design and Development Approach

This study reports the design and development of Iva: A Playful Humanoid Robot with Educational Flare for Little Patients, implemented on the NAO humanoid platform (Aldebaran Robotics, NAO V5 Blue) using the Choregraphe environment (version 2.1). No child participants were involved; the system was prepared for future deployment with trained healthcare staff to facilitate interactions for paediatric patients, aligning with best practices in child–robot interaction design (Belpaeme et al., 2018; Robinson et al., 2021).

2.2 Technical Implementation and Internal Testing

Interaction behaviours, walking, dancing, a flag card game, stretching, and push-ups, were scripted using Choregraphe's visual programming, with sensor inputs (touch, vision, audio) enabling responsive engagement. Safety parameters were configured to ensure compliance with environment constraints (e.g., joint limits, movement speeds), in line with recommendations for social robots in healthcare (Broadbent et al., 2009). Internal functional testing by the research team verified reliability, timing, and speech accuracy, following an iterative debugging cycle as described in human–robot interaction prototyping literature (Kanda and Ishiguro, 2013).

2.3 Workflow Documentation and Planned Evaluation

The workflow was broken down into stages, illustrated in Figure 1. Figures 2 and 3 show the interaction flow and sensor-based functions, respectively. Future evaluation will be conducted with healthcare staff in clinical environments, following institutional ethics approval, to assess operational usability and integration into care routines (Wang et al., 2017).

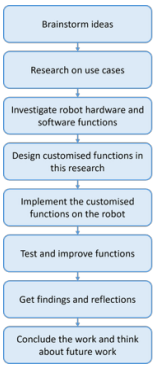


Figure 1: The workflow diagram showing the workflow in the research

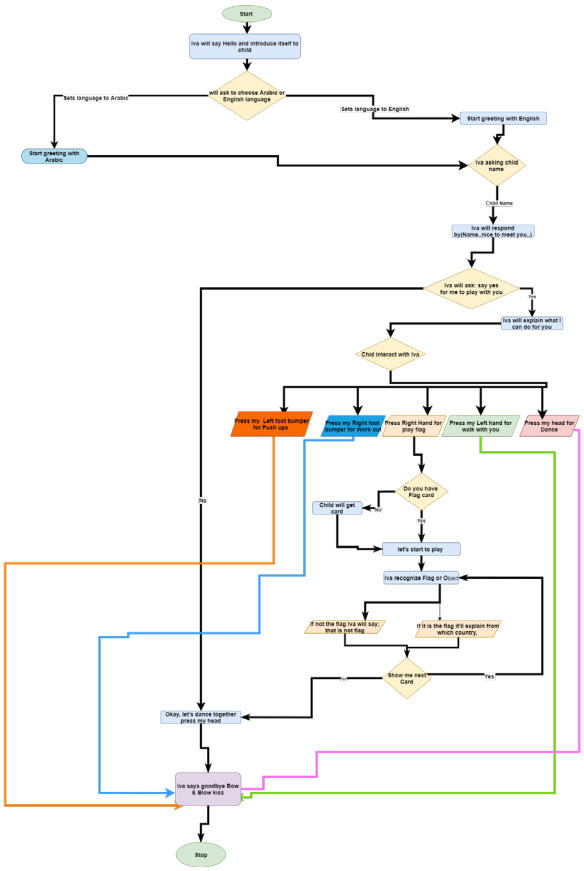


Figure 2: Iva's program flow and interactions with child patients

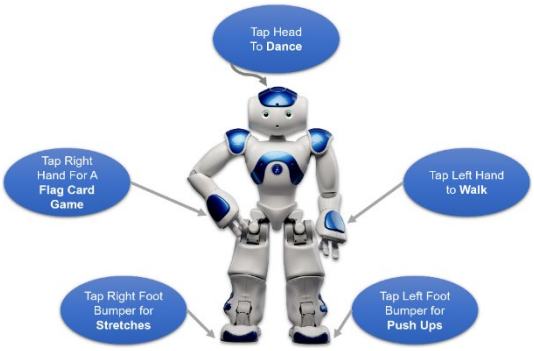


Figure 3: Iva's sensors used in the project

2.4 Ethical Concerns

Emotional child safety is important to maintain. As customised texts can be put into Iva's program, the languages Iva speaks need to be ensured not to upset or threaten users, especially when interacting with child patients. Children may be anxious or sensitive when talking about certain themes. Ensuring that no offensive words or actions are performed by Iva is important, especially since different social and cultural backgrounds need to be considered. These words and actions also need to suit children's ages and reduce the potential for misinterpretation.

The 'Three Laws of Robotics' (Asimov, 1942) was considered along with advice delegated by leading UK university roboticist professors as procured by the UKRI (EPSRC, 2021). One ethical consideration made, which also ties in with legality, is privacy. Privacy would need to be ensured, especially with regards to data retention and facial detection to enable GDPR compliance, privacy of the users and prevent third-party misuse, which would be of most importance, being that the users of Iva are primarily children. The Tokku Zone was introduced for balancing innovation with safety, ethical and legal issues (Hu and Chew, 2024). In EUREKA Robotics Centre, there is EUREKA Tokku RT Zone as one of the Tokku Zones, providing highly ethical concerns and protections when working on this research.

3. Design and Implementation

To provide functions to children, the software, Choregraphe, is used for programming Iva. Iva is supported in programming with Python. Python can give more options in programming and make it more flexible, however, Choregraphe provides rapid development and easier enhancement when discussing with users. Figure 4 shows the whole program of Iva. There are different sections, A to G, in the program that show different functions within the whole Iva's abilities.

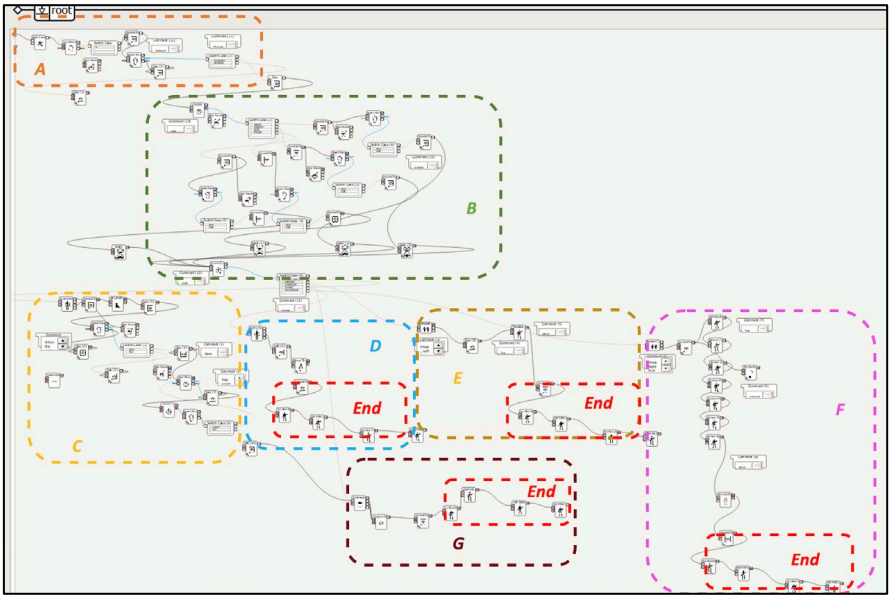


Figure 4: The program of Iva in Choregraphe with sections marked from A to G

Figure 5 shows the details of sequence A, which is the startup of the whole program and executed when a user comes into Iva's recognition range. Facial and speech recognition are used as triggers. The introduction begins when an unmasked face appears in front of Iva, using Iva's awareness of users with her animated eyes, which have LED colours that change, and the movement of head and arms, which make Iva more realistic. There are two languages provided, which lets users choose between English and Arabic and use Iva's speech recognition when talking to Iva and to get responses.

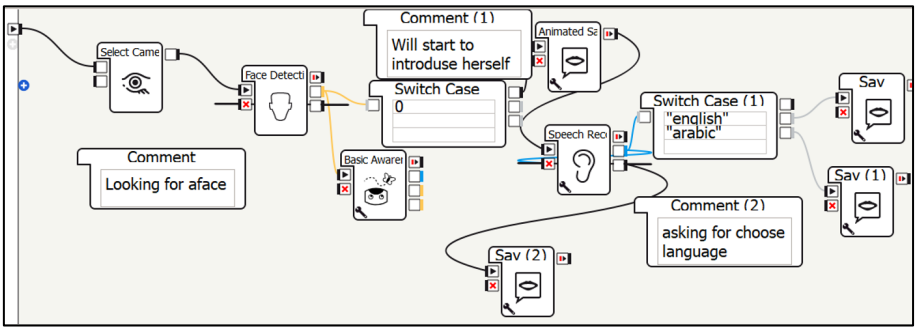


Figure 5: Choregraphe Sequence A – Introduction

Figure 6 shows the details of sequence B, which is the introductory sequence. It begins once the user chooses one of the languages. Iva will ask for the user's name at first and offer different functions to see what the user would like to do. If the user responds "yes" to Iva, Iva will speak to list the functions she can offer and introduce how the user can operate her. For the functions, the user can tap Iva's head to let her dance, hold her left hand to let her walk, hold the right hand for playing the card game together, push the left foot for push-ups, and push the right foot for stretches.

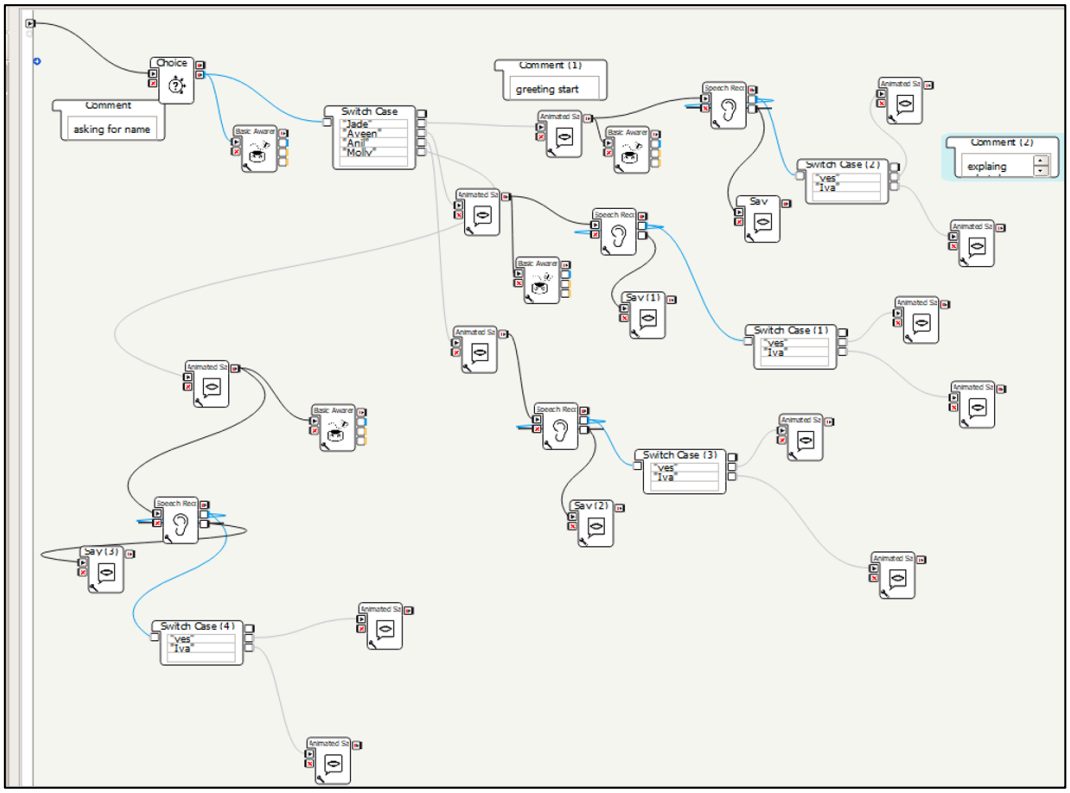


Figure 6: Choregraphe Sequence B – Introductory Sequence

Figure 7 describes the sequence C, the card game using Iva's tactile sensor, speech and vision. The card game only starts after the user pushes the right foot to confirm that the user wants to play with Iva. First, Iva will ask if the user has a card. After the user says "yes", Iva will let the user show a card to her. She uses visual recognition to see the colours and patterns on the flag and tries to check which country or region it stands for. Once determined, she will say the result and ask for another flag card if you have one.

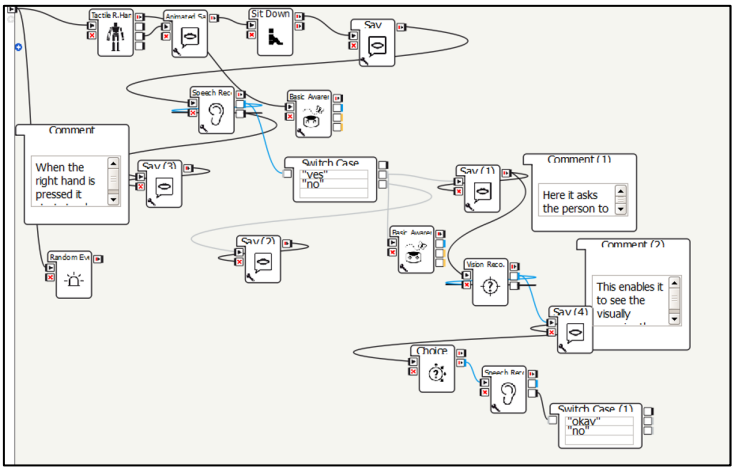


Figure 7: Choregraphe Sequence C – Card Game

Figure 8 is the sequence D for walking. It starts when the user holds Iva's left hand. Iva will respond and start walking on the floor.

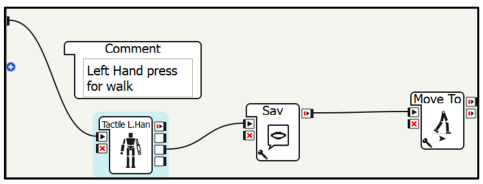


Figure 8: Choregraphe Sequence D – Walking

Figure 9 shows the sequence E for push-ups. When the left tactile sensor detects it being pushed, Iva will say a short speech and then start to do the push-up. She will finish and stop after a few seconds.

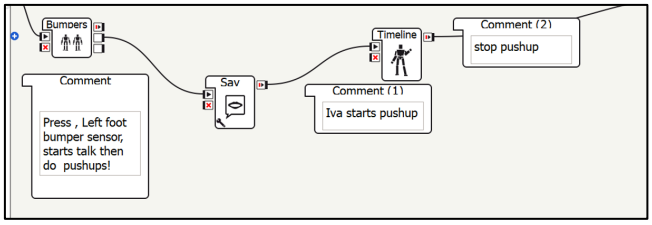


Figure 9: Choregraphe Sequence E – Push-up

Figure 10 shows the details in sequence F, which are the slow stretches that Iva does. When the right tactile sensor detects a push, Iva will do some slow stretches. The music will be played during the stretches, and the user can follow these actions together with Iva.

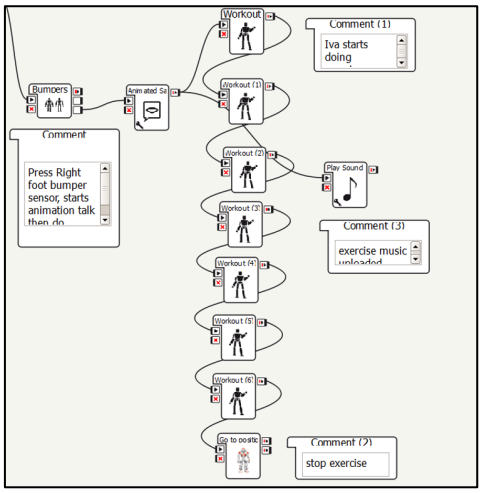


Figure 10: Choregraphe Sequence F – Slow Stretches

Figure 11 shows the details of sequence G, dancing. When the user taps Iva's head, she will dance, which will show different kinds of actions for each part of the body. The song Gangnam Style by Psy is chosen for its popular, upbeat, and all-ages rhythm that bring joy to the children.

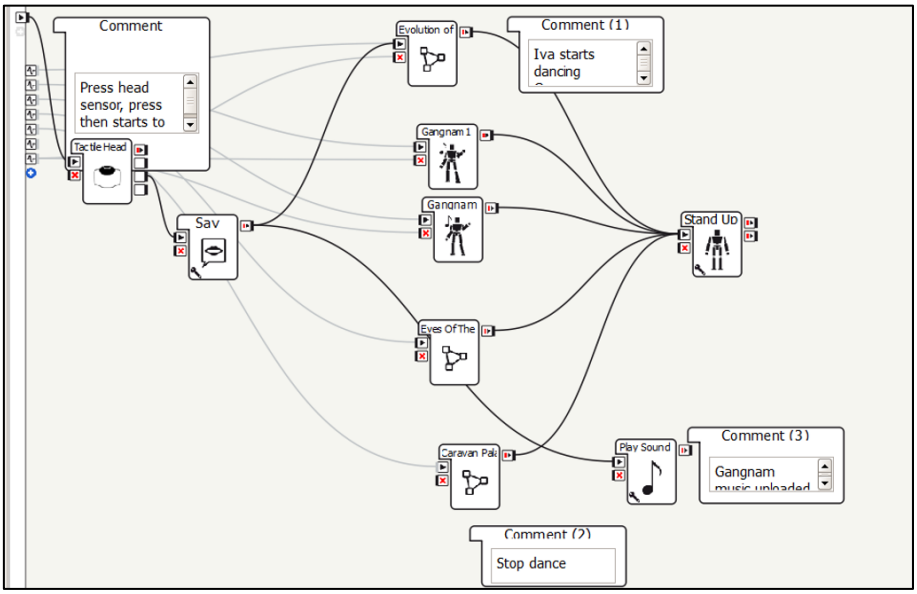


Figure 11: Choregraphe Sequence G – Dancing

Figure 12 is one of the "end" sequences, which are located at the end of sequences D, E, F and G. In these sections, Iva will say goodbye to the user and offer well wishes. These are designed to let the user not be pressured to keep interacting with Iva if they have had enough.

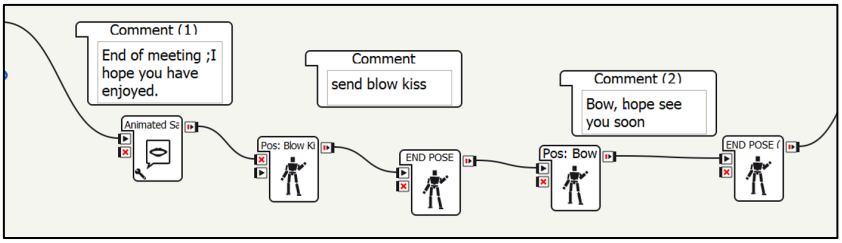


Figure 12: Choregraphe Sequence "End" – Saying Goodbye

4. Findings

This preliminary study explored the use of Iva, a playful humanoid robot, to support social interaction and engagement among young adults. Participants, aged 18 to 22, took part in individual sessions within the EUREKA Tokku RT Zone.

4.1 Observed Engagement with Iva's Activities

Participants engaged with Iva through a range of interactive activities, including simple conversations, a flag card game, walking, dancing, and light stretching exercises. Overall, engagement levels were positive, with most participants showing sustained interest. Three out of Four completed all activities without requiring prompts, and four expressed verbal feedback such as "interesting", "fun", or "novel" suggesting a generally favourable experience.

4.2 Initial Hesitancy and the Role of Playfulness

Four participants initially showed signs of hesitation, such as minimal speech or reserved body language. However, their level of engagement noticeably increased once Iva initiated the dancing activity, which involved upbeat music and expressive movements. This shift highlights the potential of playful design features to act as effective icebreakers, helping to ease initial reluctance and promote interaction. Figure 13 shows how people talk with Iva using Iva's speaking and hearing functions. Figure 14 indicates three of the different ways to let people enter, confirm or make decisions on Iva's functions using Iva's sensors. Iva can do card picture recognition and respond fast when people show different cards to Iva (as Figure 15). Figure 16 shows Iva dancing and doing push-ups performing actions vividly and sympathetically.



Figure 13: A user talking with Iva

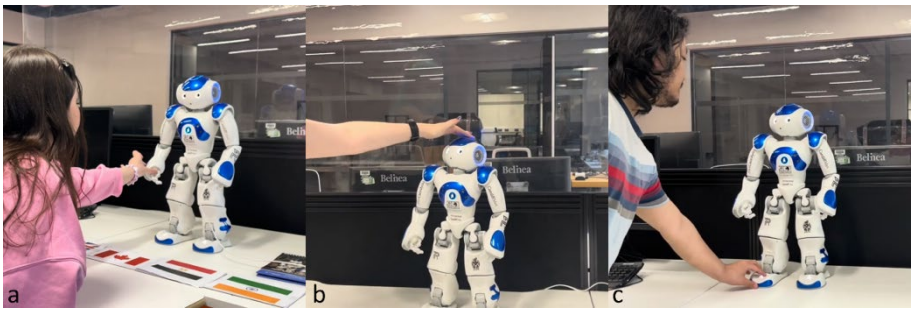


Figure 14: A user giving command to Iva using sensors – (a) hand touching, (b) head touching, (c) foot bumper pressing



Figure 15: Iva recognising cards with the country's flags on them during the card game - Learning National Flags

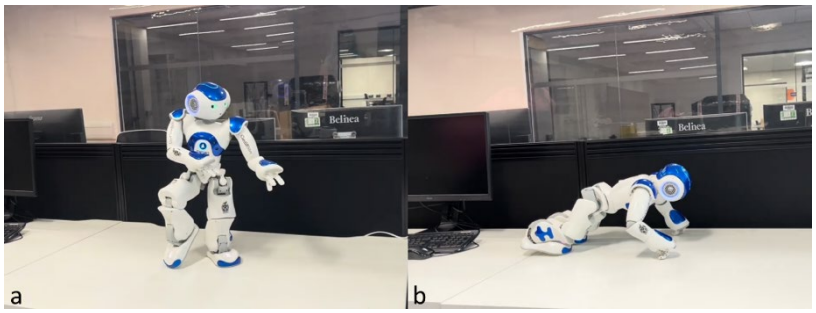


Figure 16: Iva (a) dancing and (b) pushing-up - Learning a dance and exercises

4.3 Accessibility and Comfort with Interaction

Iva has friendly and easy-to-use interactions that children can understand and interact with. As an example, a child who just had a shoulder surgery cannot do push-ups but can play card games with Iva or enjoy her dancing. Although all participants interacted with Iva in English, there were variations in their comfort levels during the early stages of the session. Some appeared more confident than others in responding to Iva's prompts, but overall, participants adapted quickly and were able to follow the activities with minimal difficulty. This suggests that Iva's design and language use were generally accessible to this age group.

4.4 Challenges in Card Game Interaction

The research has a very physical, hands-on nature, which brought some difficulties when programming and testing Iva. While the flag card game was generally well received, two participants had difficulty understanding Iva's initial instructions and required clarification. In most instances, the robot's visual recognition system performed reliably, with an estimated accuracy rate of 90%. However, occasional delays in processing disrupted the flow of the interaction and slightly impacted the overall experience.

4.5 Qualitative Feedback and Anecdotal Observations

Informal feedback from participants was mostly positive. One participant described the interaction as “a unique experience” and found Iva “quite interesting”. While anecdotal, comments like these offer insights into how humanoid robots may provide novel and engaging social encounters for young adults.

4.6 Reflections

In critical reflection, the Arabic language in Iva was limited, while the development and testing were conducted in the UK, Arabic or more languages can be extended in Iva in further support. In the UK, there are also some foreigners who speak English as a second or third language. In most cases, it is better to let Iva speak in the user’s native language. Letting Iva chat and perform in multiple languages will make more people feel more comfortable, especially for child patients. This can help some nervous child patients feel more at home as well if Iva, a robot companion, speaks their home language. When Iva asks a question, it would be more accessible to let the user choose from more options. If Iva asks a question that only supports a yes or no response, the user cannot get accurate feedback at every time. Allowing a non-verbal response can make users more comfort to talk with Iva. In other cases, for someone who is finding it difficult to speak, such as a patient with difficulty or just has had a surgery, giving Iva more ways to get feedback and communicate, such as nodding or shaking head, can let the user to interact with her easier. This can put more attention on letting the user experience Iva’s activities and company without worrying about speech or more control. In this case, the game Iva offers can also be enhanced. Iva’s card game does not require speaking, except when asking if the user wants to play. However, the user is required to hold up cards to interact with her in the game. This can sometimes be more common as most of the users are child patients in the hospital. It is difficult for those who have limited mobility in their arms. Providing alternative ways to entertain users, such as getting Iva to tell jokes to amuse users or play verbal games, would allow more people to enjoy Iva’s functions and abilities.

Lighting can interfere with facial recognition. While attempting object and facial recognition, sometimes it was difficult to keep the robot focused on the user or presented objects. This was due to the robot focusing on bright lights, which in part interfered with its ability to visualise the users’ eyes as well. This issue was mitigated through experimenting with different lighting for different use cases.

4.7 Limitations

The study took place in a controlled laboratory setting, which does not fully reflect real-world social contexts. Additionally, the small sample size limits how widely the findings can be applied. The absence of a control group also makes it difficult to determine whether any changes in engagement were directly caused by interacting with Iva. Another limitation was the difficulty interpreting accents, speech impediments, or quiet voices. This impacted engagement with Iva.

5. Future Work and Conclusions

Based on the findings, building multiple languages will significantly improve the user experience and let more users enjoy Iva around the world. This can be simply worked on and tested within the research in the future. An improved game can also be redesigned to enhance the accessibility and experiences of users who have difficulties. After testing Iva in the lab, a more realistic test, such as letting child patients use Iva in a hospital, is planned in the future. Currently, we have developed Tokku Zones in Cardiff and Vale Health Board in Wales. These can be the places for deploying and testing Iva to provide relevant real-life integration feedback from child patients, patients or medical staff. More users’ data and feedback can be used to improve and modify Iva’s current functions and experiences and create new thoughts and ideas. Moreover, with the use of Iva in the hospital, more functions for patient care rather than entertainment and education, such as fall detection or management for some cases, can be integrated into such a practical robot-like Iva (Wei et al., 2023).

Through the research and investigation of the status of traditional child patient care and theory, and the use of robots in healthcare scenarios, it is important to enhance the child patients’ experience. Research shows that robot assistants like Iva are invaluable in care facilities and hospitals, within the lab-controlled environment and demo in hospitals. From 2025-2028, Iva will be integrated into the paediatrics department for field evaluation. It is expected that Iva will give companionship to children, staff of various ages and offer distraction from a stressful environment in the hospitals. We have designed Iva for child patients to play and be educated by designing and implementing friendly and interesting conversations, actions, interactions and games, which provide different ways to improve children’s experiences when they spend time in hospital. A variety of sensors were used when programming Iva, including but not limited to camera (vision), microphone (listening), speaker (speech), tactile

sensors (interactive touches) and motion sensors. This allowed children of various ages to be able to interact with Iva, test Iva in EUREKA Tokku RT Zone in Wales, in an ethically and legally protected. We would propose that Iva is a caring assistant who works as a companion in hospitals, assisting children with patient enhancement experiences, fun educational interaction during the long wait, and distraction procedures in the healthcare assessment and treatment.

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Ethics Declaration

This preliminary study received ethical approval from the Cardiff Metropolitan University Ethics Committee before it began, ensuring all research procedures met institutional ethical standards. This study did not involve any human participants, including children, and no data was collected from individuals during this phase.

AI Declaration

The researchers declare that they did not use AI in any aspect of the writing of this paper.

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Appendices

Iva's programme files running on Choreographe software and codes for Python used in this research: https://github.com/AveenNajm/Iva-Humanoid-Robot

AI-Integrated Instructional Design to Enhance AI Literacy Among Pre-Service Teachers

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Abstract: The growing integration of artificial intelligence (AI) into educational tools and practices has made AI literacy an increasingly critical competency in teacher education. Pre-service teachers must be equipped to use AI both comprehensively and effectively. This study aimed (1) to explore pre-service teachers' experiences and needs related to AI in education and (2) to design and develop an AI-integrated instructional design (ID) model to enhance AI literacy. A quantitative survey was conducted using a questionnaire administered to 1,673 pre-service teachers in Thailand. A pilot test was first conducted with 30 students, and the reliability of the instrument was assessed using Cronbach's alpha. The results indicated high reliability across all items, including perceptions of AI, perceived impacts of AI, motivation to use AI, and the current learning ecosystems. No significant differences were found between STEM and non-STEM groups across these dimensions, suggesting a common need for AI training. Key training needs included (1) learning activities such as information searching, brainstorming, and discussion; (2) resources such as selected websites/blogs and online MOOC platforms; and (3) preferred instructional media, including interactive quizzes, gamified platforms, and learning management systems. Based on these findings, an ID research approach was employed to develop the AI-integrated ID framework. The initial framework was validated through an expert review by five specialists in educational technology. Grounded in design-based learning principles, the resulting framework comprises seven components: (1) Acquiring Key Contents, (2) Requirements Focus, (3) Trial Initiatives, (4) Embedding Co-Creation, (5) Manufacturing the Artifact, (6) Inspecting Results, and (7) Synthesizing Reflection. The findings provide an adaptable framework for embedding AI literacy in the teacher education curriculum and redesigning courses accordingly. The framework also highlights co-creation and design thinking as effective strategies for AI-integrated pedagogy, offering valuable insights for educators and curriculum designers seeking to enhance AI-related teaching competencies.

Keywords: Higher Education; Teacher Education; Pre-Service Teachers; AI Literacy; Instructional Design

1. Introduction

Artificial Intelligence (AI) is increasingly recognized as a transformative force in education, driving innovations such as personalized learning and data-driven assessment (Markauskaite et al., 2022). This growing influence necessitates that teachers be adequately prepared to integrate AI into their pedagogical practices. Globally, educators and policymakers have stressed that AI literacy among teachers must encompass not only technical knowledge but also the ethical, social, and cultural dimensions of AI (Ng et al., 2023). Such a comprehensive understanding enables teachers to employ AI tools to enhance student learning outcomes. Accordingly, numerous studies have emphasized the need for teacher education programs to embed AI training into curricula, thereby equipping future teachers to effectively harness AI technologies in the classroom (Sperling et al., 2024).

Pre-service teachers, as future AI-competent educators, require targeted preparation to develop AI-related competencies within educational contexts. However, many current teacher candidates remain underprepared; most lack a foundational understanding of how AI functions and, consequently, are unable to use it effectively in pedagogical settings (Du et al., 2024). Research on the integration of AI in teacher education is still emerging, yet early findings suggest that many educators experience anxiety about AI's complexity, which leads to reluctance in adopting AI tools (Du et al., 2024). In Thailand, where digital transformation is a national priority, a recent study found that teachers' AI literacy remains moderate: while many educators acknowledge AI's potential benefits, they lack the proficiency to apply AI meaningfully in practice (Chakamanont & Thabmali, 2025). This underscores a research gap in AI-focused training within Thai pre-service teacher education programs.

Addressing this need requires an instructional design (ID) approach that actively fosters AI literacy. Design-based learning (DBL) is an active learning strategy that engages learners in iterative, hands-on design processes, allowing for a deeper understanding of technological concepts (Amplo & Butler, 2023). Grounding teacher training in DBL principles may help pre-service teachers learn about AI by collaboratively designing, testing, and reflecting on AI-enhanced educational solutions. This study is also informed by the AI-TPACK framework, which

extends the established Technological Pedagogical Content Knowledge (TPACK) model to include AI-specific technological knowledge (Celik, 2023; Ning et al., 2024). The AI-TPACK framework offers a theoretical basis for identifying the competencies pre-service teachers require to integrate AI effectively into their teaching. Considering these perspectives, this study adopted a DBL approach to develop an AI-integrated instructional model for teacher education. Specifically, the research has two primary objectives: (1) to explore Thai pre-service teachers' experiences and needs regarding AI in education and (2) to design and develop a DBL-based instructional model that enhances their AI literacy.

2. Literature Review

2.1 Design-Based Learning

DBL provides pre-service teachers with authentic, problem-centered experiences that directly contribute to the development of AI literacy. In DBL environments, learners address real-world, ill-defined problems by designing AI-integrated solutions, thereby situating their learning in meaningful contexts rather than abstract theory (Gómez Puente et al., 2013). The iterative design process—comprising planning, prototyping, testing, and refining—encourages experimentation with AI-driven tools and learning through failure. This process fosters a deeper understanding of AI principles through hands-on engagement. Collaboration is another integral component of DBL. Working in teams on design challenges simulates real-world interdisciplinary work, allowing future educators to exchange knowledge and skills in AI use, ultimately enhancing their confidence and competence with the technology (Yüksel, 2025). Throughout the DBL process, structured reflection and self-assessment help pre-service teachers critically evaluate how and why they employ AI in their solutions. The key principles of DBL—authentic tasks, iterative design, collaborative learning, and reflective practice—are closely aligned with effective ID in teacher education.

DBL is rooted in constructivist, active learning strategies and is characterized by five core dimensions: (1) engagement with real-world tasks, (2) inclusion of iterative and creative problem-solving processes, (3) the teacher's role as a facilitator, (4) integrated formative assessment, and (5) a socially interactive learning context that promotes collaboration and communication (Amplo & Butler, 2023; Gómez Puente et al., 2015). In DBL settings, instructors serve as guides and scaffolds rather than content deliverers. Ongoing formative assessments, such as design reviews and reflective journals, are used to monitor progress and inform instruction. The deliberate incorporation of collaborative teamwork fosters a professional learning community in which teacher candidates actively exchange ideas and support one another's learning.

2.2 AI Literacy for Pre-Service Teachers

Teacher education frameworks are evolving to integrate AI competencies. The AI-TPACK model extends the widely adopted TPACK framework by incorporating AI-specific technological knowledge, enabling pre-service teachers to align AI tools effectively with pedagogical strategies and subject content (Celik, 2023). These models outline the knowledge and skills that teachers need to use AI meaningfully in the classroom (Bautista et al., 2024). AI technologies offer personalized, adaptive learning experiences, enhance student engagement, and support instructional tasks. Teachers proficient in generative AI tools report increased productivity and improvements in teaching strategies (Tunjera & Chigona, 2023; UNESCO, 2024). However, significant concerns persist, including issues related to ethics, bias, and academic integrity. Addressing these concerns requires educators to receive sufficient training and resources to ensure equitable and responsible use of AI technologies (Kanont et al., 2024; Zhao et al., 2022). Current research highlights the need for more focused professional development in AI, as many studies have emphasized technological capabilities over pedagogical training needs (Tan et al., 2025).

Several studies have stressed the importance of comprehensive AI literacy for pre-service teachers. This includes the ability to recognize AI technologies, understand core AI concepts, apply them pedagogically, and engage with them ethically (Long & Magerko, 2020; Ng et al., 2021; UNESCO, 2024). The empirical findings suggest that a strong conceptual grasp of AI correlates with teachers' capacity to identify educational applications of AI, implement them in classroom practice, and uphold ethical standards (Ayanwale et al., 2024). In response, teacher education programs worldwide are beginning to incorporate targeted AI literacy training. For instance, a recent professional development intervention significantly enhanced pre-service teachers' AI literacy skills, prompting calls for the integration of AI tools and activities into teacher education curricula (Younis, 2024).

3. Method

This study was conducted in two phases. In the first phase, the researchers collected data using an online questionnaire administered to 1,673 pre-service teachers through a simple random sampling method. Participants were students currently enrolled in Thai universities, and data collection took place during the fourth quarter of 2024. The pre-service teachers were categorized into two groups: (1) STEM students, who majored in science, technology, engineering, or mathematics-related fields, and (2) non-STEM students, who were studying subjects unrelated to those disciplines.

The questionnaire, developed as the primary research instrument, was pilot-tested with 30 students and comprised 38 items. These items covered various components, including student needs, experiences, and opinions about AI literacy (9 items; $\alpha = 0.878$), perceptions of AI's impact (3 items; $\alpha = 0.861$), motivation to use AI (3 items; $\alpha = 0.862$), current learning ecosystems related to AI (3 items; $\alpha = 0.787$), current AI usage (15 items), desired learning ecosystem for enhancing AI literacy (5 items), and student demographics (8 items). The results of the pilot test indicated high reliability, with all Cronbach's alpha values exceeding the acceptable threshold of 0.70. Respondents completed the questionnaire using various response types, including single-choice, multiple-select, and 7-point Likert scale formats. The data were analyzed using descriptive statistics, including frequency, mean, and standard deviation (SD).

In the second phase, the researchers analyzed key findings from the quantitative data and synthesized them with existing literature on AI literacy in education, DBL, related learning theories, and the foundations of ID. This process was used to derive the initial design principles for developing an AI-integrated Instructional Design Model (AI-IDM) aimed at enhancing AI literacy among pre-service teachers. To validate and refine the proposed design principles, five experts in the field of educational technology were purposefully selected to participate in semi-structured interviews. The experts provided feedback, offered recommendations, and validated the initial principles. The data obtained from these key informants were analyzed and used to iteratively revise and improve the AI-IDM.

4. Results

4.1 Needs and Experiences of Pre-Service Teachers

As shown in Table 1, the survey was administered to a total of 1,673 pre-service teachers. The sample comprised 570 male participants (34.07%) and 1,103 female participants (65.93%). Regarding academic year distribution, 487 respondents (29.11%) were freshmen, 654 (39.09%) were sophomores, 312 (18.65%) were juniors, and 220 (13.15%) were seniors or beyond. In terms of disciplinary background, a majority of participants were enrolled in non-STEM fields (n = 1,164; 69.58%), while 509 participants (30.42%) were from STEM-related disciplines. The average grade point average (GPAX) was 2.87 for non-STEM students and 3.20 for STEM students. Concerning digital engagement, non-STEM students reported an average of 8.86 hours of computer use per week, compared to 9.66 hours for STEM students. For internet use related to educational purposes, non-STEM students averaged 8.32 hours per week, whereas STEM students averaged slightly less, at 8.07 hours.

In the Table 1, Most participants reported having access to digital technology: 83.51% of non-STEM students and 95.68% of STEM students owned a computer with internet capability, while nearly all students owned a portable internet-enabled device (99.05% of non-STEM; 99.80% of STEM). Moreover, internet-based learning activities were widely integrated into university coursework, as reported by 99.48% of non-STEM and 99.80% of STEM students. However, institutional support for AI-related education was comparatively limited. Only 83.59% of non-STEM students and 70.14% of STEM students indicated that their faculties had provided AI training or awareness initiatives. Despite widespread access to technology, actual use of generative AI tools was significantly higher among non-STEM students (55.33%) than among STEM students (22.40%). Additionally, 21.13% of non-STEM students indicated a need for learning resources or tutors to support their use of AI tools, compared to 8.06% of STEM students. In contrast, 42.44% of STEM students reported being capable of independently learning and using AI, as opposed to 34.19% of non-STEM students.

Table 1: Participants' experiences with AI and digital tools

Questions / Items		non-STEM		STEM	
		f	%	f	%
Does your university/faculty organize teaching/training/PR on AI?	Yes	973	83.59	357	70.14
	No	191	16.41	152	29.86
Have you ever used generative AI?	Yes	644	55.33	114	22.40
	No	520	44.67	395	77.60
Do you need a learning resource or tutor to use AI?	Yes	246	21.13	41	8.06
	No	279	23.97	216	42.44
Can you learn and use AI technology on your own?	Yes	398	34.19	73	14.34
	No	241	20.70	179	35.17

Regarding the use of digital applications to support academic tasks, a majority of non-STEM students (56.27%) reported consistent use, compared to only 36.15% of STEM students. Conversely, occasional use was more prevalent among STEM students (63.65%) than their non-STEM peers (43.47%). Very few participants in either group indicated that they never used digital tools (0.26% non-STEM; 0.20% STEM). When asked about their perceived ease of using AI technologies, only 7.86% of STEM students described their experience as "effortless," whereas 18.81% of non-STEM students did. Similarly, 13.75% of STEM students and 34.45% of non-STEM students characterized AI use as "uncomplicated."

The average duration of experience with AI tools was comparable across groups: non-STEM students reported a mean of 5.20 months, while STEM students reported a slightly longer average of 5.24 months. The survey also examined the specific purposes for which AI tools were used. Common uses included creating presentations (n = 335, 7.47%), analyzing data (n = 342, 7.62%), summarizing content (n = 329, 7.33%), translating languages (n = 331, 7.38%), and brainstorming ideas (n = 298, 6.64%). Sources of awareness about AI varied. Social media was the most frequently cited channel (n = 457, 24.58%), followed by teachers (n = 423, 22.75%), friends (n = 309, 18.24%), and news websites (n = 323, 17.37%). In terms of learning pathways, most participants reported learning to use AI independently (n = 516, 37.36%), followed by peer sharing (n = 307, 22.23%) and formal training (n = 243, 17.60%).

Interest in receiving further training on AI for educational purposes was high across both experienced and inexperienced users. Among students with prior AI experience, 302 were "very interested" and 346 were "interested." Among those without prior experience, 259 expressed being "very interested," while 559 indicated they were "interested." Participants were also asked about their expectations of AI's impact on future careers. The majority in both groups anticipated a significant effect. Specifically, 277 of those with AI experience and 238 without experience believed AI would have a "great impact" on their professional futures. Additionally, a substantial number anticipated a "medium impact," especially among students without prior AI experience (n = 436), compared to 249 among experienced users.

Overall, both STEM and non-STEM students reported moderately high levels across all indicators. STEM students rated their current learning environment for supporting AI literacy slightly higher (M = 5.84, SD = 0.93) than non-STEM students (M = 5.64, SD = 1.26). Similarly, motivation to develop AI literacy was somewhat greater among STEM students (M = 5.64, SD = 0.99) than among their non-STEM peers (M = 5.49, SD = 1.22). In terms of perspectives on AI's impact, both groups again showed positive attitudes, with STEM students reporting a slightly higher mean (M = 5.69, SD = 0.95) than non-STEM students (M = 5.55, SD = 1.25). A similar trend was observed in students' self-assessments of their own AI literacy, with STEM students rating themselves higher (M = 5.78, SD = 0.83) than non-STEM students (M = 5.60, SD = 1.16).

To inform the development of effective ID for AI literacy, the study explored students' preferences regarding instructional models, learning activities, resources, and assessment tasks. A majority (65.29%) favored a blended classroom model combining face-to-face and online formats. In terms of instructional strategies, the most valued activities included peer discussion (10.40%), brainstorming (10.62%), information searching (9.20%), and self-directed learning (8.56%). As for learning resources, students preferred websites and blogs (14.61%), MOOC platforms (14.15%), video/animation content (10.71%), and e-books (13.03%). Regarding digital tools to support AI learning, students most often selected interactive quizzes (20.46%), learning management systems (LMS) (15.40%), collaborative tools like Padlet (17.37%), and gamified platforms (16.92%). The most effective

assessment formats were perceived to be educational innovation projects involving AI integration (19.14%), mini-teaching demonstrations using AI tools (18.78%), and reflective reports on AI in education (15.92%).

These findings provide a comprehensive picture of Thai pre-service teachers' engagement with, perceptions of, and aspirations toward AI literacy. While there are notable differences between STEM and non-STEM groups, both demonstrated strong interest and acknowledged AI's transformative potential in education and professional development. These insights underscore the importance of designing responsive, inclusive, and experiential learning experiences that equip future educators with practical AI competencies.

The following key findings serve as design principles for the next phase of research in Table 2:

4.2 Designing and Developing an AI-Integrated ID to Enhance AI Literacy

4.2.1 Initial Design Principles

Drawing on the findings from the previous research phases, a set of empirical design principles ([DP1]–[DP6]) was developed. To further enrich ID through digital tools and the learning environment, this study adopts Distributed Cognition (DC) as its theoretical lens. DC conceptualizes cognition as distributed across learners, tools, and the environment (Fowlin et al., 2025; Hennessy, 1993) [DP7-DP9]. Moreover, the synthesized findings from the DBL approach identified five further principles applicable to this context (Amplo & Butler, 2023; Gómez Puente et al., 2015) [DP10-DP14] in the Table 2.

Table 2: Design Principles and description for conjecture mapping

Design Principles	Details
[DP1] Flexible Learning	Blended classrooms are the most suitable formats, and ID should integrate both online and face-to-face components to support diverse learning contexts and enhance accessibility.
[DP2] Emphasize Experiential and Inquiry-Based Learning	Activities such as peer discussions, brainstorming, problem-solving, and self-directed learning were highly valued and promoted deeper understanding, critical thinking, and learning autonomy.
[DP3] Utilize Interactive and Multimedia Learning Resources	Offering AI literacy content in diverse formats promotes inclusivity and supports various learning preferences.
[DP4] Integrate Gamified and Digital Tools	Interactive quizzes, gamified platforms, and collaborative tools enhance engagement, provide real-time feedback, and support formative assessment.
[DP5] Design Tasks that Reflect Real-World Practice	Tasks such as mini-teaching demonstrations, innovation projects, and reflective reports allow students to apply their knowledge and simulate professional uses of AI in education.
[DP6] Provide Scaffolded Support and Promote Self-Regulated Learning	ID should balance autonomy with guidance through peer sharing, tutor support, and demonstration sessions with generative AI tools.
[DP7] AI as a cognitive partner	AI should be positioned as a learning support tool, such as a thinking companion that supports learners in idea generation, problem solving, and content creation. Then, the learner have to be the key decision maker and respond to validate and use the AI-genertated contents.
[DP8] Emphasizing cognitive interactions among individuals, tools, and digital environment	Learning activities should empahzie leaner to reason, analyze, and reflect while interacting with AI platforms, to enhance the distributed cognition across human and digital learning ecosystem.
[DP9] Knowledge co-creation through social interaction and collaborative learning activities	Learners should be encouraged to co-construct knowledge through peer collaboration or Think-Pair-Share activities.
[DP10] Engagement with real-world tasks	Students should apply AI tools to solve practical problems or conduct educational tasks based on current classroom challenges.
[DP11] Iterative learning design	Learners should experiment with AI tools in multiple rounds, improving their outputs based on AI feedback, peer input, or instructor guidance
[DP12] Collaborative learning	Collaboration should be embedded through group discussions, co-design tasks, and interactive challenges that require collective reasoning and shared responsibilities among peers.
[DP13] Reflective practice	Learners should do the reflection on their experiences using AI, examining how their understanding, what ethical considerations, and how AI biased their cognitive.

Design Principles	Details
[DP14] Facilitator support	Instructors are a key man in scaffolding AI literacy by presenting responsible AI use, unitize appropriate AI tools, and providing just-in-time feedback.

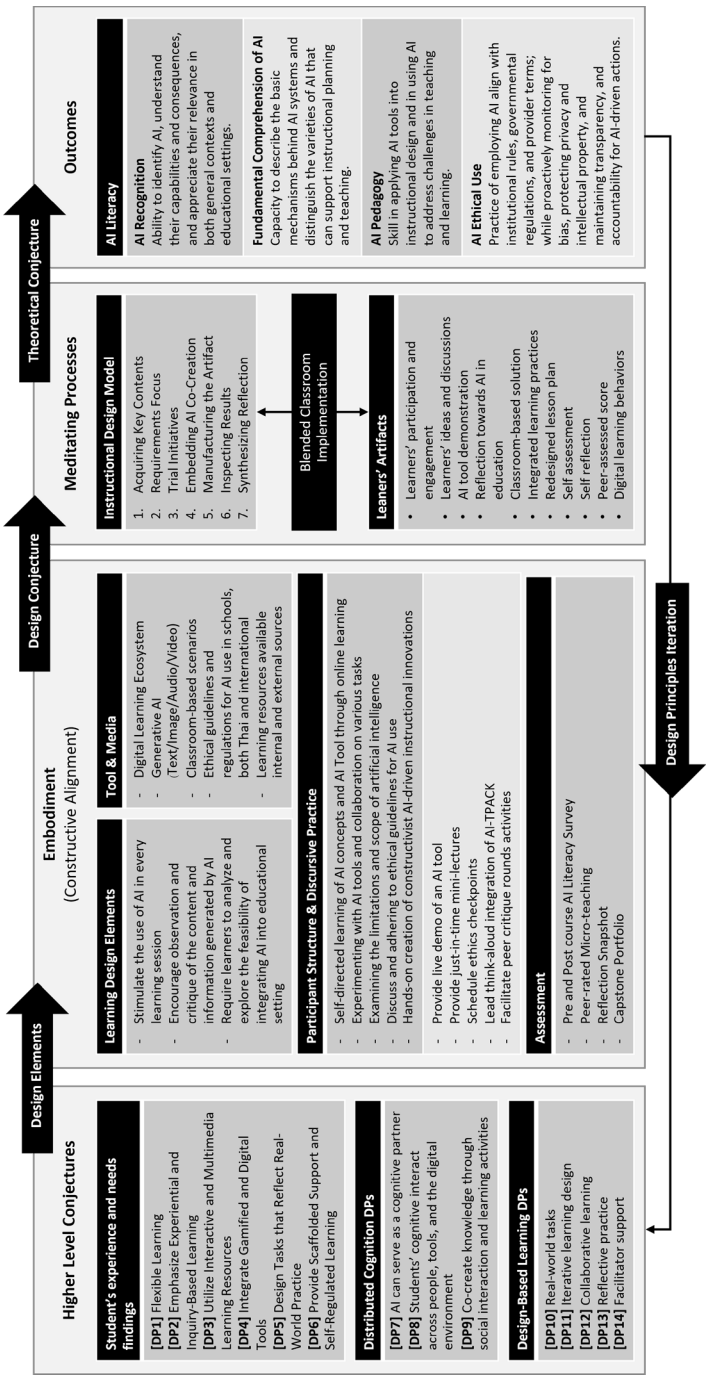


Figure 1: Initial conjecture map of AI-integrated ID to enhance AI literacy

To structure the AI-integrated ID, these 14 design principles were mapped using Sandoval's (2014) conjecture mapping approach. This method explicitly links theory, design embodiments, mediating processes, and expected learning outcomes. In the conjecture map, "higher-level conjectures" are derived from learner needs and theories of DC and DBL. The design embodiment includes AI-integrated learning activities, tools, and media; collaborative and self-directed learning structures; ethical discussions; and practical applications of AI tools. These processes generate mediating processes such as co-creation, critical reflection, and knowledge application, which lead to measurable outcomes in literacy development, as shown in the following **Figure 1**.

As a result, the proposed framework—designed as a classroom-oriented ID model—comprises the following seven key components as the **Figure 2**:

- [1] Acquiring Key Contents: Provides foundational knowledge of AI concepts and integration frameworks (e.g., AI-TPACK) through demonstrations and guided study, thereby establishing a solid conceptual base.
- [2] Requirements Focus: Defines the educational design challenge as a practical, real-world problem, ensuring that AI applications are aligned with specific pedagogical objectives.
- [3] Trial initiatives: Learners generate preliminary ideas and develop prototype solutions, promoting hands-on exploration of AI tools.
- [4] Embedding AI Co-Creation: Involves the collaborative refinement of these solutions with AI systems, peers, and instructors, integrating AI meaningfully into the creative process.
- [5] Manufacturing the Artifact: Learners construct tangible outcomes such as functional AI prototypes or AI-enhanced lesson plans, translating abstract ideas into applied practice.
- [6] Inspecting Results: Entails evaluating the effectiveness of the solutions and engaging in peer feedback and reflection.
- [7] Synthesizing Reflection: Encourages learners to articulate insights, synthesize lessons learned, and identify best practices to guide further iterations.

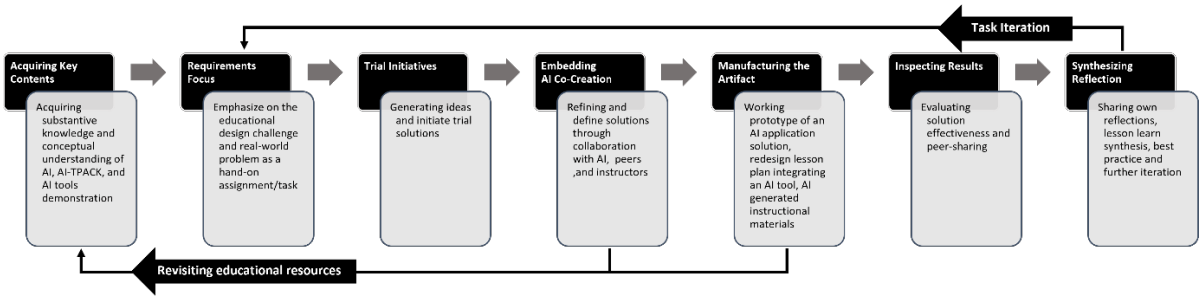


Figure 2: Proposed framework of AI-integrated ID model

Based on expert suggestions from interviews, the overall design principles and the ID model were considered applicable to real-world educational contexts. Accordingly, the author revised and refined the design principles to further develop the conjecture map, as shown in the **Table 3** below.

Table 3: Experts' suggestions and revisions to the design principles for AI-Integrated ID Model

Initial Design Principles	Experts' Suggestions	Iterated Design Principles
Student's Experience and Needs Findings [DP1−6]	• Provide additional declarative and procedural knowledge about AI tools as just-in-time learning resources, such as prompting skills, TPACK case studies, and ethical issues in education • Emphasize more non-AI learning activities to increase AI awareness and reduce cognitive offloading • Be aware of AI overuse during self-paced or online learning • Facilitate student discussions and group reflection on AI in education to promote AI literacy	**Added:** [DP15] Self-paced learning modules via multimedia **Modified:** [DP8] Students' cognitive interaction across people, tools, and the digital environment via classroom guidelines [DP9] Co-creating knowledge through social interaction, AI, and learning activities [DP12] Collaborative ideating with peers [DP13] Reflective practice for individuals and groups
Distributed Cognition DPs [DP7−9]		
Design-Based Learning DPs [DP10−14]		

Hence, the proposed AI-Integrated Instructional Design (ID) Model has not yet been implemented to evaluate its effectiveness among pre-service teachers. To address this, the author plans to develop a digital learning ecosystem to serve as a mediating platform for the model's deployment in the upcoming academic semester. The implementation will take place in a blended learning environment, embedding the model's phases into weekly learning activities for a cohort of pre-service teachers enrolled in an educational technology course. Both formative and summative evaluations will be conducted through pre- and post- self-assessments of AI literacy, classroom observations, and learner reflections. During the implementation, the reseachers acknowledge ethical implications of AI in teacher training, including concerns of bias, privacy, and algorithmic transparency,

and commit to critically evaluating these aspects in the model's future development and implementation. Then, this phased implementation approach will support iterative refinement of the instructional model and its underlying design principles based on real-world classroom feedback, thereby enhancing both its practical practice and theoretical conception.

5. Discussion

Pre-service teacher education programs should be reimagined to embed AI literacy throughout the curriculum or related courses. This approach aligns with international recommendations that digital and AI competencies should be mainstreamed in initial teacher training, ensuring that all future educators can confidently and ethically employ AI tools (OECD, 2023). Similarly, UNESCO's *AI Competency Framework for Teachers* urges teacher education systems to cultivate the knowledge, skills, and values necessary for ethical and effective AI integration in classrooms (UNESCO, 2024).

The proposed model includes the integration of AI fundamentals into teachers' reflective practices. This aligns with the findings of Ayanwale et al. (2024), who reported that increased AI knowledge predicted improvements in AI use, detection, ethics, creation, and problem-solving. In addition, insights from the model underscore the importance of embedding AI in various subject areas and learning activities. Effective instructional strategies emphasize hands-on AI applications paired with collaborative discussions which grounded with social-constructivist through peers interaction and the help of others for co-creating knowledge and shared experiences and perspectives. Ding et al. (2024) found that a case-based professional development sequence—beginning with an introductory AI lecture and progressing to complex case scenarios—significantly enhanced teachers' AI-related problem-solving abilities.

The ID of AI literacy initiatives should integrate a theoretical learning environment with practical application and ethical inquiry. Tammets and Ley (2023) proposed a teacher-centered model in which curriculum development is intertwined with AI tool co-creation. In this model, teachers' "professional vision" informs the design of AI solutions, fostering deeper pedagogical reasoning. In the context of the current study, this may involve pre-service teachers engaging in the *Embedding AI Co-Creation* stage by designing an AI-powered educational artifact, followed by the *Inspecting Results* stage, where they analyze AI-generated data or feedback to refine instruction. The final stage, *Synthesizing Reflection*, encourages a critical evaluation of AI's influence on learning and teaching decisions, situating AI literacy within broader pedagogical objectives.

This study has several limitations. First, it was conducted over a short period, limiting participants' ability to observe longitudinal changes in AI literacy or assess sustained pedagogical impact. Second, as the proposed AI-IDM has not yet been implemented in actual classroom settings, its effectiveness is inferred only from expert judgments rather than empirical evidence. Third, all data were obtained from Thai pre-service teachers, thus restricting the generalizability of the findings to other cultural, technological, and curricular contexts.

Although this study introduces a theoretically grounded AI-IDM, it remains a proposed framework. A systematic implementation phase is essential for evaluating the pedagogical efficacy of the model and refining its components. Specifically, a quasi-experimental design that integrates learner performance data with qualitative evidence would enable the triangulation of results. Moreover, while the model's design principles are currently anchored in DBL and DC, they can be enriched through the integration of complementary theoretical perspectives. For instance, socio-constructivist frameworks may support the collaborative nature of AI co-creation, while self-determination theory and digital critical thinking models could inform learner motivation and higher-order reasoning.

Ethics Declaration

This paper ethical permission was obtained from Chulalongkorn University (reference number 429/67). Therefore, all research participants' identities and data remain unidentifiable and will be deleted immediately after the research is completed. All participants consented to the data for research purposes.

AI Declaration

The authors declare that they have used AI tool, Grammarly to proofreading and enhance the readability of this manuscript. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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GenAI-Enhanced Learning: A Framework to Align the Third Level of Bloom's Taxonomy

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Abstract: Since the first release of ChatGPT, every aspect of today's world has been impacted. Artificial intelligence is no longer confined to high-tech companies or large industrial R&D departments. Countless smartphone applications are being continuously launched and immediately adopted by end users. In view of this, ethical concerns have been raised in several studies, emphasizing the urgent need for the responsible use of generative AI. The education system is no exception. Students across academic levels now use generative AI for essay writing, coding, and project-based assignments. Pedagogical and EdTech researchers worldwide express increasing concern about the future of education. However, the detrimental effects of using these tools have become evident. Recent studies have observed a significant decline in students' competencies in fundamental subjects such as mathematics and languages. Furthermore, the role of teachers extends beyond presenting information to students. Teaching is a complex process that involves providing learner support, closely guiding students, and offering learning paces tailored to their needs. While AI cannot replace educators, action plans are needed to adapt to the undeniable presence of generative AI in education. Thus, this study asks how we can harness the power of AI to assist teachers to design classroom activities, rather than focusing on student use of these tools or imposing bans in schools and universities. We therefore explored the alignment of Bloom's Taxonomy levels with AI-enhanced learning, specifically leveraging the third level of Bloom's Taxonomy, "Applying". This paper introduces a framework to assist teachers in designing workshops and learning activities. By applying acquired knowledge through AI-powered simulations, and grounding this approach in Kolb's Experiential Learning Theory, the framework aims to reinforce cognitive domain concepts from Bloom's Taxonomy while placing experiential learning at its core and offering substantial added value to the learning experience.

Keywords: AI-enhanced Learning, Generative AI, Bloom's Taxonomy, Learning Activities, Educational Technology, Kolb's Experiential Learning Theory.

1. Introduction

Artificial intelligence began in the late 1950s, and has since evolved into complex systems. With the release of the publicly shared applications, accessible to end users, ChatGPT and other applications that generate content have become emergent. In the last decade, AI has become omnipresent in many fields, from social media and healthcare to education (Yue Yim, 2024). In the field of education, different academic institutions around the world have implemented grading systems based on AI and have already started using intelligent tutoring systems (ITS). Nevertheless, the powerful capability of generating responses to every question has raised concerns in the education sector. Students across disciplines use ChatGPT for most homework except in hands-on tasks like art or cooking.

In our study, we discuss the cognitive learning level of the Bloom's Taxonomy and its adaptability in the generative AI era, and we suggest a framework based on Kolb's Experiential Learning Theory to assist teachers in creating their learning activities. The main research questions for this study are:

RQ 1: How can Bloom's "Applying" level and Kolb's theory guide a framework to help teachers design AI-supported learning activities?

RQ 2: What are the practical benefits of using the proposed AI-enhanced framework in terms of scenario creation, preparation time, and teacher usability?

Six main sections are presented in this paper. Following the introduction, the second section provides an overview of generative AI and its influence on education. The third section highlights the evolution of Bloom's Taxonomy, exploring its relevance in the digital age, as well as an overview of Kolb's Experiential Learning Theory. The fourth section reviews related work on the integration of AI tools with Bloom's cognitive taxonomy and lesson design supported by AI. The fifth section presents the methodology used in this study to develop and test the proposed framework and details the AI-enhanced framework for the design of workshop and learning activities. The final section describes the pilot implementation of the framework, including a demonstration of its practical application and effectiveness in a real educational context.

2. Theoretical Background & Related Work

2.1 Generative AI and Education

AI advances began with early projects like Eliza (Martin, 1993). Since then, many chatbots have been developed with more complex analytical functionalities. In the field of education, chatbots are widely used by students nowadays to provide immediate answers. ChatGPT can generate essays or solve math tasks with high accuracy. The quality of generated content in all formats depends on both the training data of the model and the quality of the prompts provided by the user.

As AI tools have become an undeniable player of the educational process, numerous research studies have been conducted to analyze several aspects of this inclusion. (Elmourabit, Asmaâ Retbi, and Nour-Eddine El Faddouli, 2024) conducted a comparative study to analyze and compare human and AI-generated exams and has shown that generative AI can enrich learning and assessment when used as a partner with teachers. AI-guided resource selection and content review have provided the most effective outcomes. In the field of engineering education, (Rebelo, 2025) emphasizes that educators should consider adapting engineering education to take advantage of generative AI while mitigating potential drawbacks. Relevant data were collected by (Ouhaddou, Retbi and Bennani, 2023) on students to propose an approach using large language models (LLMs) to support student orientation with a focus on identifying key factors that affect student academic orientation.

2.2 Core Learning Theories: Bloom's Taxonomy and Experiential Learning

Created in 1956, Bloom's Taxonomy has been applied for decades by educators to classify cognitive learning objectives (Wilson and Leslie, 2016). Anderson and Krathwohl published a revised version in 2001, to address a more dynamic learning process (Coşgun Ögeyik, 2022). In 2008, Churches proposed the digital Bloom's Taxonomy (DBT), which includes three levels related to digital technology (Gunarso *et al.*, 2024). In our study, we focus on the "Applying" level of the Taxonomy. This level consists of carrying out or using learned concepts through execution or implementation (Wilson and Leslie, 2016).

To support real-world knowledge use, Kolb's experiential learning theory (Kolb and Kolb, 2022) includes case studies, fieldwork, and simulations. Focusing on the "Applying" level of the revised Taxonomy and grounded in experiential learning theory, this paper explores the active use of knowledge in real-world contexts.

2.3 Related Work on AI-Supported Learning: Applying Bloom's Taxonomy and Experiential Learning

Several researchers have studied AI and Bloom's Taxonomy as intersecting paths to enhance pedagogy and empower learning experience. (Jiménez Romanillos and Andersson, 2024) and (Almatrafi and Johri, 2025) reported how generative AI enhanced educational design and creativity, leveraging Bloom's Taxonomy for improved learning. Teachers experiences with AI tools for preparing educational content have been discussed in several studies. (Ding, Li and Hui, 2025) tested the impact of teacher-AI collaboration and found a valuable effect on engagement. (Romero, 2024) proposed a template for pre-service teachers to co-design learning activities to facilitate the design process. The structured approach suggests a step-by-step process that enables the synergy of human and AI co-creativity.

Previous research has studied integrating AI within instructional design. (Park *et al.*, 2023) and (Cooper, 2023) highlighted how generative AI and ChatGPT support science education and instructional design. Their studies demonstrated the utility of ChatGPT in designing science courses and quizzes. (Gunawan *et al.*, 2020), (Lee and Zhai, 2024), and (Shamir-Inbal, Levi and Blau, 2024) analysed lesson planning with generative AI, highlighting benefits in preparation, time efficiency, and instructional design. Simulations used in science classes by (Falloon, 2019) in their study, applying the experiential learning theory, are beneficial for the class engagement, and enable the practice of higher order skills. (Falloon, 2019) emphasizes the need for further research to explore pedagogical models for using simulations in class and assist fundamental learning processes.

To the best of our knowledge, while prior studies have explored the use of AI tools in educational design, few have proposed structured frameworks grounded in established learning theories. Building on this gap, our study introduces a theoretically grounded model that integrates Bloom's "Applying" level and Kolb's experiential process to support AI-assisted workshop design for teachers.

3. Methodology & Proposed Framework

This study is based on a design-based research approach (DBR) that combines theoretical development and practical application in the educational field. The goal is to suggest a framework to help teachers design workshops focused on Bloom's "Applying" level and Kolb's Experiential Learning.

This research was conducted in two phases:

Phase 1: Framework development:

Prior research was reviewed on AI in education, digital Bloom's Taxonomy, Kolb's model, and instructional design. Key observations were incorporated into a structured framework to support teachers in designing workshops that improve "Applying" learning outcomes.

Phase 2: Framework testing through a pilot implementation:

The framework was utilized for primary school science workshop design. Teachers were guided in using AI tools during the pilot implementation, with specific recommendations tailored to the workshop.

3.1 Nested Theoretical Foundation for AI-Enhanced Learning Activities Design

In this section, we introduce a structured framework to support educators in designing workshops and learning activities. This framework allows educators to integrate generative AI tools into the design process. The proposed framework is based on Kolb's Experiential Learning Theory (ELT). The stages are aligned with the phases of ELT and supported by generative AI tools. It also relies on the "Applying" level of Bloom's Revised Taxonomy, ensuring the focus on using knowledge in real-world and practical contexts for the learning activities and workshops.

The diagram (Figure 1) represents our suggestion for the nested theoretical foundation of AI-Enhanced learning activities design.

The diagram presents the layered structure of the proposed framework. Bloom's "Applying" level defines learning goals ('what') and Kolb's experiential model defines the process ('how'). At the core, the proposed framework provides the practical implementation tools ('how to').

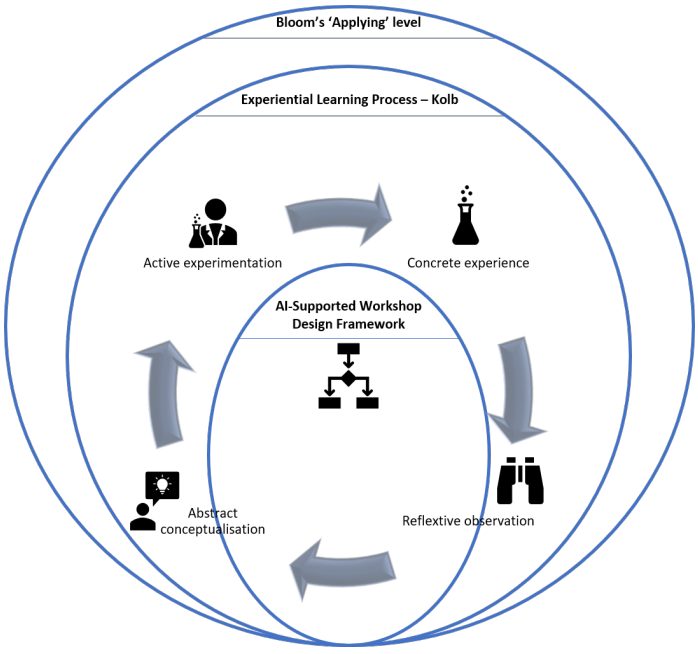


Figure 1: Nested foundation for AI-Enhanced activity design

3.2 Framework Design and Components

In view of the main goal of this study, by assisting teachers in designing workshops in a human-AI collaborative mode, application of knowledge in practical contexts and strengthen cognitive engagement can be achieved.

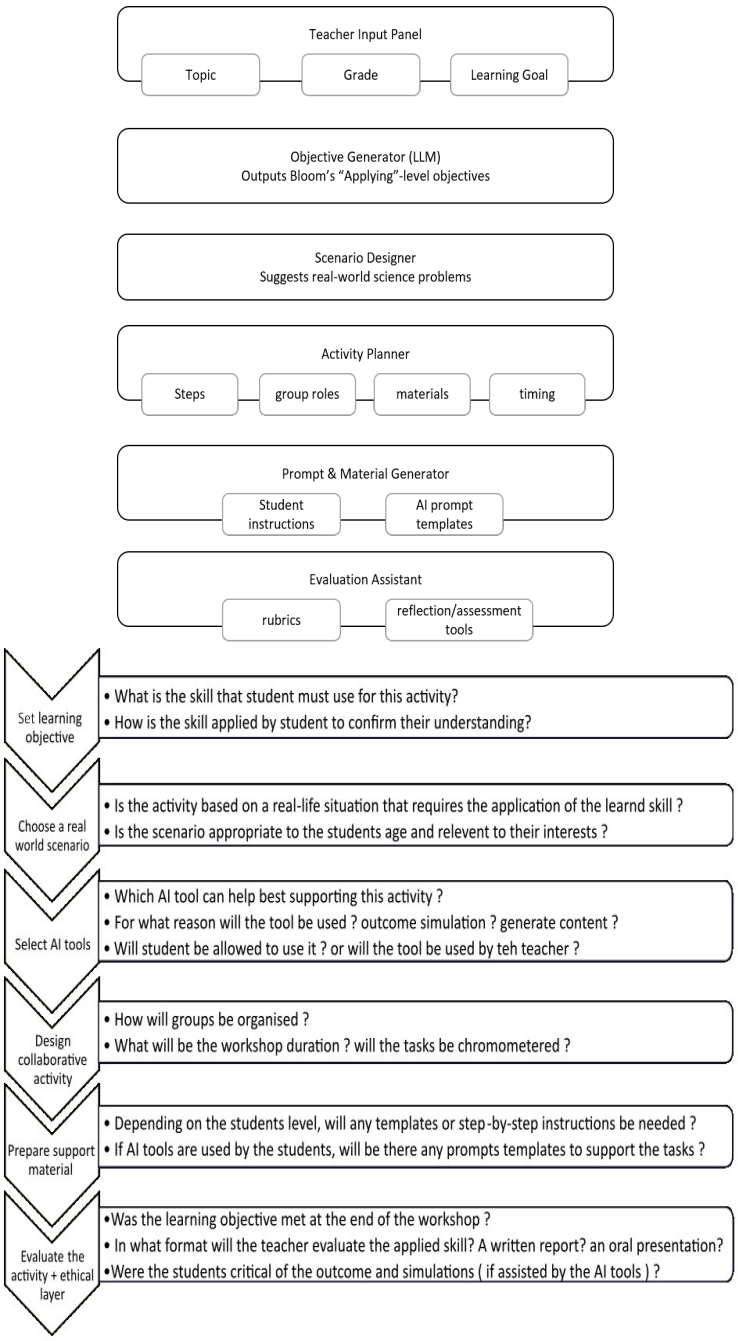


Figure 2: Overview of AI-enhanced workshop design framework

The framework (Figure 2) provides teachers a step-by-step structure for designing workshops. In the following clarification of the process, we outline the progression of pedagogical components, from defining learning goals to evaluating outcomes.

The elements describe how generative AI is used not only for content generation but also to enhance the design of real-world scenarios. This approach underlines the teacher's irreplaceable role while using AI as a co-pilot to increase efficiency and adaptability in instructional design.

- Stage 1: Define learning objectives, aligned with "Applying" Bloom's Taxonomy level

At this first stage, teachers define measurable learning objectives using action verbs. AI tools such as ChatGPT or Eduaide.ai can help teachers refine and clarify outcomes.

- Stage 2: Choose real-world scenarios for the activity

Teachers use AI to generate relevant scenarios and up-to-date problem. ChatGPT or Eduaide.ai can be helpful tools for role-playing dialogues.

- Stage 3: Select appropriate AI tools

Tools like Scratch or Google Teachable Machine can support simulations aligned with target skills.

- Stage 4: Design collaborative activity

Planning tools like Miro help organize instructional tasks and workshop timing.

- Stage 5: Prepare support material

AI tools help prepare instruction sheets and prompt templates.

- Stage 6: Evaluate the activity and ethical considerations

A pre- and post-workshop checklist is recommended to reflect on Bloom's alignment, AI integration, and framework usability.

4. Implementation

To illustrate the application of the proposed framework for AI-enhanced workshop design, we present a pilot implementation in this section from a primary school science class. The chosen topic focuses on the "Water Cycle" course. This case study demonstrates the framework's application in a real classroom.

The workshop objective for this class is the application of their knowledge from the "Water Cycle" course. The students will be able to simulate environmental scenarios and propose solutions to current weather problems. Concepts such as evaporation, condensation, precipitation, and collection will be observed.

We present in the following the preparation of the workshop, based on the proposed framework.

Stage 1: Set learning objectives

AI assistance tool: ChatGPT

Proposed prompt: Generate learning outcomes for a 1h primary science class workshop on the water cycle, targeting the third level of Bloom's Taxonomy.

Stage 2: Choose a real-world scenario

AI assistance Tool: www.Eduaude.ai

Eduaide suggested a hands-on water cycle model using everyday materials. The Hands-on Model activity was described in detail by the AI. The generated output is presented in Figure 3.

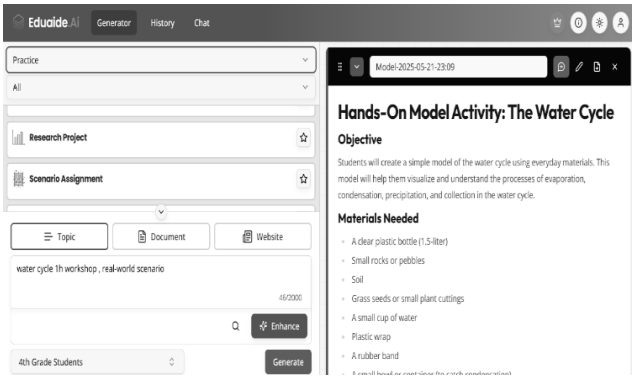


Figure 3: AI-generated hands-on plan for a primary science workshop

The possibility of adjusting the model and adapting it to the number of students, the available and affordable materials, or any given condition makes it highly adaptable.

The strengths of this platform include outputs that are aligned with Bloom's learning goals, class levels, and disciplines. Also, it allows tuning to match cognitive domains.

Stage 3: Select AI tools

If the teacher is willing to create their own simulation or interactive activity, detailed steps can be prompted from ChatGPT, and the simulation or interactive tool can also be suggested.

Depending on students' access to personal laptops and internet access during the workshop, the learners can be invited to co-create the activity with the teacher, either in pairs or in groups. Step sheets can be adapted for use by primary school students.

In our implementation, among the suggested interactive tools, we selected Scratch from https://scratch.mit.edu/

Every step of the creation is detailed, from background design to animation.

Stage 4: Design collaborative activity

AI can help share and design the roles for the activity and suggest collaboration assistance. The activities can be run in pairs or small groups.

Proposed AI platform: https://www.eduaide.ai

For our implementation, the prompted subject was about engaging collaborative activities. The output generated was interesting and enjoyable to implement.

4.1 Results and Discussion

The framework implementation showed promising results. AI effectively supported learning objectives, aligned with Bloom's "Applying" level. Preparing interactive activities was efficient. The AI-generated simulation sheets were adaptable and saved teachers significant preparation time. These results show the framework enhances practical learning through AI.

The framework guides teachers through stages to support adaptive learning. The implementation shows how generative AI can be an efficient partner for teachers in designing their activities at every stage of the workshop process.

AI-driven workshops engage students in "Applying" knowledge in real-world environments. AI tools let students simulate real-life situations and observe outcomes.

The framework was also tested by a group of three education trainees, who were asked to prepare different science learning activities, both with and without AI Tools, following the given framework. Table 1 compares preparation times for three science workshops, with and without AI.

Table 1: Preparation time for science workshops with and without AI

Topic	Manual Preparation	With AI Tools	Time saved
Water Cycle	3.5 hours	1.5 hours	**2 hours**
Pollination	4 hours	1.5 hours	**2.5 hours**
States of Matter	3 hours	1.2 hours	**1.8 hours**

The estimated preparation times reflect common teacher workflows, where manual planning involves searching for lesson objectives, drafting activity instructions, sourcing materials, and designing assessment tools. In contrast, using AI tools like Eduaide.ai for scenario design, ChatGPT saved between 1.8 and 2.5 hours.

In addition, the three primary educators reviewed the framework through a usability study.

Table 2 shows teacher ratings of the framework's usability on a 4-point scale.

Table 2: Teacher ratings of AI-supported workshop design

Criteria	Description	Rating (1-4)		
Alignment with learning objectives	The framework helped define objectives aligned with Bloom's "Applying" level.	3	4	3
Support in scenario creation	AI tools helped generate real-world learning scenarios.	4	2	3
Efficiency of planning process	The framework reduced time and effort in planning.	4	4	4
Clarity and usability	The steps, tools, and resources were clear and easy to follow.	2	2	3
Confidence in AI integration	Teacher felt confident integrating AI tools into instructional design after using the framework.	1	1	3

Teachers' feedback highlighted the clarity of the scenario builder and the usefulness of AI prompt suggestions.

However, confidence in using AI tools was reported as moderate in the teacher rubric (see Table 2), prompting further investigation. To explore this issue among a broader group of educators, we conducted interviews with primary school teachers from pioneer schools in the Rabat region of Morocco.

Additionally, based on a dataset of 20 teachers, questionnaires were administrated to identify existing gaps in support needs. The results revealed that 55% had never used any technological tools to prepare their learning activities (aside from basic internet browsing for information), and 40% reported facing challenges due to a lack of training and technical support.

4.2 Limitations and Further Work

This study explored using generative AI to support Bloom's "Applying" level, based on Kolb's Experiential Learning model. The framework is an initial step to align pedagogy with AI capabilities. In our study, while the proposed framework demonstrates the benefits of integrating AI into workshop design, several limitations should be considered. The framework was not tested across various disciplines, and thus, the generalizability can be limited. Additionally, digital literacy and the small-scale pilot (with feedback from three trainee teachers) are also limitations. Future work should involve testing with more educators. We aim to develop a platform where teachers can input course information and generate structured AI-enhanced activities. Future developments will focus on building a digital platform that integrates the framework's components and supports teachers in real time. Additional features may include LMS integration, collaborative tools, and AI-guided prompt generation.

Additionally, many researchers cited in the related work section have presumed that the integration of AI in the educational system will not be effortless. (Ng, Chan and Lo, 2025) assume the need to further examine how teachers will adopt generative AI and how their perception will be of this new technology. In the same context, the UNESCO report raised the question of how education will prepare humans to live with AI (*Transforming education towards SDG 4: report of a global survey on country actions to transform education - UNESCO Digital Library*, 2024). (Habiballa *et al.*, 2025) point out that the rapid evolution of AI applications and models report the demand for more diverse studies, taking into consideration various samples and educational parameters. Another consideration was raised by (Jiménez Romanillos and Andersson, 2024), stating that it will be problematic to understand the teacher's role in the GenAI-enhanced learning process when it is affordable to skip the first two fundamental categories in Bloom's Taxonomy; remembering and understanding. Nevertheless, Salman Khan discussed how the emergence of AI tools into the academic field can be leveraged, raising a "call for educated bravery" (Khan, 2024).

5. Conclusion

We proposed a theoretical framework to help teachers design AI-enhanced workshops, aligned with the "Applying" level of Bloom's Taxonomy and based on Kolb's experiential learning theory. This framework was piloted in a classroom setting, and the results showed its potential to enhance pedagogy while maintaining the educator's role. As generative AI becomes increasingly an embedded practice in the educational field, adapted approaches such as the framework presented in our study provide a roadmap to responsibly harnessing this emerging technology and leverage meaningful human-AI collaboration. The nested framework, grounded in Bloom's taxonomy and Kolb's experiential learning model, contributes to a structured and theory-aligned design approach. However, further refinement is recommended to ensure adaptability across various educational disciplines.

Our work represents an initial exploration into the potential of generative AI to support educational technology. Looking ahead, future efforts will focus on developing an integrated solution for teachers using large language models (LLM) and Retrieval augmented generation techniques (RAG). The solution development will also emphasize refining prompt engineering methods to improve interaction with AI systems and provide a more accurate learning experience. Preliminary feedback suggests gains in teacher satisfaction and a reduction in preparation time when using the proposed framework.

Ethics and AI Declaration

This research did not involve data collection requiring ethical declaration.

ChatGPT was used for grammar correction. Also, during the implementation phase, AI tools were used to apply the framework stages and generate workshop content, which was reviewed by the author.

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Work in Progress Papers

A Literature Review Assignment: Fostering Skills in the use of Generative AI

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Abstract: The use of generative AI for scientific writing is expanding, but creation of a polished final product requires critical evaluation and editing of outputs. We redesigned a traditional undergraduate literature review assignment with the goals to develop student understanding of the capabilities/limitations of generative AI, build skills to critically analyse and refine AI-generated outputs, and strengthen proficiency in producing a literature review. Students first conducted a traditional database search to identify references related to a chosen research question and then used Microsoft Copilot (an enterprise edition that conforms to our university's usual privacy and data protections) to create an outline for the review (with AI-identified references). The students revised the outline and used it along with Microsoft Copilot to generate a literature review that they edited. For this assignment, the initial literature search, a one-page critique of AI-generated outputs and the revised outline were graded. The responses in the critique section of the assignment provided insights into the student perceived limitations of the use of generative AI in this context. Specifically, an analysis of all responses (n = 71) to the question: *"Are there any critical areas or perspectives missing that would strengthen the [generative AI] literature review?"* revealed several themes. Almost half of the students (n = 33) reported that the AI-generated review lacked specific details/examples with several reporting that biological mechanisms of action were missing (n = 15). The poor quality and lack of citations from the scientific literature was also a common theme (n = 12). Other themes included lack of future research directions/gaps in knowledge (n = 12), missing information about ethics/privacy (n = 8) and lack of information about drug complications/long-term unwanted or adverse effects (n = 8). When asked about the assignment in course surveys, the majority indicated that they were confident in their ability to evaluate AI-generated output and had gained a greater understanding of its potential limitations and advantages in supporting scientific writing. Our analysis highlights the value of our revised literature review assignment in helping students better understand the current limitations of generative AI and in building critical thinking skills. We believe that this assignment acknowledges the increasing use of generative AI in scientific writing and encourages its thoughtful use by students.

Keywords: large language learning models, generative artificial intelligence, critical thinking, scientific writing, literature review, skill development

1. Introduction

Generative AI, particularly large language models (LLMs), is transforming university education by offering tools for learning, research, and academic support. These models are trained on vast datasets to understand and generate human-like text, enabling them to assist with tasks such as drafting essays, summarizing complex readings, generating code, and facilitating language translation. In educational settings, LLMs can enhance personalized learning, support students with diverse needs, and streamline administrative tasks for educators. As their capabilities continue to evolve, integrating LLMs thoughtfully into curricula presents both opportunities and challenges that merit careful exploration (Alasadi and Baiz 2023; Bobula 2024; Behringer and Maguire 2024).

The recent and widespread availability of generative AI and LLMs that have the capability of rapidly completing assignments has necessitated a rethink of ways to develop skills that are needed to effectively use these tools (Maphoto et al. 2024). We believe that skill in the use of AI tools requires competencies that have previously been described in lists of undergraduate program learning outcomes. At our institution for example, graduating bachelor students from the Faculty of Arts and Science are expected to have acquired depth of knowledge in least one field of study and "competencies in learning and applying knowledge" that include: critical and creative thinking, communication, information literacy and social and ethical responsibility. In many undergraduate programs, critical thinking, communication and literacy skills are developed through assignments and tests. In

the life sciences, for example, these assignments can include literature reviews, abstracts, oral presentations, laboratory reports, and research proposals.

The recognition that scientists and other professionals are using AI (Wang et al. 2023; Black and Betts 2025) prompted us to redesign the first assignment in a larger scaffolded research proposal assignment in a third-year course for life science students entitled: *Research Readiness and Advancing Biomedical Discoveries*. In the past, the assignment required students to search the literature to identify papers on a chosen scientific curiosity and write a short literature review. The review forms the basis of a research proposal assignment that is submitted at the end of the course. In the revised assignment, students were still required to search the literature in the traditional manner (i.e. using Boolean strings within large publication databases) but are then instructed to use Microsoft Copilot to generate an outline (including references) of the literature review. The next step in the assignment was to critique and edit the generative AI output and submit the modified literature review outline. Thus, the goals of the revised assignment were to develop student understanding of the capabilities/limitations of generative AI, build skills to critically analyse and refine AI outputs, and strengthen proficiency in producing a literature review.

Here we describe our analysis of the effectiveness of the assignment in helping us achieve these goals.

2. Methods

To assess whether the students were able to critically evaluate the generative AI literature reviews, we analysed their responses to the assignment question: "*Are there any critical areas or perspectives missing that would strengthen the [generative AI] literature review?"* Specifically, the responses were anonymised and then grouped into themes using inductive coding.

Information regarding students' perceptions of the use of AI in the literature review assignment was also obtained via in-class anonymous surveys. Specifically, students were asked to rate the following statements: "*I feel confident in my ability to critically evaluate the information provided by AI-powered tools (in the literature review assessment)*" and "*I have a better understanding of the potential limitations and advantages of AI tools in supporting my scientific writing process*" on a 5-point Likert scale (where 5 = strongly agree and 1 = strongly disagree). The mean and standard error of the mean (SEM) of the ratings were calculated.

3. Results

A total of 71 students completed the literature review assignment, and several themes emerged upon the analysis of responses to the question: "*Are there any critical areas or perspectives missing that would strengthen the [generative AI] literature review?"*. Among the five most common themes, almost half of the students (n = 33) reported that the AI-generated review lacked specific details/examples with several reporting that biological mechanisms of action were missing (n = 15). The poor quality and lack of citations from the scientific literature was also a common theme (n = 12). Other themes included lack of future research directions/gaps in knowledge (n = 12), missing information about ethics/privacy (n = 8) and lack of information about drug complications/long-term unwanted or adverse effects (n = 8).

The responses to the survey questions regarding students' perceptions of AI use were also favourable (response rate: 85%, Figure 1). The majority (64%, mean +/- SEM = 3.33 +/- 0.14, n = 59) strongly agreed or agreed with the statement: "*I feel confident in my ability to critically evaluate the information provided by AI-powered tools (in the literature review assessment)*". In addition, the majority (75%, mean +/- SEM = 3.95 +/- 0.13, n = 59) strongly agreed or agreed with the statement "*I have a better understanding of the potential limitations and advantages of AI tools in supporting my scientific writing process*".

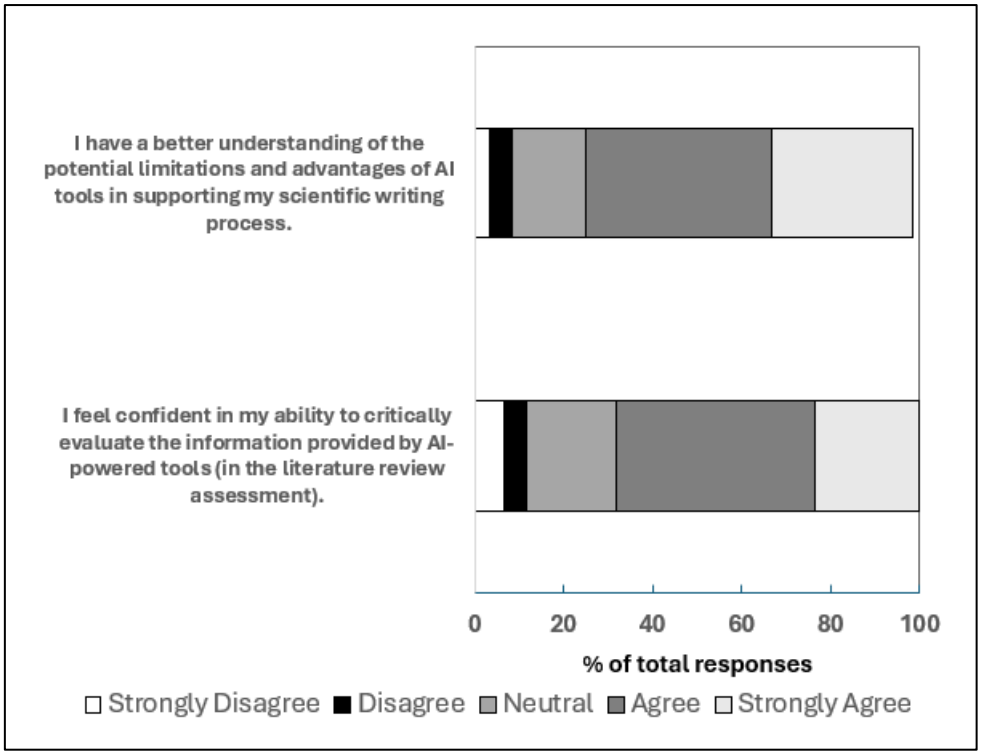


Figure 1: Students gained an understanding of and confidence in the use of generative AI in scientific writing. Data represent student responses along the Likert 5-point scale from 'Strongly Disagree' to 'Strongly Agree' to the above statements related to the use of generative AI in the literature review assignment. N = 60, note that one student did not respond to the statement at the top of the figure.

4. Discussion

The recognition that the use of generative AI employing LLMs is increasingly being adopted in several contexts prompted us to redesign our literature assignment to develop student understanding of the capabilities/limitations of generative AI and build skills to critically analyse and refine AI outputs. Our emphasis on critical analysis aligns with most university program learning outcomes. The assignment relies on a scaffolded approach and provides students with a model for interacting with generative AI, in that the process should be iterative and include critical thinking and goals for writing that in our opinion will become the standard approach to scientific writing.

Although the general availability and use of LLMs is relatively new, we note that other educators are beginning to adopt similar types of assignments requiring the use of generative AI and the analysis of its outputs. For example, Holtzman et al. (2025) have developed an assignment that they call ChatGPT Fact-Check in which students use ChatGPT to generate essays and then are asked to evaluate both the AI-generated sources and scientific claims by reviewing experimental evidence from primary sources. Although this assignment was deployed in three different biology courses, no analysis of the student critique was reported (Holzmann, Anand, and Payumo 2025). In a biochemistry course, students were asked to use ChatGPT to create an essay on nucleic acids and then were instructed to evaluate and iteratively refine the output (Reddy, Walter, and Sevryugina 2024). Two graduate level courses on counseling also included assignments in which students were asked to use ChatGPT to complete writing assignments and to critique the output (Csaszar and Curry 2024).

In terms of the student critique of AI-generated outputs, students in our course identified several limitations including lack of details and a lack of and poor quality of the citations. In the biochemistry assignment described above, students had generally positive impressions about the general knowledge provided by the AI tool but were mostly dissatisfied with citations and flow and style of the writing (Reddy, Walter, and Sevryugina 2024). The graduate students in the counselling course said that while the use of AI was beneficial as a starting point, it had limitations including lack of depth, absence of human qualities such as empathy, and issues with citations (Csaszar and Curry 2024). In a survey of over 400 university students, 68% of them reported using generative AI with most (94%) reporting that they used it for text generation. Despite their use of AI assistance, most students

were critical of generative AI output, and this mindset was reflected in their reported interactions with ChatGPT (Chen, Tallant, and Selig 2025).

Others have directly assessed the benefits and limitations of the use of generative AI tools in writing essays in the biomedical sciences. Specifically, essays were generated using three distinct LLMs and then marked by instructors using well-defined grading criteria. The AI tools were able to generate essays that generally met the scientific accuracy criteria for both undergraduate and postgraduate levels. Poorer performance was noted in the areas of providing mechanistic details and the coherence of the essays (Williams 2024). These limitations and those described above echo the main themes identified by students who completed our literature review assignment. This combined with the generally positive survey responses regarding student confidence and understanding of the limitations of AI use demonstrates that we achieved our assignment goals.

In closing, while it is important for students to fully understand the current limitations of generative AI in writing (Cohen and Moher 2025), we concur with others who have called for educators to teach thoughtful AI use as a tool for the future (Behringer and Maguire 2024). We believe our literature review and other similar types of assignments opportunities will help students develop critical thinking and communication skills and learn to iteratively assess and edit generative AI inputs/outputs.

Ethics declaration

This study was approved by the Institutional Research Ethics Board (University of Toronto, REB# 38613).

AI declaration

AI tools were not used in the creation of this manuscript.

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AI Training in Higher Education: Students' Experiences and Expectations Across Disciplines

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Abstract: As generative AI tools such as ChatGPT become increasingly embedded in higher education, students across disciplines are using them extensively—often without sufficient guidance. This study investigates how students from two contrasting faculties—economics and administration, and health and social sciences—experience current AI training and what they expect from future education in this area. Using a mixed-methods approach, the study analyses survey data from spring 2025, combining quantitative results with thematic analysis of open-ended responses. The study aims to offer practical insights to inform the development of effective, discipline-specific AI training in higher education.

Keywords: Artificial Intelligence, Innovation, Students, Training, Discipline-specific

1. Introduction

Artificial intelligence (AI), particularly following the emergence of generative AI tools such as large language models (LLMs), is rapidly changing the landscape of higher education. These technologies offer significant advantages, such as enhancing teaching through personalized support, dynamic content generation, and promoting active learning strategies. ChatGPT also fosters efficient and self-directed learning habits among students while assisting educators with administrative tasks, thereby enabling more time for pedagogical innovation (Sarker et al., 2023). Students are increasingly using AI for tasks such as searching for information, generating ideas, improving writing quality or organizing notes (Jereb & Urh, 2024; Zhou et al., 2024). Norway's 2024 National Student Survey by NOKUT, 'Studiebarometeret', with 26,000 respondents, underscores this trend, revealing that a substantial 81% of students used AI in their studies in 2024 (NOKUT, 2025). Yet, whilst many students have begun to use AI tools, 67% of students stated they lacked sufficient instruction on the responsible use of AI. This gap highlights a significant mismatch between student reliance on these technologies and the institutional support provided. The NOKUT survey also indicated clear interdisciplinary differences: 79% of economics and business students reported using AI frequently or sometimes, compared to only 48% of students in health, social work and sports sciences.

As large language models are rapidly integrated into higher education, often without sufficient pedagogical alignment or institutional support, both students and staff face significant challenges. Key concerns include ethical and legal uncertainties, unreliable AI-generated content, the potential for plagiarism, inequity in assessment, difficulty in detecting AI-generated work, and a lack of clear guidelines for ethical use. These issues threaten academic integrity, suppress student creativity, and create digital divides due to unequal access. They also highlight the urgent need for institutions to develop proactive strategies, including updated assessment designs, clear policies, and comprehensive training for both staff and students (Peláez-Sánchez et al., 2024; Cotton et al., 2023).

This study investigates how students from different disciplines perceive current AI training and their expectations for future learning in this area. The findings aim to equip universities with insights for designing tailored and relevant AI training.

2. Literature Review

According to Ng et al. (2021), AI literacy can be described as the foundational knowledge, abilities, and mindset that people require to comprehend, apply, assess, and develop AI technologies in a responsible and ethical manner across everyday life, professional settings, and educational contexts. Laupichler et al. (2022) emphasize that AI literacy is not limited to technical expertise, but includes the ability to critically engage with AI, communicate and collaborate with AI systems, and make informed decisions about their use. They argue that AI literacy must be adapted to the needs of specific groups—particularly non-experts in higher and adult education—who are increasingly expected to interact with AI in their professional lives.

An AI literacy course should give students a clear and practical understanding of artificial intelligence, including both how to use it and how to think about it responsibly. According to Hazari (2024), students should learn key

terms and concepts related to AI, and be able to write and improve prompts to interact effectively with AI tools. They should also know how to apply these skills in different situations, such as academic writing, creative projects, and business communication. In addition, students need to be able to judge whether AI-generated content is reliable, understand possible biases, and think about the ethical issues involved. They should also learn how AI can be used in different fields of study.

Hornberger et al. (2023) found that students in computer science and engineering more often have access to AI-related courses, while students in the humanities and social sciences are less likely to encounter such content in their study programs. This unequal distribution leads to significant differences in students' AI competence across disciplines. For example, engineering students score significantly higher than social science students on tests measuring AI literacy. Based on these findings, Hornberger et al. (2023) argue that AI education should be made more widely available in higher education and tailored to students' prior knowledge and disciplinary background. The goal is to ensure that all students, regardless of their field of study, are prepared to engage with AI technologies in their future careers. Lérias, Guerra, and Ferreira (2024) emphasize that teachers and educational leaders play a important role in the successful integration of artificial intelligence (AI) in higher education.

Students' experiences with AI education differ significantly between fields of study. In business studies, students often see AI as a tool for promoting innovation and improving efficiency. Many express a strong interest in learning more about AI, viewing it as an important asset for their future careers (Almaraz-López et al., 2023). In health sciences, students tend to approach AI with more caution. There is a strong focus on the ethical and professional consequences of using AI, especially in sensitive areas like patient care. As a result, these students call for education that not only teaches technical skills but also encourages a thoughtful and responsible attitude toward the use of AI in healthcare (Vázquez-Parra et al., 2024).

3. Aims and Research Questions

The study explores students' experiences with current AI training and their expectations for future training across disciplines. The aim is to identify what students need to effectively use AI in their studies and future professions. This leads to the following research questions:

> *How do students in different disciplines experience the training they have received in the use of AI in their studies?*
>
> *What training do students in different disciplines wish they had received in the use of AI in their studies?*

4. Method

This study uses a mixed-methods research design. While the research primarily emphasizes quantitative survey data, it is supplemented by an open-ended qualitative question designed to provide deeper insights into students' experiences with the AI training they have received and their expressed needs or wishes for future AI education within their respective disciplines.

Data was collected in spring 2025 through a digital survey sent to students in two faculties: economics and administration, and health and social sciences. Including these contrasting disciplines enables comparison between groups with differing AI use, as indicated by the national student survey Studiebarometeret (NOKUT, 2025). The survey was conducted via Nettskjema.no and distributed through Canvas and in-person during lectures.

Quantitative data derived from the survey will be analysed using SPSS. Qualitative data from the open-ended question will be subjected to thematic analysis to identify recurring patterns and themes in students' perceptions of how lecturers employ AI in their teaching.

Thematic analysis, as outlined by Braun and Clarke (2006, 2019), is a flexible and widely used method for identifying, analysing, and reporting patterns (themes) within qualitative data. It involves a systematic process typically encompassing familiarisation with the data, generating initial codes, searching for themes, reviewing potential themes, defining and naming themes, and finally, producing the report. This approach is particularly suited for exploring the full range of students' experiences, perceptions, and expectations expressed in the open-ended survey responses. It allows for a rich, detailed, and complex account of the data, providing deeper insights into how students understand and relate to AI training, and what they require from future AI initiatives.

Key limitations include the single-university sample (two faculties), which may affect generalisability; reliance on self-reported data, risking response bias; and the cross-sectional design, which makes it impossible to see long-term training effects.

5. Contributions

A challenge in developing AI training within higher education is the considerable variation in students' needs and expectations across different academic disciplines. Merely offering a generic, 'one-size-fits-all' approach to an AI curriculum may prove unsatisfactory. This study aims to make a contribution by directly addressing this issue, specifically examining how students from distinct faculties experience the formal AI training they receive and articulate their preferences for future AI training.

Ethics Declaration

No sensitive personal data were collected through anonymous surveys. The project complied with national ethical standards and was assessed as not requiring SIKT (Norway's Agency for Shared Services in Education and Research) approval. Participation was voluntary, with informed consent obtained via a pre-survey information text to the students (adults).

AI Declaration

Artificial intelligence (AI) was used as a support tool to improve language and phrasing in drafts of the paper. All academic analyses were carried out solely by the authors. No AI tools were used to generate content, but selected text sections were translated with assistance from ChatGPT. The authors have ensured the quality of the content.

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Review of Influencer Impact on Youth: Media Literacy, Consumer Behavior, and Critical Thinking

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Abstract: This literature review offers a comprehensive examination of current research on the influence of social media influencers on children and adolescents within the digital environment. It focuses on three core areas: the development of media literacy, the formation of consumer behaviour, and the capacity of young users to identify manipulative techniques and informational bias. Drawing on a wide range of scholarly sources, the review explores how influencers shape the values, attitudes, and decision-making processes of young social media users. Special attention is given to the subtle, emotional, and often elusive nature of this influence, which contributes to its effectiveness while simultaneously amplifying potential risks. The analysis highlights the role of influencers in the construction of digital identity and in shaping young people's perceptions of and engagement with commercial content. The findings provide a theoretical foundation for future research in media education and inform the development of educational interventions designed to promote digital well-being and media resilience among younger generations.

Keywords: Influencers, Social Media, Media Literacy, Consumer Behavior, Digital Identity, Critical Thinking, Review

1. Introduction

In today's digital age, social media influencers have become a ubiquitous presence in the lives of young people. With the rise of platforms like Instagram, TikTok, and YouTube, influencers have amassed large followings and wield significant influence over their audiences. However, the impact of influencers on youth has sparked debate among scholars, policymakers, and parents. This literature review aims to synthesize the existing research on the relationship between influencers and youth, with a focus on media literacy.

2. Literature Review

The proliferation of social media platforms has ushered in an era where influencers wield considerable power, particularly over the younger demographic, shaping their opinions, consumer behavior, and overall worldviews (Staňková & Kuchta, 2020). This influence stems from the parasocial relationships cultivated between influencers and their followers, blurring the lines between genuine connection and strategic marketing (Pirker, 2021).

Understanding the mechanisms by which influencers exert their sway is crucial for fostering media literacy, promoting responsible consumerism, and nurturing critical thinking skills among youth. The rise of influencer marketing reflects a paradigm shift in how brands engage with consumers, moving away from traditional advertising methods towards more personalized and seemingly authentic endorsements (Al-Mu'ani et al., 2023). Influencers, perceived as relatable and trustworthy figures, can significantly impact consumer buying behavior by leveraging their credibility and perceived authenticity (Rani et al., 2022).

The evolving digital landscape necessitates a comprehensive examination of the influencer phenomenon, its potential benefits, and its inherent risks, especially concerning its impact on young individuals (Permana et al., 2021).

The influencer marketing domain has emerged as a dominant force in digital engagement, surpassing conventional marketing methodologies in efficacy and consumer trust (Migkos et al., 2025). Influencers adeptly navigate platform affordances, experimenting with novel engagement strategies while sometimes testing community guidelines and service terms (Riedl et al., 2023). This necessitates a thorough investigation into the influencer's role in brand management and strategic decision-making (Sanz-Marcos et al., 2024).

More recent studies delve deeper into how specific platforms, particularly TikTok, have accelerated the personalization and immediacy of influencer engagement. A study published in *Nature Human Behavior* (2024) highlights the difficulties adolescents face in setting personal boundaries when engaging with TikTok content, suggesting a deterioration in digital well-being and time management skills. These findings underscore the importance of contextualizing influencer impact not just by message content, but also by the structural and algorithmic design of the platforms themselves.

Similarly, research by Muslimin (2025) conducted in Indonesia provides a cultural lens on the behavioral influence of TikTok, demonstrating how repetitive exposure to certain influencer norms fosters conformity among teens, extending from online personas to offline behaviors. This confluence of digital and physical spheres suggests that influencer impact transcends screen-based consumption and extends into the identity formation and social conduct of youth.

Furthermore, the development and proliferation of generative AI has added a new dimension to the challenges surrounding influencer influence. As content creation becomes increasingly automated and synthetic influencers enter the scene, distinguishing between real human endorsement and algorithmically generated promotion becomes increasingly difficult. This raises critical questions for media literacy education. Risko and Gilbert (2024) discuss how reliance on AI tools has led to a phenomenon known as "cognitive offloading," where individuals transfer critical thinking and decision-making tasks to external systems. For younger users, this can impair the development of independent judgment and media discernment.

In response to these developments, institutions such as UNESCO have emphasized the urgency of equipping influencers—and their audiences—with fact-checking competencies and resistance to misinformation. In its 2024 report, UNESCO calls for structured training programs for content creators and digital literacy campaigns that address the risks of manipulation, deepfakes, and algorithmic bias. These recommendations are particularly relevant considering the increasing professionalization of influencers, whose commercial interests may conflict with ethical responsibilities.

The educational sector has started to respond to these concerns by developing media literacy curricula that are both reflective and adaptive. Incorporating critical thinking into digital citizenship education has become a priority in many national strategies. These curricula aim to cultivate evaluative habits in students, encouraging them to question the motives behind content, analyse persuasive techniques, and identify biases—skills that are especially pertinent in influencer-dominated spaces. As noted by several scholars, the most effective interventions are those that situate media analysis within students lived experiences online, leveraging their familiarity with platforms while guiding them toward reflective and ethical engagement.

2.1 Digital Identity and Psychological Development

The relationship between social media influencers and the development of digital identity in youth is both intimate and complex. Adolescents, in the process of constructing their identities, are particularly susceptible to external role models. Influencers present highly curated versions of their lives, which often promote idealized standards of beauty, success, and lifestyle. This can result in social comparison and pressure to conform, with significant consequences for self-esteem and psychological well-being. Multiple studies have shown a correlation between exposure to idealized influencer content and increased levels of anxiety, body dissatisfaction, and feelings of inadequacy among teenage users (e.g., Tiggemann & Slater, 2014; Fardouly et al., 2018).

The issue is exacerbated by the algorithmic amplification of such content, which repeatedly exposes young users to narrow aesthetic and behavioral norms. As a result, adolescents may internalize unrealistic ideals and orient their self-worth around externally validated metrics such as likes, comments, and follower counts. This dynamic not only impacts mental health but also shapes long-term attitudes toward identity, value, and success in digitally mediated contexts.

2.2 Educational Interventions and Best Practices

In response to the growing influence of digital content creators, various countries and international organizations have initiated educational interventions aimed at strengthening youth media literacy. Programs like the European Commission’s DigCompEdu framework and UNESCO’s MIL curriculum focus on developing critical evaluation skills, digital citizenship, and ethical content engagement. These initiatives emphasize participatory learning, scenario-based analysis, and the inclusion of real-life digital case studies, which resonate more strongly with students than traditional didactic methods.

Research also suggests that involving influencers themselves as mediators or role models within media education programs can be a highly effective strategy. When influencers promote responsible behavior, transparency, and critical engagement, their messages are often more readily accepted by young audiences. This highlights the potential for influencers to serve not only as marketing agents but also as powerful allies in fostering digital resilience.

2.3 Methodological Challenges in Research

Studying the impact of influencers on youth presents several methodological challenges. Much of the existing data relies on self-reported behavior and perception, which may be subject to social desirability bias and inaccuracies in recall. The rapid evolution of digital platforms also complicates longitudinal research, as platform affordances, algorithms, and user cultures can shift dramatically within short time frames.

Another challenge lies in capturing the layered and often indirect nature of influencer impact. Effects may not be immediately observable and can unfold over time, especially in areas such as identity formation, value adoption, and peer dynamics. There is a pressing need for mixed-methods approaches that combine quantitative metrics (e.g., engagement rates, usage patterns) with qualitative insights (e.g., interviews, discourse analysis) to fully understand the depth and nuance of influencer influence.

3. Conclusion

This literature review has demonstrated that social media influencers have a complex and multifaceted impact on youth, extending beyond consumer behavior into the realms of identity formation, psychological development, and cultural adaptation. The pervasive nature of influencer content—amplified by algorithms and platform design—intensifies its influence, particularly among adolescents in vulnerable developmental stages. Influencers shape not only what young users buy or value, but also how they perceive themselves and others. The internalization of curated ideals promoted by influencers can erode self-esteem and distort digital identity, contributing to anxiety and body dissatisfaction. These effects are not uniform; they are mediated by cultural context, platform-specific norms, and the degree to which youth have access to critical media literacy skills.

Educational efforts must therefore address these challenges with adaptive, culturally responsive, and evidence-based interventions. Programs that engage both youth and influencers in the co-creation of reflective and ethical digital practices have shown promise. Additionally, research into influencer impact must move beyond surface-level metrics to include longitudinal, mixed-methods approaches that account for the evolving digital ecosystem.As artificial intelligence further blurs the line between authentic and synthetic influence, the need for critical thinking, emotional resilience, and ethical digital engagement becomes ever more urgent. It is imperative that educators, policymakers, researchers, and platforms work collaboratively to ensure that young people are not only protected but also empowered to navigate the influencer-saturated media landscape with awareness, agency, and confidence.

Ethics Declaration

No ethics approval was required for the preparation of this literature review article.

However, an application for ethical approval has been submitted to the ethics committee in relation to the forthcoming empirical research.

AI Declaration

AI tools were used in a limited and supportive role during the preparation of this paper. Specifically, DeepL Pro was employed for translation purposes and Elicit was used to assist with the identification of relevant academic sources.

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Co-Creating GenAI Imaginaries

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Abstract: Educational futures are often shaped by techno-utopian narratives. Moving beyond technology-pedagogy dichotomies, this paper adopts the concept of entangled pedagogy to explore how GenAI and large language models (LLMs) can reshape inclusive language education. Using a speculative and scenario-based participatory design approach, we engaged pre-service and in-service teachers in envisioning future classrooms. Through imaginative case studies and recursive scenario development, we examine how imaginaries inform practical design for postdigital learning environments. The study focuses on teachers meaning making when given concrete and pedagogical scenarios of GenAI use cases co-created by human-AI interaction. The results reveal tensions between imagination and the imaginable, hope and caution, underscoring the crucial role of the sociocultural context, as well as the importance of human mediation in GenAI-driven futures.

Keywords: Sociotechnical Imaginaries, Generative AI, Meaning Making

1. Introduction

The transformative potential of generative artificial intelligence (GenAI) in education is increasingly narrated through the lens of technological imaginaries (Jasanoff and Kim, 2015): utopian visions that promise personalized learning, greater inclusion, and unprecedented pedagogical efficiency. These discourses often emphasize the affordances of Large Language Models (LLMs) as intelligent partners in the learning process, capable of automating tasks, adapting to learners' needs, and supporting creative inquiry. However, such imaginaries frequently remain disconnected from the sociocultural and affective realities of educational practice (Qi and Chen, 2025). The day-to-day experiences of teachers—marked by emotional labor, ethical concerns, institutional pressures, and deeply held pedagogical values—are often rendered invisible in mainstream innovation narratives (Rahm, 2023). Considering these backdrops, the authors of this paper move from instrumentalist views (Bardone, Mõttus and Eradze, 2024) to a postdigital perspective (Jandrić, MacKenzie and Knox, 2023) of education. Rather than treating technology as external to (and separated from) pedagogy, we embrace the concept of Entangled Pedagogy (EP) (Fawns, 2022), which understands teaching and learning as situated within sociotechnical assemblages — complex, dynamic interactions between tools, values, infrastructures, imaginaries and the cultural practices of users. In this framework, neither pedagogy nor technology can be meaningfully discussed in isolation; their effects and meanings are co-constituted within contexts.

To engage with this complexity, we turn to scenario-based and speculative methodologies (Carroll, 2000; Rahm, 2024) as epistemic tools. Scenarios allow us to externalize and iterate future possibilities, serving as boundary objects through which participants can reflect on their desires, fears, and pedagogical priorities. Speculative design creates space for imagination, enabling the articulation of futures that are not yet realized but are shaped by present conditions (Ross, 2022). These methods are especially valuable for interrogating innovation in a postdigital condition—one in which digital and non-digital, human and non-human, infrastructural and affective elements are increasingly entangled (Knox, 2019).

2. Background

Previous research demonstrated how speculative and scenario-based methods can scaffold imaginative engagement with future classrooms. The present study focuses on how in-service teachers respond to, critique, and reshape speculative designs concerning pragmatic and socio-emotional dimensions of GenAI implementation. Moreover, EP offers a productive lens to investigate how educational futures are imagined, resisted, and negotiated. It foregrounds the socio-material and affective dimensions of educational change, emphasizing that innovation is not a linear process of adoption but a recursive, relational, and often contested practice. As such, it opens space for participatory inquiry into the imaginaries that teachers and students bring into their interaction with emerging technologies—imaginaries that are informed by culture, past experiences, professional identities, and visions of desirable futures. Building on sociotechnical imaginaries (Jasanoff and Kim, 2015), educational futures (Manna and Eradze) scenario-based research (Carroll, 2000) and speculative research methodologies (Rahm, 2024), we explore how future scenarios function as epistemic artifacts: mediating between the imaginative and the imaginable, the designed and the enacted, the emotional and the institutional.

3. Research Design

The project involved two key participant groups: pre-service teachers (n=78) which participated in speculative classroom design using GenAI platforms and persona-based scenarios, and in-service teachers (n=6), that participated in a co-design session focused on negotiating the GenAI future scenarios developed by pre-service teachers in earlier phases. A three-phase iterative process was implemented:

1. Student-generated speculative designs and personas
2. Researchers scenario co-creation with ChatGPT based on student input
3. In-service teacher co-design session, followed by sentiment and thematic analysis.

The student-generated speculative classroom designs from Phase 1 served as foundational inputs for the scenario generation process in Phase 2. Researchers first systematically analyzed (as reported in Manna and Eradze,2025) the student submissions to extract key themes, recurring values, envisioned classroom dynamics, and types of AI interactions imagined by the pre-service teachers. These insights were then reformulated using a prompt with custom ChatGPT to co-create pedagogically meaningful, narrative-driven outputs, emphasizing both pedagogical intent and stylistic tone. The resulting AI-generated scenarios aimed to extend the students' ideas while translating them into coherent and imaginable narrative forms. However, as discussed later, the outputs tended to standardize or neutralize speculative richness, revealing limitations in GenAI's capacity to maintain the complexity of human-designed imaginaries.

Phase 2 was conducted by a single researcher, who is one of the authors of this study, which acted as a mediator between the imaginative outputs from pre-service teachers and the AI-based scenario generation process aiming at concretizing the narrative-driven actionable scenarios. Drawing on the personas and speculative classroom designs from Phase 1, the researcher created prompts for custom chatGPT aiming to preserve the tone, goals, and educational values implicit in the student contributions. It must be acknowledged that her positionality as a researcher embedded in critical, postdigital education studies, inevitably shaped the interpretation of these inputs, introducing both reflexivity and bias in how the scenarios were curated.

Through all the phases, the data were collected through scenario texts, transcribed discussions, researcher notes, and audio recordings. Analysis employed narrative inquiry (Clandinin and Connelly, 2000), thematic coding (Saldaña, 2021) and sentiment analysis in R.

4. Data Analysis and Discussion

4.1 Imaginaries in Conflict: Findings From the First and Second Iteration

The contrast between students' and teachers' imaginaries revealed distinct orientations toward GenAI-mediated educational futures. Students envisioned post-institutional, nature-connected classrooms featuring shrinking furniture, AI-assisted sensory tools, and immersive ecological environments. These visions were playful, utopian, and largely unbound by infrastructural or policy constraints, positioning technology as a fluid enabler of embodied, experiential learning. In contrast, teachers perceived these scenarios as emotionally detached, pedagogically unfeasible, and potentially dystopian. Their primary concerns included the erosion of human connection, the difficulty of managing fragmented and hyper-individualized AI interactions, and the risk of amplifying educational inequalities. Moreover, the scenarios generated by ChatGPT—though seeded with imaginative prompts—tended to reproduce normative, tech-deterministic frameworks, underscoring the limitations of using GenAI as a co-designer. Rather than extending speculative complexity, the AI reinforced familiar tropes, revealing its tendency to default to dominant sociotechnical scripts and to struggle with speculative complexity (Ross, 2022; Dron, 2023). An example of a student-generated scenario is an "edible learning garden" where plants respond to children's questions through embedded GenAI interfaces, blending nature, language learning, and multisensory feedback. In contrast, the AI-generated version translated this into a more conventional outdoor classroom equipped with holographic displays and a biometric attendance system, sanitized of ecological metaphor and affective layering. This illustrates how imaginative play was flattened in AI output, reflecting normative narratives despite speculative input.

4.2 Fear of the Imaginable: Findings From the Third Iteration and co-design Activity

The third iteration of the study where the human-AI co-created narratives were presented to teachers, four interrelated thematic concerns surfaced that reflect what we term the *fear of the imaginable* and which are: The role of the teacher in an AI-driven classroom; Potential impacts on student learning and development;

Classroom design and organization; The role of technology in education. First, participants expressed their anxiety about the shifting role of the teacher in AI-mediated classrooms. While acknowledging the potential for educators to act as facilitators rather than mere content deliverers, they underscored the irreplaceable value of teacher empathy and emotional presence—qualities perceived as irreducible to algorithmic functions. Second, there were significant concerns regarding the impact of technology on student learning and development. Teachers worried about the erosion of personalized support and the widening of existing inequalities, particularly for students requiring differentiated attention. They emphasized the need for a sustained human-technology balance to safeguard holistic educational development. Third, reflections on classroom design revealed interest in flexible, needs-responsive spaces over traditional layouts, though infrastructural constraints were seen as major obstacles to implementation.

Finally, while participants recognized the affordances of technology—such as real-time feedback and personalization—they consistently warned against over-reliance. They argued for a critical pedagogical stance in which technology serves to augment rather than replace human interaction, with teachers positioned as active mediators of the educational experience. Together, these themes reflect a cautious, context-aware approach to GenAI integration—one that values technological affordances while defending the relational core of teaching and learning. Thematic coding followed an iterative process using NVivo and Saldaña's two-cycle coding approach. Initial descriptive codes (e.g., "loss of empathy," "tech overload," "flexibility") were later clustered into broader categories reflecting both affective and pedagogical concerns. Notably, the theme "role of the teacher" intersected heavily with both emotional labor and control over AI-mediated environments, indicating a central axis of negotiation. These overlaps suggest that tensions between relationality and automation permeated multiple thematic domains.

4.3 A Bad or a Good Feeling Towards the Future? Overall Sentiment Analysis

The sentiment analysis of the co-design discussion offered a nuanced emotional landscape, highlighting the ambivalent yet generally constructive attitudes of teachers toward GenAI integration. Positive sentiment emerged as the most dominant category (score = 20), suggesting that, despite expressed concerns, participants approached the future of GenAI entangled pedagogy with an overall optimistic and open mindset. Figure 1 shows a dominance of positive and trust-related sentiments, with lower but notable scores for negative emotion, fear, and anticipation.

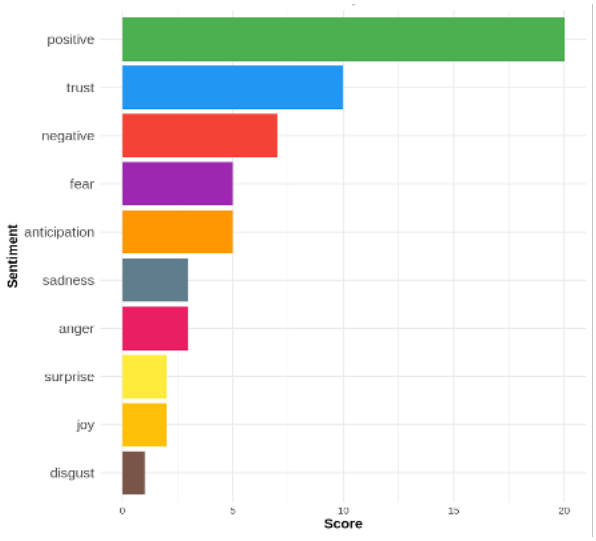


Figure 1: Sentiment Distribution of Teacher Responses to AI Integration Scenarios

Trust followed closely (score = 10), reflecting the emphasis placed on preserving foundational relational dynamics—particularly the teacher-student bond—within technologically mediated learning environments. Fear and anticipation were equally represented (scores = 5), indicating a dual orientation toward risk and possibility: while apprehensions about dehumanization and systemic inequities were present, so too was a forward-looking curiosity about educational transformation. Negative sentiment (score = 7) was evident but did not overshadow the discussion, reinforcing the notion that critiques were framed more as cautious engagement than rejection. Notably, expressions of joy and surprise were minimal (scores = 2), pointing to the pragmatism of the participants, who remained grounded in operational and ethical considerations rather than emotional

enthusiasm. The overall sentiment score (7.2) confirms a measured but hopeful stance, aligning with the broader thematic findings that underscore a desire for balanced, human-centered innovation in the postdigital classroom.

To deepen our understanding of the emotional dynamics surrounding GenAI integration, we visualized the distribution of positive vs. negative emotional categories (Figure 2). This comparison reveals a prevalence of constructive affect, with positive and trust scores outweighing all other sentiments. Nonetheless, the presence of fear, anticipation, and negative sentiment highlights a nuanced, ambivalent discourse: while participants remained hopeful, they were equally attuned to the ethical, relational, and infrastructural risks of implementing AI in educational contexts. The balance between expectation and caution—evident in the proximity of anticipation and fear—is indicative of what we describe as a postdigital realism: an approach that resists both techno-optimism and fatalism, favoring instead a grounded negotiation of sociotechnical futures. This polarity of affect, mapped across categories, reinforces the findings of the narrative analysis: teachers are not resisting technology wholesale, but rather engaging with it through a deeply relational and context-sensitive lens.

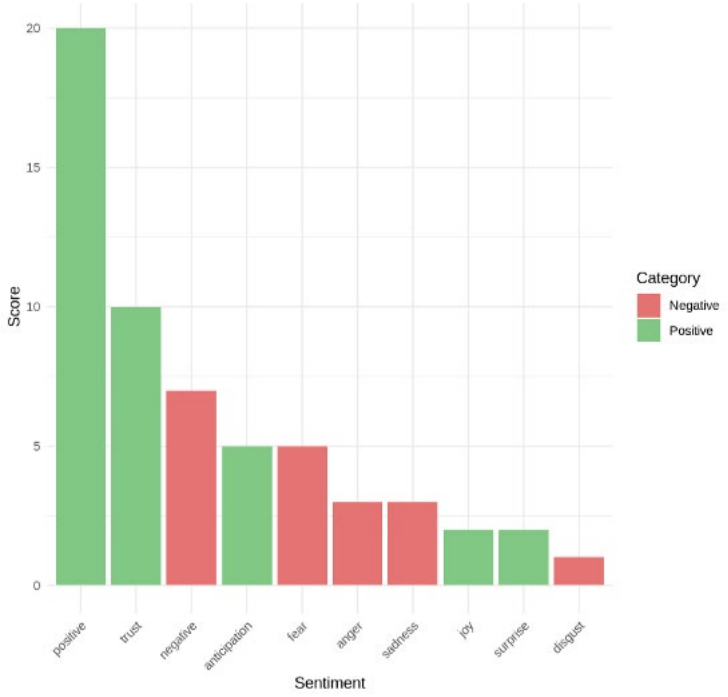


Figure 2: Comparison of Positive vs. Negative Emotional Categories in Teacher Responses

5. Conclusions

This study highlights the critical role of negotiation and contextual interpretation in shaping how GenAI is imagined and evaluated within educational settings. The participatory co-design process revealed a clear disjunction between speculative student visions—fluid and technologically optimistic—and the grounded, experience-informed perspectives of in-service teachers. While students embraced GenAI as a catalyst for reimagining space and interaction, teachers brought these imaginaries into conversation with the realities of classroom orchestration, ethical responsibilities, and the relational fabric of pedagogy. In this negotiation, GenAI emerged not only as a tool but as a socio-cultural mirror — a site where hopes for personalization and innovation coexist with anxieties about surveillance and emotional detachment. Teachers' responses underscored the need for a form of postdigital orchestration (Dron, 2023) in which technology is embedded meaningfully within the pedagogical, social, and institutional rhythms of practice.

In line with other studies (Qi and Chen, 2025), our findings stress that AI integration in education cannot be divorced from its sociocultural and institutional context. Teachers do not engage with GenAI in a vacuum; they do so as embedded actors within specific national education systems, linguistic communities, institutional structures, and pedagogical traditions. This is particularly relevant in language education, where identity, affect, and sociocultural nuance play central roles. By attending to these embedded contexts, we aim to understand not only what AI can do in education, but what it is allowed, resisted, or re-imagined doing by those at the front lines of practice. The findings obtained so far, carry institutional implications for teacher professional

development and AI policy. Teacher fears were not rooted in technological resistance per se, but in unresolved tensions between automation and care, efficiency and equity. Embedding GenAI in educational systems must therefore go beyond functionality, attending to teachers lived experiences and ethical commitments. From the perspective of entangled pedagogy, the co-design process reveals that futures cannot be designed without those who will inhabit them, highlighting the need for participatory governance in educational AI design.

Ethical Declaration

Ethical clearance was not needed, and informed consent forms were acquired from the participants.

AI Declaration

"Julius AI" was implemented as a support platform for the analysis conducted by the researchers.

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Students' Perspectives on Lecturers' Use of Artificial Intelligence in Higher Education: Perceptions and Impacts

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Abstract: The use of artificial intelligence (AI) in higher education is rapidly increasing, both among students and lecturers. However, knowledge about how students perceive lecturers' use of AI remains limited. In Norway, there are significant differences in the use of such tools across various disciplines. Students in economics and business administration are among those who report the highest use of AI, while students in health and social studies report the lowest use. It is therefore interesting to examine how students perceive lecturers' AI use within the academic communities of economics and administration, as well as health and social studies. The aim is to explore students' views on lecturers' practices, and students' acceptance and engagement with such tools in their own learning. This study addresses two research questions: (1) How do students experience openness and perceived value related to the use of AI in teaching? (2) How do lecturers' practices with AI relate to students' attitudes toward and use of the technology?

Keywords: Artificial Intelligence, Student Perceptions, Lecturer Technology Use, Innovation, Technology Acceptance

1. Introduction

Artificial intelligence (AI) is rapidly transforming a wide range of industries, including the field of education. With advances in machine learning and natural language processing, AI has the potential to enhance individual learning processes (Harry, 2023; Wu & Yu, 2024). The use of AI in higher education has increased rapidly in recent years (Crompton & Burke, 2023; Delcker et al., 2024; Mah, 2016; NOKUT, 2025), and tools such as ChatGPT are reshaping the landscape of higher education. This has sparked debate about the implications of AI for the future of teaching and learning (Korseberg & Drange, 2024; Von Garrel & Mayer, 2023).

In Norway, the national student survey *Studiebarometeret* shows that the use of AI has increased significantly in just the two years it has been collecting data on the topic. In 2023, 59% of students reported using AI tools in their studies; in 2024, the figure was 81% (NOKUT, 2025). However, students are not a homogenous group, and *Studiebarometeret* reveals substantial variation between academic disciplines. Among students in economics and business administration, 79% reported using AI often or occasionally. In contrast, only 48% of students in health, social work, and sports sciences reported the same (NOKUT, 2025). This may also raise questions about how lecturers engage with AI across different academic disciplines.

2. Theoretical Framework

This study is grounded in the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1977) and the Theory of Planned Behavior (TPB) (Ajzen, 1991). These models provide a framework for understanding how attitudes and subjective norms influence students' intentions and behaviours related to AI usage. Both theories have previously been applied in research on students' adoption of AI tools (e.g. Katsantonis & Katsantonis, 2024; Suh & Ahn, 2022).

TRA and TPB are based on the assumption that behaviour is guided by intention, which in turn is influenced by two central factors: the individual's attitude toward the behaviour and the perceived subjective norm. In TPB, perceived behavioural control is included as a third factor (Ajzen, 1991; Fishbein & Ajzen, 1977). This study focuses on attitude and subjective norm— as these are particularly relevant for understanding the value of students' perceptions of lecturers' use of AI.

2.1 Attitudes

Attitude can be defined as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour" (Eagly & Chaiken, 1998). It reflects the individual's assessment of whether a specific behaviour is positive or negative, based on expected outcomes and the desirability of those outcomes (Ajzen, 1991; Fishbein & Ajzen, 1977).

2.2 Subjective Norms

Subjective norm refers to an individual's perception of how significant others expect them to behave, as well as the individual's motivation to comply with these expectations (Fishbein & Ajzen, 1977). For example, subjective norm may influence intention if a student perceives that lecturers or academic staff have strong preferences for the use of AI, and the student is motivated to act in accordance with those expectations.

In a literature review, Hoya et al. (2024) demonstrates that subjective norms influence students' attitudes toward data use and AI. They particularly highlight how this is evident in studies on teacher education. Teo (2009) demonstrated that subjective norm influenced attitudes toward data use in teacher education in Singapore, Ursavaş et al. (2019) reported that subjective norm had a strong impact on behavioural intentions and attitudes toward educational technology among Turkish pre-service teachers, while the effect was weaker among in-service teachers. Sanusi et al. (2024) found that subjective norm was among the strongest predictors of pre-service teachers' intention to learn about AI in Nigeria. Similarly, Zhang et al. (2023) found that both perceived usefulness and subjective norm predicted AI use intention among German teacher students. Studies in other disciplines confirm this trend. Gado et al. (2022) found that subjective norm influenced psychology students' engagement with AI tools, and Ivanov et al. (2024) reported similar results in a broader university student sample.

However, there remains a research gap concerning the factors influencing students' attitudes toward AI across different academic disciplines and geographic regions, particularly with respect to the role of lecturers.

3. Aims and Research Questions

Building on the theoretical framework and the practical challenges outlined above, this study aims to contribute to a broader understanding of students' attitudes toward artificial intelligence in higher education. Specifically, it investigates how students perceive the use of AI by their lecturers, and how these perceptions relate to their own engagement with AI tools. The overall aims of the study can be divided into two research questions:

How do students experience openness and perceived value related to the use of AI in teaching?

How do lecturers' practices with AI relate to students' attitudes toward and use of the technology?

4. Methodology

This study employs a mixed-methods approach, combining quantitative and qualitative data to examine students' perceptions of lecturers' use of AI at a Norwegian university. The primary emphasis is on quantitative survey data, supplemented with an open-ended qualitative question to gain deeper insight into students' experiences and viewpoints regarding AI integration in teaching.

4.1 Survey Development

The attitudinal dimensions in the survey are based on the "Student Attitude Toward Artificial Intelligence" (SATAI) scale developed by Suh and Ahn (2022) which operationalizes the cognitive, affective, and behavioural dimensions of students' attitudes toward AI. This was supplemented with two items measuring students' attitudes toward lecturers' use of AI. These items were developed based on TRB (Ajzen, 1991), TRA (Fishbein & Ajzen, 1977). In addition, two questions were included to capture students' perceptions of how lecturers use AI in teaching. To explore students' perceptions of what lecturers, use AI for, the survey included an open-ended question.

4.2 Sample and Data Collection

Data were collected in the spring of 2025 through a digital survey distributed to students in economics and administration, as well as in health and social sciences. Including students from contrasting academic disciplines strengthens the study by enabling comparisons between groups that report high and low levels of AI use in the national student survey *Studiebarometeret* (NOKUT, 2025). The survey was administered using the Nettskjema.no platform and distributed via the university's learning management system, Canvas, as well as during lectures. A total of 104 students participated in the survey. Data collection has been completed, and the next step in the research process will be to analyse the data.

4.3 Data Analysis

Quantitative data will be analysed using SPSS. Qualitative data will be analysed using thematic analysis to identify patterns in how students perceive lecturers' use of AI in teaching.

5. Contributions

This study contributes to the growing body of research on AI in higher education by examining students' perceptions of lecturers' use of AI. Existing research has primarily focused om students' own adoption of AI tools. This study addresses a less explored area—how students experience and respond to AI use by their lecturers.

The results may have practical implications for the use of AI in teaching within higher education and may provide a foundation for further research on how lecturers' practices influence students' attitude formation and technology use.

Ethical Considerations

The study was conducted in accordance with the institution's guidelines for research ethics and data protection. Participation was voluntary and anonymous, and informed consent was obtained.

AI Declaration

Artificial intelligence (AI) was used as a support tool to improve language and phrasing in the article draft. All scholarly analysis, data interpretation, and conclusions were conducted solely by the authors. No AI tools were used to generate content or perform analyses. However, selected sections of the text were revised and translated with assistance from ChatGPT. The authors have reviewed and verified all content to ensure academic integrity.

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Students' Attitudes Towards Artificial Intelligence Across Disciplines in Higher Education

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Abstract: As artificial intelligence (AI) becomes increasingly integrated into higher education, it is crucial to understand how this affects students' learning. This study examines variations in students' cognitive, affective, and behavioral attitudes towards AI across different academic disciplines, with a comparative focus between students (n=104) in economics and administration and in health and social sciences. The increase in the use of AI tools raises important questions related to academic integrity, plagiarism, and the potential weakening of critical thinking. This study seeks to map these differences and explore how students perceive AI's impact on their learning process, with the aim of developing suitable teaching approaches for different student groups.

Keywords: Artificial Intelligence, Students, Attitudes, Innovation, Higher Education, Learning

1. Introduction

Artificial intelligence (AI) is a field within computer science aimed at solving various cognitive problems, such as problem-solving and learning. It also includes models for the development of computer systems that mimic human traits (Chassignol et al., 2018; Chen et al., 2020). ChatGPT and other large language models are based on generative artificial intelligence. These tools generate new content by analyzing patterns from diverse training data (Ooi et al., 2023). In AI-powered chatbots like ChatGPT, this occurs through interaction with the user, where responses are generated based on user input. The rapid development and lack of knowledge makes it challenging for the higher education sector to implement adequate measures to address the development and use of such tools (Korseberg & Drange, 2024). AI plays an important role in fields such as technology, economics, and politics. It is likely that the fourth industrial revolution will be defined by the relationship between humans and AI (Suh & Ahn, 2022).

The use of AI in education has thus gained increased importance (Suh & Ahn, 2022), and many researchers are concerned with what should be taught related to AI (e.g.Touretzky et al., 2019; Yoo, 2019). Xu and Ouyang (2022) note that AI can serve multiple functions in higher education: from replacing or supporting instructors to acting as a fellow student. AI can also be used to streamline tasks related to teaching and learning. Alternatively, AI tools may be regarded as unnecessary for teaching and learning purposes but can supplement the understanding of learning behaviors.

Yoo (2019) shows that openness to learning about AI is the most important precondition for developing AI-related competencies in education. If students do not have a positive attitude towards learning these skills, it is unlikely that they will master them, regardless of the quality of the training they receive (Ajzen, 1991; Fredrickson, 2001). Therefore, measuring attitudes toward AI can be an important factor in determining the success of educational efforts (Suh & Ahn, 2022). There remains a need to explore whether students embrace these technological advances and what their attitudes toward AI are - ideally in relation to different academic disciplines (Katsantonis & Katsantonis, 2024).

In Norway, 59% of higher education students report using AI in their studies either frequently or occasionally. Among the top-ranking disciplines are economics and business administration, where 79% of students report using AI. At the lower end of the scale are health-, social-, and sports sciences, where only 48% of students report using (NOKUT, 2025).

2. Theoretical Framework

The concept of attitudes is central and debated in the literature, with a range of definitions. How the attitude object is defined influences whether attitudes can be used to predict behavior.

Attitudes can be defined as favorable or unfavorable evaluations of a specific object, person, or behavior (Ajzen, 1991; Ajzen & Schmidt, 2020; Kemp et al., 2019).They often comprise three dimensions: affective, behavioral,

and cognitive (Metsärinne & Kallio, 2016; Suh & Ahn, 2022). According to Metsärinne and Kallio (2016), attitudes can be understood as a person's characteristic way of thinking, feeling, and acting.

Despite the growing importance of AI in higher education, there are still few comprehensive empirical studies that systematically examine students' attitudes toward AI. Some notable exceptions include Almaraz-López Almaraz-López et al. (2023), Ghotbi et al. (2022), Hajam and Gahir (2024) , Katsantonis and Katsantonis (2024), Lien et al. (2025), Pellas (2023) and Yüzbaşıoğlu (2021). Few of these studies, however, offer a holistic assessment of students' attitudes toward AI, and only Katsantonis and Katsantonis (2024) explicitly differentiate between cognitive, affective, and behavioral dimensions. These researchers recommend further studies and development of measurement instruments and suggest that future research should include students from a broader range of disciplines to provide a more comprehensive picture of students' attitudes toward AI. The present study responds to that recommendation by comparing students from two different faculties.

3. Research Questions

Building on the considerations outlined above, this study aims to examine the attitudes of university students in economics and administrative sciences, as well as in health and social sciences, regarding the role of AI in their education and future professions. The overall aims of the study can be divided into three research questions:

How do cognitive, affective, and behavioral aspects of attitudes towards AI vary between students in economic and administration disciplines and students in health and social sciences?

How do students in the different subject areas perceive AI's impact on their learning process?

4. Method

4.1 Survey Development

Several previous studies on students' attitudes toward AI use a survey-based research design, which is considered suitable for measuring attitudes (Cohen et al., 2002). This study adopts the same approach.

To capture a broad range of student attitudes toward AI, we employed the recently developed "Student Attitude Toward Artificial Intelligence" (SATAI) instrument. This tool measures cognitive, affective, and behavioral attitudes toward AI (Suh & Ahn, 2022) and has been used with university students (Katsantonis & Katsantonis, 2024). In this study, the scale includes a total of thirty items: 10 items measuring behavioural attitudes, 7 measuring cognitive attitudes, and 13 measuring affective attitudes. The survey was translated and adapted to the Norwegian context for higher education and supplemented with an open-ended exploratory question regarding students' views on how AI affects their learning process. The questionnaire was piloted with both faculty members and students with varying levels of experience using AI in educational contexts. The testing showed that the items were relevant, and only minor linguistic adjustments were made.

4.2 Sample and Data Collection

In spring 2025, a digital survey was distributed to students (n = 104) at two faculties at the University of Inland Norway: the Faculty of Health and Social Sciences and the Inland School of Business and Social Sciences. The selection of faculties was based on data from the national student survey (Studiebarometeret), which showed contrasting levels of reported AI use between these disciplines (NOKUT, 2025). Data were collected using Nettskjema.no, a secure and institutionally recommended tool for research data collection in Norwegian higher education. The survey was distributed through the digital learning platform Canvas and during selected teaching sessions. Participation in the survey was voluntary and anonymous. Information about the purpose of the study was provided at the beginning of the questionnaire and in the accompanying text during distribution.

4.3 Analysis

Quantitative data will be analyzed in SPSS using descriptive statistics to provide an overview of background variables and map students' attitudes toward AI. To validate the Norwegian version of the SATAI scale, an exploratory factor analysis will be conducted. Correlation analyses will be used to identify relationships between the attitude dimensions and various background variables. Qualitative responses will be analyzed thematically to identify patterns in how students perceive AI's impact on their learning.

5. Aims

The study aims to contribute insights into how higher education institutions can adapt their teaching approaches to meet the needs and attitudes of various student groups regarding AI. The study will provide a basis for developing relevant teaching programs.

Ethical Declaration

The study was conducted in accordance with ethical research guidelines. Participation was voluntary and based on informed consent. Data collection was anonymous to protect participants' privacy and autonomy. No sensitive personal data were collected, and the data are considered to have low identifiability. No follow-up contacts were made with participants. The ethical considerations align with the principles described by Johannessen et al. (2010).

AI Declaration

Use of AI was used as a support tool to improve language and phrasing in the article draft. No AI tools were used to generate content or perform analyses. However, selected sections of the text were revised and translated with assistance from ChatGPT. The authors have reviewed and verified all content to ensure academic integrity.

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Late Submissions

Harnessing the Generative AI Wave Towards Fair and Diverse Higher Education Assessments: A Comprehensive Analysis through an Innovative Lens of Students

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Abstract: While Generative Artificial Intelligence (GAI), particularly tools powered by Large Language Models (LLMs), offer benefits in teaching and learning, they also raise critical concerns about academic integrity, fairness in examinations due to their potential for generating educational content. This evolving landscape requires higher education institutions to rethink their assessment models, ensuring they remain robust, inclusive, and aligned with the realities of AI-enhanced learning environments. In this backdrop, this study investigates the practical, GAI-resistant assessment frameworks in higher education. It explores how alternative, skill-focused methods such as oral exams (vivas) and AI-integrated tasks can be included in future assessment models. Central to the study is the understanding of how students perceive current assessments and envision future methods that fairly and effectively measure both knowledge and skills. The empirical investigation is based on a case study at a Swedish University. Research methodologies include a survey questionnaire administered to 30 students enrolled in a semi-theoretical course on innovation and technology, and a future workshop (FW) with 22 of them in five groups. The two research instruments corresponded to answering the two research questions, respectively. The survey results revealed students' clear concerns about the academic integrity challenges posed by essay and report-based take-home assessments, as well as online quizzes. They also expressed apprehension about the potential impact of relying solely on proctored and supervised exams, highlighting the risk of reducing diversity in assessment methods, and thereby raising red flags for the need for a new and innovative approach to assessment methods that is hardly affected by unauthorised assistance from GAI. Responses to open survey questions reflected their problem-solving mindset and deep thinking of how cheating can be minimised by increased peer collaboration and solving real problems, contextualised to specific and ongoing learning activities in class. The outcomes of the FW provided insights, such as active learning-based assessments, combined with real-world problem-solving or context-specific question-based assessments. These findings are intended to inform course design, policy-making, and broader discussions on educational reform in the digital age.

Keywords: AI-resilient Assessment, Academic Integrity, Fairness in assessment, Diversity, Higher Education

1. Introduction

Generative Artificial Intelligence (GAI) is rapidly transforming higher education, particularly in learning and assessment (Alam, 2021; Tlili et al., 2023). GAI, powered by Large Language Models (LLMs), enables new learning pathways by generating human-like text (Kasneci et al., 2023; Thorne, 2024). GAI variants, i.e., Generative Pre-trained Transformers (GPTs) such as ChatGPT and MS Copilot, have become handy in reshaping education (Ouaazki et al., 2023), but raising concerns about academic integrity (Gopane et al., 2024; Sullivan et al., 2023). The current research evidence pinpoints significant challenges to certain assessment methods in higher education due to GAI (Kasneci et al., 2023). Given that basic university courses predominantly aim to assess core conceptual understanding aligned with intended learning outcomes, the use of GAI during assessments raises concerns about academic integrity, particularly due to its capacity for reproducing content with minimal student input (Gamage et al., 2023). Non-proctored written exams, take-home assignments, and online quizzes, which have long been used to assess students' continuous progress in learning, are now increasingly vulnerable to AI-assisted academic misconduct (Xia et al., 2024). The situation is inarguably more troubling in online courses. However, dropping AI-vulnerable assessment types could negatively impact the quality and diversity of examinations since the potential of non-proctored examinations (especially with open-ended, application-based tasks) on deeper learning has been well justified in contemporary education research and practice (Gamage et al., 2023; Karunaratne et al., 2025). Such limitations will directly affect the diversity of the assessments since having scaffolded and different types of assessments is essential for fair measurement of skills and competencies (Karunaratne et al., 2025). Under these circumstances, teachers will now have to ensure they either use innovative complementary methods that are non-sensitive to AI or limit the assessment methods only to traditional proctored forms. Consequently, students may miss the opportunities to perform their assessment

tasks in a more explorative, relaxing and enjoyable environment. Limiting to a few assessment types will also negatively impact the overall education quality (Karunaratne et al., 2025). Therefore, an urgent need has emerged for a shift toward more authentic, dynamic, and practice-oriented assessment methods that also utilise human competencies, such as collaboration, creative thinking, critical analysis, and effective communication, which are soft skills becoming essential for students to successfully navigate and contribute to an AI-driven workforce (Xia et al., 2024).

Despite growing recognition of these challenges in higher education, established and scalable models for AI-resilient assessment remain scarce, especially in semi-technical courses that contain intended learning goals to balance the evaluation of theoretical knowledge with the development of practical skills. (Aghaee & Karunaratne, 2023). The pragmatic challenge lies in developing innovative, diverse assessment frameworks that ensure fairness, sustain engagement, and accurately measure students' abilities while preventing academic misconduct related to AI. What is significant here is the dual and interconnected view on innovative and authentic assessments, particularly emphasising the soft skills students should develop and demonstrate during both formative and summative activities within an academic course. Numerous studies in the literature, including the study by Aghaee & Karunaratne, (2023), highlight the significance of excelling in skills such as communication, collaboration, teamwork, leadership, creativity, participation, academic writing, and so forth to succeed in assessments. For example, in an oral exam (examination vivias or viva-voce), students must not only deliver the content verbally but also express it more concisely, clearly, and progressively. Such soft skills are increasingly being explicitly assessed in future education scenarios to enhance employability (SkillsMatch, 2018). Therefore, in this study, we argue that innovative assessment methods cannot be effective without considering the soft skills embedded within them.

In this backdrop, this research essentially emphasises the lack of insights into pragmatic frameworks for innovative assessment methodologies resistant to GAI. Therefore, it investigates how and what alternative, skill-focused assessment models, including oral exams, activity-based evaluations, and AI-integrated critical analysis tasks, can be suitably integrated for future university education. In doing so, we examine how students envision their learning can be better assessed in the age of GAI. However, for students to envision an ideal future assessment structure, they must first understand the current examination landscape within both formative and summative assessments and their view of the potential of the current assessments in measuring their skills and subject competencies. Thus, this study will first explore how students envision the roles of soft skills in their education and employability in the job market. Specifically, this study is driven by the following research questions:

[RQ1]: How do students perceive knowledge and skills assessment in the current higher education examination landscape?

[RQ2]: How do students envision the assessment methods that can reflect students' learning, knowledge, and skills while promoting fairness in grading in higher education?

By answering these RQs, we intend to derive insights to form guidelines that can be utilised in various courses and used to examine the effectiveness of these methods in real-world course settings. Furthermore, the outcomes will contribute to the future development of scalable, AI-resilient assessment strategies that enhance learning integrity and align with the evolving demands of higher education and the workforce. As universities, policymakers, and employers seek solutions, the study outcomes are also expected to provide insights for timely alternatives that will inform education policies, improve assessment practices, and contribute to wider discussions on digitalisation and learning integrity, making it highly relevant to academia, industry, and public debate.

2. Methodological approach

As described above, this research was formulated to explore how students envision the innovative composition of an AI-resistant assessment framework. Considering that understanding how students perceive the current assessment landscape is a mandatory component, the first step is to investigate how students envision their typical assessment frameworks in their courses, as a basis for problematisation of the assessment frameworks for the future. Thus, the methodological design combined preparatory background data collection with a short survey, followed by a deep dive into AI-resilient assessments through the Future Workshop (FW) that developed creative collaboration, critical reflection, and the co-design of potential solutions. This study employed FW methodology, following the structure outlined by Vidal, (2006) and based on the original model developed by Jungk & Müllert, (1987). The approach was selected for its alignment with democratic problem-solving and

participatory design principles, particularly its capacity to create collaborative ideation and critical engagement among participants with shared learning contexts.

2.1 The case study

In this empirical research, a case study strategy is applied for several reasons, including that case studies enable a deep and nuanced exploration of the problem being investigated. The selected case study is a course in informatics that integrates design thinking into digital transformation at a higher education institution in southern Sweden. The specific reason for choosing this course is that it is semi-technical, requiring the evaluation of both theoretical knowledge and practical skills to meet the intended learning goals. As mentioned above, such courses demand diverse assessment methods to capture students' knowledge and skills. Additionally, the course also addresses the transformative aspects of technology and includes learning objectives for developing innovation competence. Since the students are the subjects of this study, selecting such a course helps to minimise bias caused by students' design methodological knowledge. In other words, the students involved already possess knowledge of the technical and social aspects of digitalisation and innovation methodologies, which reduces bias related to skills and competence in design thinking and innovation design.

2.2 Study participants

The participant group comprised 30 bachelor's students, organised into five groups for the workshop activity. Of these, 22 students provided informed consent for their contributions to be included in this publication. One group participated in the full workshop activity but later indicated that they did not wish their input to be included in the publication. Consequently, the analysis for this study is based on the inputs from the four remaining groups. Although the gender proportion was fair, no demographic information, such as age or gender, was directly collected to preserve anonymity. All participants had prior familiarity with key concepts such as Generative AI, co-design, and assessment diversity, which enabled them to engage meaningfully with the workshop content. Furthermore, no personal data, nor any reflections derived from students' course results or assessments, were collected or utilised in the FW activity, or neither in the preparation of this publication.

2.3 Pre-workshop survey

The pre-workshop survey consisted of a brief questionnaire administered to 30 students via the interactive digital platform Mentimeter. Participation was voluntary, and informed consent was presented and obtained prior to the submission of responses. This survey included three closed-ended and three open-ended questions. The questions assessed students' awareness of how different assessment types reflect the skills and subject competencies, the challenges students face generally in higher education regarding demonstrating their learning, the assignment types they perceived to be best showcasing their knowledge acquisition, and whether supervised exams or vivas would make the assessments fairer. The open questions allowed students to state other assessment types, challenging them to demonstrate their knowledge, and how they envision re-designing exams to allow them to showcase their competencies. The data collected served to contextualise the upcoming workshop activities by revealing the participants' conceptual entry points and general orientation toward the topic., While the questionnaire serves as a basis for understanding the perception of assessment types and their consequences, it also sensitises facilitators about students' abilities of design thinking.

2.4 Future workshop for participatory co-design

The Future Workshop followed the classical three-stage structure as outlined by Vidal (2006). Preparatory activities were an official initial phase to start the workshop, serving as a warm-up and providing information to the participants. The short survey was also conducted as part of the preparation phase. During this stage, students were also asked to problematise the topic, having an awareness of the task to build. In the second phase, the critique phase, participants in groups collectively identified the challenges and shortcomings in current assessment types in higher education, reflecting their own experiences and perceptions triangulated with the existing accessible knowledge available. These reflections, grounded in students' academic experiences, enabled them to critically examine prevailing challenges in the practices of higher education. The moderator additionally introduced and facilitated brief discussions on the role of generative AI and the growing importance of soft skills in the context of ongoing educational transformation.

In the third phase, the fantasy phase, participants generated speculative ideas for innovative assessments that could address the previously identified problems and develop solutions connected to AI-resilient exams. In line with the FW model, this phase encouraged participants to suspend constraints of realism and explore aspirational, creative design directions. The emphasis was placed on open-ended thinking rather than immediate feasibility, creating space for imaginative alternatives to conventional learning strategies. The fourth and final phase in this workshop, referred to as the implementation phase, required groups to refine and consolidate

their concepts into more concrete forms. This was done using the MoSCoW prioritisation framework (Waters, 2009), which helped participants distinguish between essential and non-essential features of their proposed solutions. MoSCoW is a requirements prioritisation method that categorises features into Must have, Should have, Could have, and Won't have (at this time). Each group created low-fidelity prototypes (due to the complexity of the problem, limited time for design activity, and the outcomes are not complete) to illustrate their concepts, using digital tools such as Padlet, Canva, and Miro, or traditional tools like pen and paper, to visualise interaction flows, motivational elements, and intended learning outcomes.

The workshop phases marked a transition from problem and abstract ideation to grounded design work, allowing students to articulate how their ideas might be realised in practice. As there was no direct prototype or product resulting from this workshop, the follow-up phase was not included in the workshop, and participants were informed accordingly. Throughout all phases of the workshop, the process was designed to encourage democratic participation, mutual learning, and the negotiation of meaning among group members (Spinuzzi, 2005). These elements are central to both participatory design and the pedagogical goals of developing soft skills.

3. Results and Discussion

The results were organised in two sections, i.e., the survey study outcomes intended to answer RQ1: the students' understanding of the current assessment landscape and the viewpoint for the future, and the FW activity for innovation of AI resilient assessment, answering RQ2.

3.1 Pre-workshop survey on the current assessment landscape

The pre-survey is guided by a preamble of the problem, namely, that "*the rise of GAI tools is disrupting the traditional assessment methods in higher education, making take-home assignments and online quizzes increasingly vulnerable to AI-assisted cheating. We are studying how to design fair and engaging university assessments in the age of AI. The survey asks for your opinions on current exams and ideas for new assessment models. The survey is to gather students' input on designing AI-resilient exams for the next round of this course and similar courses in higher education*".

The questions were constituted with an overview of the exam landscape. Firstly, capturing the view of common types of (continuous) assessments, such as project work, project reports, project oral presentations, oral examinations (Viva-voce), online quizzes, supervised exams (in exam halls) and other types that students feel provide the opportunity to demonstrate their knowledge and skills acquisition. As Figure 1 shows, students think project works enable their knowledge reflection the most. The interesting outcome here is that online quizzes are not among the most attractive assessment types.

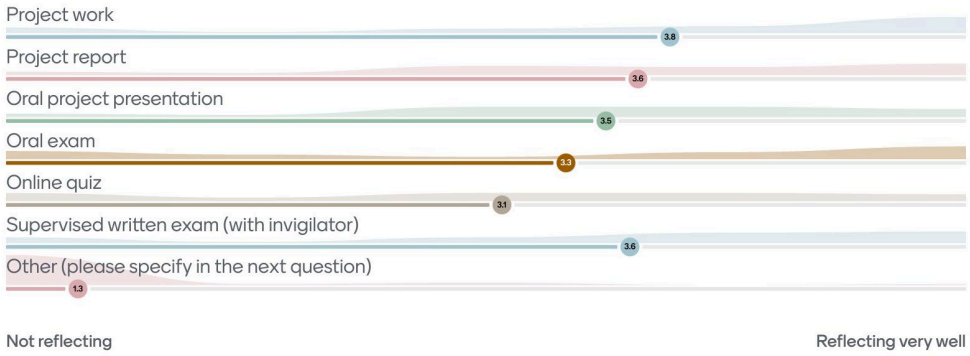


Figure 1: Student perception of the assessment types reflecting the knowledge and skills acquired

Students were allowed to give their views on other types of assessments in the following questions. Students also believed that combined assessments, such as an individual project plus presentation, group projects (not essays but actual projects), more verbal exams, home exams with context-specific questions which are harder to answer with GAI support, and Industry/real-life related problems/projects, could be useful to showcase their competencies. Students were also promoting code-checking questions in verbal forms for specific programming courses.

Regarding the challenges when demonstrating students' learning (cf. Figure 2), students think that the risk of AI-assisted results affecting assessment fairness is the biggest among the provided factors. They also foresee the lack of practical/real-world problems/applications within the assessment frameworks.

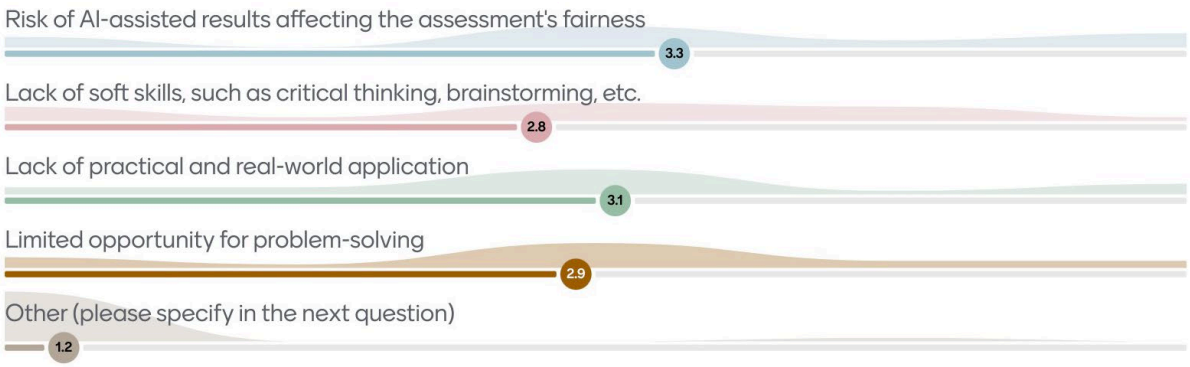


Figure 2: How challenging the given options are in demonstrating students' learning on a scale of 1-5.

Students also believe that the project works, and AI-assisted assignments are the most beneficial among the other types of oral examinations and real-time discussions, project oral presentations, and pitching ideas/products. In the question of whether students perceive that oral exams and supervised (proctored) exams would make assessments fairer, it was surprising to see that only 6 students thought that it is. 10 students have not even answered that question. This result reflects that there could be significant resistance among students to increasing oral and supervised assessment types in response to AI and cheating. Students also recognise the academic burden of conducting oral exams. The question about what types they think are harder to reflect their knowledge acquisition, written examinations (proctored), was one of them. Thus, a clear caution emerges here; simply increasing or restricting assessment types to only supervised, written exams is not a sufficient or effective solution.

In the open question about how other types of assessment approaches students view beyond that already mentioned, they focused on more of methodologies and processes for assessments: i.e., "*All types of exams give us some confidence and push to prepare ourselves better to deal with the exams. So in my opinion, AI is helping to learn things easily and in up-to-date way*". Another similar open response was "*Develop an AI-based examination system where AI agents loop into learning materials, exam policies, grading and generate dynamic questions based on the answers or explanations provided by the students*", so the students envision an interconnected facility of learning and assessment in contrast to typical views for standalone decisions for simply "using AI" based on cases or exam types. Another interesting response was "*In coding courses the best examination in my opinion is when the code is reviewed at an oral examination and the student has to explain the code and expected to answer questions about it*". What is interesting in these responses is that they are really in the "problem solving" mindset in their responses, deeply reasoning on the possible solution space and reflecting on learning opportunities, instead of a pure focus on the "problem space".

These outcomes justify the potential of students to provide impactful solutions when they immerse themselves in problematisation, problem-solving, and design thinking situations.

3.2 Deep dive outcomes

The deep dive activity is conducted in a future workshop (FW) with 22 students following the methodology described above. Of the 5 FW work groups, four have delivered their outcomes. Figure 3 shows two of those deliverables.

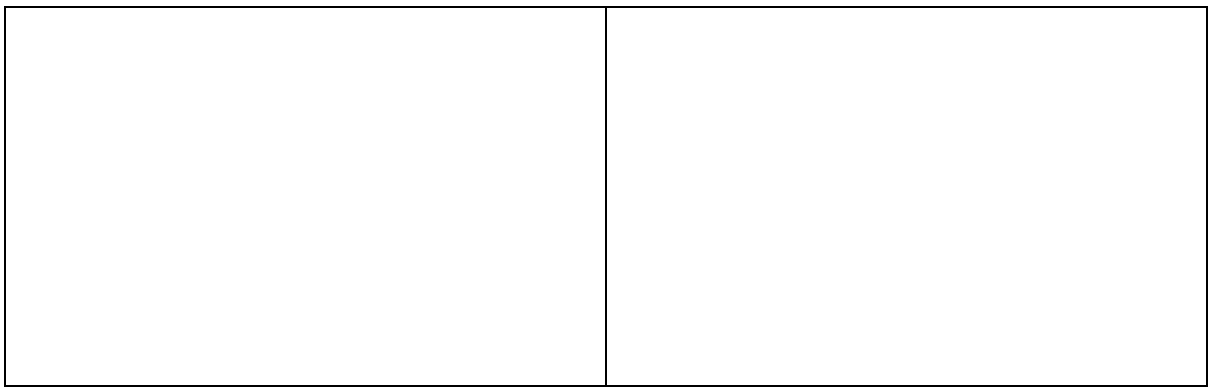


Figure 3. FW deliverables

According to the FW framework, problematisation, design, and implementation steps of a low-fidelity prototype are carried out. The summary of the delivered design processes is presented in Table 1.

Table 1: The prototypes delivered

G#	Critique	Fantasy	Implementation (MSCW)
1	1. Too easy to cheat on take -home exams/quizzes 2. Traditional Methods focus on memorisation 3. Memorisation won't get you far in work environments 4. Critical Thinking is not tested efficiently using traditional methods 5. Subjective marking for open-ended questions	1. Workshops to be able to discuss (Practical critical thinking) 2. Oral assessment (expanding how and why) 3. Use cases (Link concepts into real life contexts /situations 4. Pen & paper (focus on memorisation)	M : Use cases (#3 of Fantasy) S: Oral Assessment (#2) C: Workshops (#1) W: Pen & paper
2	1. Hard to evaluate all written assignment that are not fully supervised 2. Hard to measure the soft skills of writing/ being creative and analytical thinking 3. Same assessments feel uninspiring and that students feel that they just go through the motions. No problem solving. Feels like predetermined path	1. Students being assessed by solving a larger more difficult challenge/task while being allowed to use any means or tools available with not necessarily one correct answer/solution 2. More discussion /opposition-based assessment, not presentations. Students have to verbally defend their work individually 3. Teachers need to hold students accountable for their learning 4. There is a clear and good purpose with every assignment /assessment	M: 1. No definitive answers 2. Hold students accountable for their work and learning 3. Clear purpose with all assignments S: Larger tougher, projects allowing AI usage C: Examinations in MA so no AI is available W: Access to AI in exams
3	1. The assessment could be considered unfair (in cases of AI-use) 2. No tools for identifying AI-generated text. 3. Grading inflation - the grades get better because student use AI and therefore also the requirements for higher grades increase 4. If students use AI to complete school work, there is a risk that their soft skills, such as collaboration, communication and problem solving, won't develop	1. Real-time assessments 2. Points for attendance in workshops / seminars 3. Encourage participation in case exercises and workshops 4. Create an AI tool similar to Urkund that can analyze whether the text is AI-generated without mistakes 5. More oral examinations as they make it impossible for AI to influence the outcome.	1. Develop a standardized format for real-time assessments (e.g., oral exams, live problem-solving,) 2. Encourage active participation through structured discussions, workshops, quizzes, or reflections to develop soft skills 3. Some form of opposition from the grading teacher regarding the submitted work (exam, written assignment) to allow the student to prove that they can stand by what they have written and that it represents their own thoughts and knowledge - Negative aspect: very time consuming
4	1. Students may be less informed of the course material because of the functions of AI 2. Harder for teachers to assess the level students are during examinations 3. Students risk losing/stagnate in their critical thinking 4. Almost all forms of examinations taken at home have the possibility to be manipulated by AI 5. LLMs can be used to help with programming writing text and proposing solutions to exam questions 6. Students that use AI tools during their studies face the risk of not being able to conduct future work tasks in a way that reflect their own ideas given by ChatGPT etc. 7. Lack of integration of AI tools in classroom or assignments	Supervised examinations where the students are able to explain their way of thinking when presenting projects, they may have written at home while still using AI	Could use AI tools to create a collaboration assignments where they work together. But importantly with predefined goals for the human and AI

In answering the second research question of how students envision the assessment methods that can reflect students' learning, knowledge, and skills while promoting fairness in grading in higher education, firstly, the identified critiques are transformed into design baseline requirements, which serve as the guiding principles of the solution space as follows.

1. Authenticity of the assessments: Move beyond mere memorisation to real-world, problem-based scenarios.
2. Accountability: Ensure students can defend and demonstrate their work, including the thinking process.
3. Include both skills and competencies in the assessment: Assess both hard skills (knowledge, technical ability) and soft skills (critical thinking, communication, collaboration).
4. Fairness & Integrity: Ensure to minimise the AI-related cheating risks while acknowledging legitimate AI use.
5. Improve Engagement: Create meaningful assessments with clear purposes to prevent "going through the motions."

3.2.1 Design Elements (Fantasy mapped to Implementation prioritised via MoSCoW)

From the design concepts identified in the prototypes, the following strategies are derived according to the MoSCoW priorities the students envisioned (cf. Table 2).

Table 2: The strategies for the assessments

MoSCoW Priority	Assessment Strategies	Purpose
Must Have	1. Real-life use case tasks linked to professional practice. 2. Oral/real-time assessments (presentations, live problem-solving, viva voce). 3. Larger, open-ended projects with no single "correct" answer. 4. Explicit accountability checks (student defends their work). 5. Clear objectives for every assignment.	Ensure authenticity, prevent over-reliance on AI, promote deep learning.
Should Have	1. AI-permitted assignments with guidelines and transparency. 2. Structured opposition/discussion instead of static presentations. 3. Active participation grading via workshops, case exercises. 4. Collaboration tasks integrating AI under controlled conditions.	Encourage productive AI use while building soft skills.
Could Have	1. Periodic supervised exams without AI tools. 2. AI-detection systems to flag suspicious work (similar to plagiarism checkers). 3. Teacher-led "challenge" questions post-submission to validate authorship.	Strengthen integrity and safeguard fairness.
Would Have	1. Purely memorisation-based pen-and-paper tests without real-world context. 2. Fully unsupervised AI-free exams without alternative verification methods.	Avoid outdated, low-impact assessment methods.

3.2.1 Implementation Pathway

Lastly, from summaries of the implementation priorities in Table 2, triangulated with the design principles derived from the critiques, the following pathways have emerged.

- **Integrate** diverse assessments: combine real-time oral, collaborative, and AI-enabled tasks to create a balanced evaluation.
- **Embed** accountability moments: post-submission viva, peer opposition, or structured debates.
- **Design** for transparency: make AI use permissible in certain contexts, but require process documentation.
- **Prioritise** soft skill development: Wherever possible, add communication, collaboration, and creativity measurements as explicit assessment criteria.
- **Iterate & evaluate:** pilot in small courses, gather feedback, adjust weighting of AI-permitted vs AI-free components.

3.3 Discussion: outcomes impact on formative and summative assessment practices

Generative AI applications are shown to be risky to adopt, especially when it is used for assessment-related activities. Academic dishonesty and over-reliance on AI have been highlighted as negative impacts of AI in several studies (Dempere et al., 2023; Gopane et al., 2024; Kasneci et al., 2023). This study instrumented a deep dive study into students' perceptions on the challenges and opportunities of AI in examinations, and echoes the fact that universities are in need to adapt to innovative assessments, as resisting them may lead to disruption (Lucas, 2016). There are also abundant examples of prior research showing how students can enhance their learning with the use of GAI-based tools (Dempere et al., 2023; Kasneci et al., 2023), which is recognised by the students

of this study. Essentially, the generative tools enable students to generate content effortlessly, which means they challenge the integrity of conventional assessments such as take-home and online examinations and assignments (Akintande, 2024; Gopane et al., 2024), but the rapid adoption of GAI in educational settings is raising concerns about academic integrity and the effectiveness of traditional assessment practices (Dempere et al., 2023; Kasneci et al., 2023).

The Low-fidelity prototypes from FW showcased potential design solutions in response to these challenges, specifically, AI-resistant assessment strategies, such as connecting examinations with real-world problems and progressive tasks monitored and assessed using multiple or combined methods, i.e., project work, peer review, oral presentations, etc. A process-product assessment approach, as such, demonstrates the transformative influence of GAI on assessment practices according to the FW outcomes. The innovative potential of such a process framework is also explored in related research (Awadallah Alkouk & Khlaif, 2024; Nartgün & Kennedy, 2024). It is also a fact that the integration of AI in educational measurement has altered assessment methods, and enabling automated scoring, rapid content analysis, and personalised feedback through machine learning and natural language processing also raises significant ethical concerns regarding validity, reliability, transparency, fairness, and equity (Bulut et al., 2024).

As a response to the challenges of academic integrity, assessment fairness, limited diversity in assessment formats, and the lack of robust methods for evaluating soft skills, higher education institutions must critically rethink assessment models. They must be resilient against AI-assisted misconduct while effectively assessing both disciplinary knowledge and essential skills such as critical thinking, problem-solving, communication, and collaboration (Aghaee & Karunaratne, 2023). The outcomes of the FW provided insights for priorities: **must-have approaches** include embedding real-world use cases, oral and real-time assessments, and clear accountability for students' learning; **should-have approaches** emphasize challenging, open-ended projects where AI can be used as a tool under guided conditions; **could-have approaches** involve workshops and structured discussions that foster participation and develop soft skills; while **would-like-to-have approaches** include minimising traditional pen-and-paper elements with specific memorisation purposes. By integrating these priorities into assessment design, educators can not only safeguard academic integrity but also create richer, more diverse, and student-centred assessment environments that foster deeper learning and transferable skills.

4. Concluding remarks

This research focused on a deep exploration into AI-resilient assessment through the perspectives of higher education students, addressing two core questions: the significance of authentic, skill-focused methods such as oral examinations and AI-integrated tasks, and how students envision diverse assessments in future. The outcomes regarding the current assessment practices, students perceived authentic and compound assessments as a part of a continuous process, would mitigate the challenges of the AI-influenced academic misconduct. The low-fidelity prototypes designed by students in FW revealed potential implementation pathways to future AI-resilient assessments. These strategies can be piloted, iteratively refined, and scaled to build assessment systems that encourage integrity while developing deeper, transferable learning. Moving forward, higher education institutions should view such designs not only as a safeguard against misconduct but as an opportunity to cultivate more authentic, equitable, and future-ready learning environments as a step for transformation in education.

Ethics declaration

This study followed the ethical standards and research integrity guidelines of the host university, with confirmation from the head of unit. As the research was conducted within an educational context and did not involve the collection of sensitive personal data, no formal ethical approval was required. Participants were informed about the purpose of the study, its potential for a research publication, and how their data would be handled. Participation was voluntary, anonymity was ensured by excluding personal identifiers, and informed consent was obtained through their submissions, with the option to withhold material from inclusion in the study.

AI declaration

No AI tools were directly used in conducting the research. Language correction tools were employed during the development of the workshop and the writing of the manuscript to proofread and correct language errors.

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Leveraging Generative AI and Audio-Visual Cloning to Democratise Digital Learning

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Abstract: This paper explores the transformative potential of Generative Artificial Intelligence (GenAI) and audio-visual cloning technologies in reshaping digital education, grounded in the ongoing project ACCLAIMED (Artificial Intelligence Content Cloning of Language-Agnostic Media for Education Democratisation). As education systems increasingly rely on digital platforms, the imperative to ensure accessibility, inclusion, and ethical integrity becomes more pronounced. ACCLAIMED introduces a novel triadic framework, namely, Course Generator, Guardrail, and AI-Renderer, to address e-learning challenges. The Course Generator collaborates with educators to produce comprehensive, pedagogically sound multilingual content. The Guardrail ensures human oversight, reinforcing societal norms, factual accuracy, and ethical alignment. The AI-Renderer transforms materials into realistic, human-like audio-visual formats, delivering engaging, culturally sensitive learning experiences. We discuss how ACCLAIMED advances the state-of-the-art by surpassing conventional AI tutors and adaptive learning systems through deeper pedagogical integration and ethical AI moderation. A key feature is its ability to deliver high-quality content across multiple languages, removing linguistic barriers and fostering educational equity especially for underserved or non-English-speaking populations. The paper also critically addresses broader issues: ethical concerns around AI-generated content, privacy and data protection (GDPR, EU AI Act), and digital sovereignty. Consideration is given to how such innovations can bridge or deepen the digital divide depending on their responsible and inclusive deployment. Ultimately, this paper calls for a reconceptualisation of digital learning, not merely as content delivery but as an inclusive, ethical, and adaptive ecosystem. It positions ACCLAIMED as a forward-looking blueprint for educational technologies prioritising innovation, equity, and societal impact.

Keywords: Generative AI, Audio-visual cloning, Digital learning, Ethical AI.

1. Introduction

Digital education is undergoing a profound transformation, driven by advances in artificial intelligence (AI), natural language processing, and multimedia generation (Arias Ortiz, et al., 2025). The integration of AI technologies in educational contexts has demonstrated significant potential to address longstanding challenges in learning delivery, with applications ranging from intelligent tutoring systems to automated content generation. Natural language processing technologies have emerged as particularly powerful tools for creating personalized learning experiences, enabling adaptive content delivery and multilingual support that caters to diverse learning styles and linguistic backgrounds (Tamilarasan, Selvaraj, & Buckingham, 2025). The proliferation of multimedia integration in e-learning environments has further enhanced educational accessibility and engagement. Modern educational platforms increasingly leverage interactive videos, simulations, and dynamic content to transform passive learning into active participation, addressing various learning modalities and improving knowledge retention. These technological advances align with contemporary pedagogical frameworks that emphasize learner-centered approaches and inclusive educational practices (MOEE, 2012). Despite the proliferation of e-learning platforms and technological innovations, significant barriers remain that prevent equitable access to quality digital education (Vishnu, Tengli, Ramadas, Sathyan, & Bhatt, 2024). Linguistic exclusion represents one of the most pervasive challenges, with the digital language divide creating disparities between dominant languages and low-resourced languages in terms of digital content availability and technological support (Okolo & Tano, 2024). This disparity particularly affects speakers of indigenous and minority languages, who often find themselves excluded from the benefits of digital technologies and educational resources. Cultural adaptation deficits further compound accessibility challenges in digital learning environments (Zhao, Wang, Li, Zhou, & Li, 2021). Many mainstream e-learning platforms fail to adequately address the unique learning styles, preferences, and cultural sensitivities of diverse populations, leading to reduced effectiveness and engagement among learners from different cultural backgrounds (Viberg, Jivet, & Scheffel, 2022). The lack of culturally responsive educational content not only diminishes learning outcomes but also perpetuates educational inequities by failing to recognize and validate diverse cultural knowledge systems (Milheim, 2015). Ethical concerns surrounding the deployment of AI-generated content in educational settings have emerged as another critical barrier (Nguyen, 2025). The complexity of AI systems often makes it difficult to understand decision-making processes, leading to concerns about transparency, accountability, and potential bias in educational applications (EC, 2025). These ethical considerations are particularly significant given the formative nature of educational experiences and their long-term impact on learners' development and

opportunities (EC, 2025). These challenges are particularly acute for underserved, non-English-speaking, or resource-constrained populations, exacerbating the global digital divid (Okolo & Tano, 2024). Rural communities, low-income families, and historically marginalized groups face compounded disadvantages in accessing digital education, including limited internet connectivity, inadequate technological infrastructure, and insufficient digital literacy skills (Raihan, et al., 2025). The digital divide not only affects immediate educational outcomes but also perpetuates existing inequalities by limiting access to opportunities for skill development and career advancement (Bentley, Naughtin, & McGrath, 2024). Research indicates that students from historically and systematically excluded backgrounds, including English language learners and students with disabilities, often rely more heavily on basic assistive tools rather than advanced educational technologies, further widening the achievement gap (Assefa, Gebremeskel, Moges, Tilwani, & Azmera, 2025). The pandemic has particularly highlighted these disparities, as only educational systems with robust digital capabilities were able to maintain continuity of learning, leaving millions of students behind (Sun, Tang, & Zhao, 2024).

The rest of the paper is organised as follows. The next section will go through any related work that encompasses the different facets of this study, while Section 3 introduces ACCLAIMED (Artificial Intelligence Content Cloning of Language-Agnostic Media for Education Democratisation), a novel framework leveraging generative AI and audio-visual cloning to democratise digital learning. The next section goes through the methodology we adopted during the ACCLAIMED project followed by the early results and findings in our initial implementations, in the following section. A conclusiions and future work section completes our paper as we close with numerous recommendations and best practices especially in relation to important issues like ethical concerns, content, privacy and data protection.

2. Related Work

2.1 Generative AI in Education

Generative AI has rapidly emerged as a transformative force in education, demonstrating significant promise in areas such as automated content creation, assessment, and personalised tutoring (Qian, 2025). The advent of large language models (LLMs), including GPT-4 and Google Gemini, has enabled the rapid and scalable generation of high-quality textual learning materials, question banks, and adaptive feedback systems (Fenta, 2025). These models are capable of producing contextually relevant, curriculum-aligned content that can be tailored to individual learner needs, thereby supporting differentiated instruction and fostering learner engagement (Yunjo, Hyun, & Shadarra, 2025). Beyond text, advances in generative models, such as diffusion models and neural rendering, have facilitated the creation of synthetic media, including images, animations, and even interactive simulations (Kumar, 2025). These innovations enable the development of rich, multimodal educational experiences that transcend the limitations of traditional textbooks and static e-learning modules. However, despite these advances, most generative AI systems remain predominantly focused on English-language content and Western-centric educational paradigms (Agarwal, Naaman, & Vashistha, 2025). There is a notable lack of mechanisms for deep pedagogical integration, cultural adaptation, or robust ethical oversight. As a result, existing solutions often fail to address the needs of diverse learner populations or to ensure alignment with local curricular standards and values (Nyaaba, Wright, & Choi, 2024).

2.2 Audio-Visual Cloning

Audio-visual cloning technologies represent another frontier in educational innovation, enabling the synthesis of realistic human-like avatars, voices, and gestures through AI-driven techniques (Ingle et al., 2024). Platforms such as Synthesia, HyGen and D-ID have demonstrated the technical feasibility of generating video lectures and virtual instructors that closely mimic human appearance and delivery. These tools hold significant potential for scaling high-quality instruction and making learning more engaging and accessible, particularly in remote and asynchronous settings. Nevertheless, the adoption of audio-visual cloning in education is not without challenges (Chheang, et al., 2024). Many current implementations lack sufficient alignment with established educational standards or fail to incorporate cultural and contextual nuances critical for effective pedagogy (Baker, Smith, & Anissa, 2022). The risk of producing content that is culturally insensitive or pedagogically inappropriate underscores the need for frameworks that integrate educational expertise and local context into the design and deployment of AI-driven media.

2.3 Ethical and Legal Considerations

The deployment of AI technologies in educational contexts raises a host of ethical and legal concerns, including issues of algorithmic bias, misinformation, learner privacy, and regulatory compliance (Williamson & Eynon, 2020). AI systems, if not properly monitored, may inadvertently perpetuate or even amplify existing biases, leading to unfair or discriminatory outcomes for certain groups of learners (Kotek, Dockum, & Sun, 2023). The

risk of misinformation where AI-generated content is factually incorrect or misleading poses further challenges, particularly in high-stakes educational environments (Locke & Hodgdon, 2025). Privacy and data protection are paramount, especially given the sensitive nature of educational data and the increasing regulatory scrutiny exemplified by frameworks such as the General Data Protection Regulation (GDPR) and the EU AI Act. Many current AI-powered educational platforms operate with limited transparency, offering few mechanisms for human-in-the-loop oversight or for learners and educators to understand, challenge, or intervene in AI-driven decisions (Liao & Wortman-Vaughan, 2023). This lack of transparent guardrails not only undermines trust but also raises significant questions about accountability and the responsible use of AI in shaping educational futures.

3. The ACCLAIMED Framework

3.1 Overview

ACCLAIMED is structured around three core modules (see Figure 1):

1. Course Generator: Collaborates with educators to produce pedagogically robust content, assisting in both planning and content creation.
2. AI-Renderer: Translates textual content and transforms it into realistic audio-visual formats, adapting to cultural and linguistic contexts.
3. Guardrail: Flags concerning content for human review, ensuring factual accuracy, ethical alignment, and regulatory compliance.

3.2 Course Generator

The Course Generator component within the ACCLAIMED framework facilitates a structured, educator-guided authoring process that blends human pedagogical insight with AI-assisted automation to generate high-quality, scalable educational content. The process begins with educators uploading their instructional resources into a centralised database, from which the AI agent can retrieve relevant materials on demand using Retrieval-Augmented Generation (RAG) methods (Lee, 2025). This initial step ensures that content generation remains grounded in expert-sourced materials. Subsequently, educators engage in a co-creative dialogue with the AI to formulate a syllabus, delineating the key topics to be addressed throughout the course. Following this, educators define essential course parameters (such as intended duration, lesson length and frequency, and target audience) which the AI uses to construct a scheme of work. This scheme outlines the structure of lessons and assessments, and is subject to iterative review by the educator to ensure that it lines up with their individual style and goals. Each lesson is then individually developed through a collaborative process wherein the AI generates a detailed lesson plan based on Gagné's Nine Events of Instruction, which is validated and adjusted through feedback from both the educator and the Guardrail component described in Section 3.4. The educator may select which activities to include based on their personal style and intended audience, as recommended in Fan et al., (2024). Building on this foundation, the lesson script is automatically generated by the Lesson Generator and undergoes further scrutiny and revision by both human and AI-driven checks. The finalised script is passed to the AI Renderer (Section 3.3), which produces a video lecture that simulates human delivery in the target selection of languages, allowing the educator to review and approve the generated media. In parallel, instructional slides are automatically produced from the lesson plan's defined sections. These slides are reviewed by the Guardrail component and integrated into Google Slides via the API, enabling further manual refinement by educators within a familiar interface. The Assessment Generator creates multiple-choice quizzes to evaluate student understanding in a formative manner, exportable to platforms such as Kahoot and Google Forms, granting educators flexibility in tailoring and deploying formative assessments.

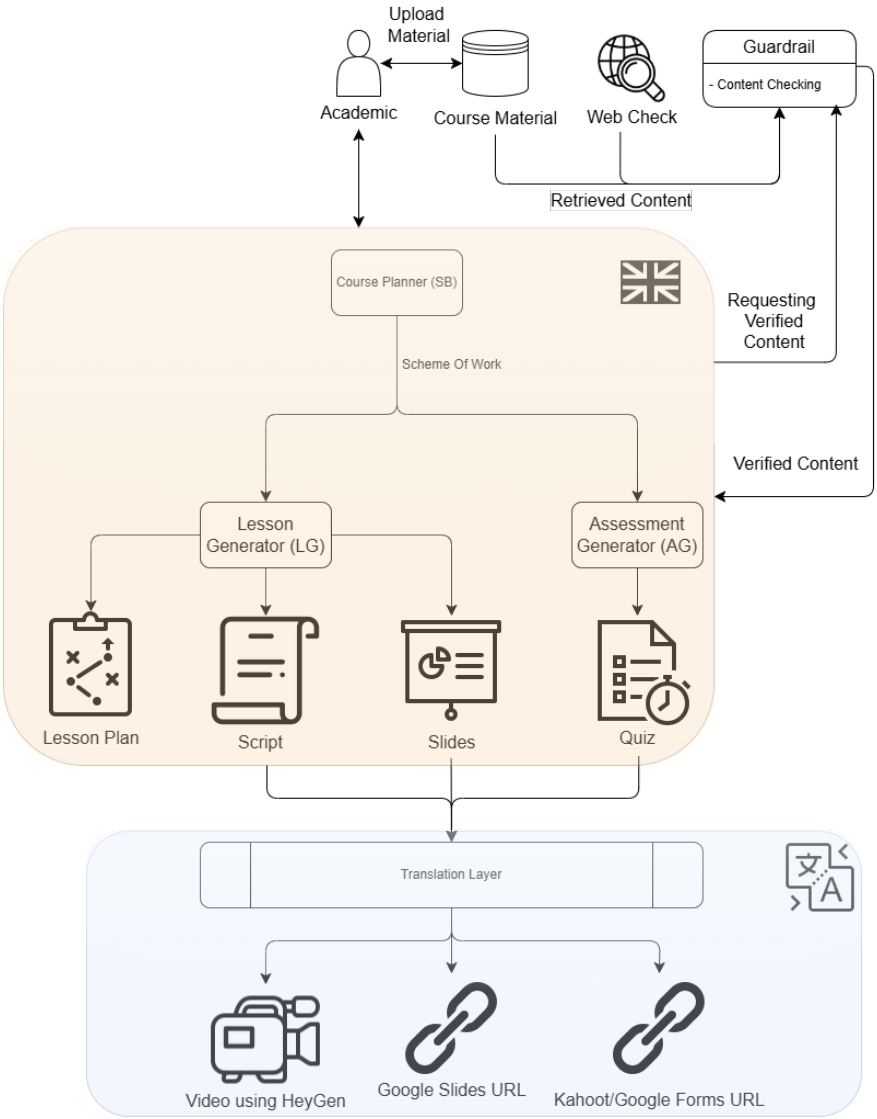


Figure 1: ACCLAIMED Architecture

3.3 AI Renderer

The AI Renderer receives the content generated and validated by the educator in their native language, and translates it into the chosen languages, before making the necessary calls to third-party services to create engaging content that is accessible by diverse learner populations. Multilingual support is achieved via translation models and cross-lingual embeddings, ensuring content is accessible to diverse learner populations. The translated content is first checked by the guardrail, and then makes use of the following third-party services to generate the deliverables as shown in Figure 1.

3.3.1 Video Avatar Generation Platform

The approved and translated script is used to generate a "talking head" video of the educator delivering the content. The output is a video lecture reproduced in the desired language set, that can be uploaded to the Learning Management System (LMS) of choice. Heygen was selected as the platform of choice for the proof of concept of ACCLAIMED as it seemed to offer the highest quality content at competitive prices upon an initial evaluation. A comprehensive comparison of providers and open source implementations will be discussed later in Section 3.5 as part of planned future updates.

3.3.2 Presentation Creation Platform

The lecture slides designed by the Course Generator are uploaded to a presentation creation platform, in this case Google Slides. This was chosen as it is widely adopted and easily accessible since a dedicated license is not required to use the platform. The integration is built via APIs made available by Google, which enables users to pass in the ID of a template presentation to use for styling. This was considered a desirable feature as it allows

educators to align the generated content with their existing course material, enabling seamless incorporation of the new content into their workflows. This feature will also allow institutions to standardise content styling across courses and educators if they desire, and any changes made to the underlying template will be propagated to the generated material automatically.

3.3.3 Quiz Creation Platform (Kahoot/Google forms)

The multiple-choice quizzes created by the Course Generator are similarly uploaded to a quiz creation platform that allows the educator to make any final modifications to the content, as well as distribute the quiz to students. To demonstrate the extensibility of the ACCLAIMED platform, two providers are integrated for educators to choose from, Kahoot and Google Forms. The gamified interface of Kahoot has proven to be effective at increasing engagement in various domains (Wang & Tahir, 2020), and allows the educator to carry out the quiz in class or distribute as an assignment. On the other hand, Google Forms might be a favourable integration for academics who might consider Kahoot as too informal for a higher education institution, or are more familiar with the Google Workspace ecosystem. Both platforms offer extensive reporting capabilities, allowing educators to assess student understanding of the concepts covered in class. By reducing the authoring burden, the ACCLAIMED platform allows educators in resource-constrained environments to reap the benefits of formative assessment with ease. This can provide near-real-time feedback to educators while the course is in progress, allowing them to adapt their teaching practices and plans accordingly. As discussed later on, we intend to look into tighter integrations with these platforms to pull in performance analytics and incorporate it directly in the content authoring loop, providing recommendations when designing/updating the course. The modular design of the AI Renderer is easily extensible to make use of any other provider for each of these use cases. This was considered a key feature when architecting the ACCLAIMED framework, so that the project can be adapted to the suite of tools in use at a particular academic institution. This will circumvent the issue of having to purchase new licenses and re-training staff. The project leans heavily into third-party services since educators are already familiar with the content authoring experience. This allows educators to fine tune the design and/or content using the comprehensive set of tools on the platforms. This combines the efficiency of AI content generation with the flexibility of proven tools.

3.4 Guardrail

The Course Generator communicates with the Guardrail component to run various checks in the content generation loop. Each of the checks listed in this section outputs a “probability of violation” and a validation error message, which is surfaced through the UI and requires educator validation when the probability exceeds a certain threshold. The checks are implemented using a mixture of existing open source platforms, namely Guardrails AI and Nvidia NeMo, as well as some custom implementations. The array of checks included:

- Content Accuracy Check: This check ensures that factual statements found in the text are supported by at least one authoritative source. Preference is given to sources from the approved list uploaded by the educator. However, these are also cross-checked against online references for consistency. This ensures that any claims made (for example, about the current state-of-the-art technique in a particular domain) are up to date, even if the content uploaded by the educator is out of date. Conflicts are escalated to the educator to resolve before proceeding. Combined with RAG, this check aims at minimising hallucinations, a known problem in LLMs (Huang, et al., 2025). Spell checks, grammar checks, and inconsistency checks are also run against the content to ensure linguistic coherence.
- Pedagogical Alignment Check: The objectives stated in the lesson plans are cross-checked against the syllabus, to ensure that there is adequate mapping between the generated content and the overall course goals. A separate check ensures that the objectives, discussions and activities are suitable for the course audience as specified by the educator in the initial course planning stages with the Course Generator. This aspect of the guardrail will evolve further.
- Ethical and Legal Compliance Check: All text output by the various components of the Course Generator, as well as any modifications made by the educator are checked to ensure that the content does not promote hate, harassment, extremism, political persuasion or self-harm. At the course design stage, the educator is asked whether they would like any medical or legal advice surfaced in the content to be blocked or flagged for verification. While it is expected that most educators will want to outright block such content, this opens the door for manual review in courses where discussions about financial and legal decisions is a core component.
- Bias and Inclusion Check: All content is checked to ensure that there are no gender, racial, cultural or ability stereotypes. This protects the educator from inclusion of micro-aggressions or exclusionary phrasing. A reading level check is also run to ensure that the content can be understood by the target

audience specified at the course level. Content that mentions violence, sexual intercourse or substance use is surfaced for educator review. The content is not blocked to allow for cases where a mature discussion of these subjects is required to meet the course objectives.

- GDPR Compliance Check: All content output by the various components of the Course Generator are checked to ensure that there is no leakage of Personally Identifiable Information (PII). While the platform does not directly deal with student data, this is added as a fail-safe against situations where the educator might (accidentally) upload material that includes student information such as grades or attendance records.
- Multilingual Consistency Check: Once the content has been translated by the AI renderer, a series of linguistic checks are run to ensure that the tone is consistent across all languages, and that there are no grammatical or spelling errors.
- Intellectual Property Check: The generated content is reviewed to ensure that adequate references are included where portions of source material is reproduced verbatim, and to ensure that all document snippets retrieved via RAG have been cited.

4. Results and Discussion

The development of ACCLAIMED has, to date, focused on rigorous internal testing and iterative proof-of-concept trials, providing a robust foundation for future large-scale deployment. This phase has been instrumental in evaluating the technical feasibility, pedagogical soundness, and practical usability of the ACCLAIMED framework. Initial results have shown that the technical performance and system stability of the beta version are very promising and encouraging. Multiple rounds of system trials were conducted to assess the performance of the Course Generator, Guardrail, and AI-Renderer modules. These trials involved generating multilingual course materials across a range of subjects and educational levels. The Course Generator demonstrated strong capabilities in producing coherent, curriculum-aligned content in English, Spanish, French, Italian and Maltese, with ongoing fine-tuning to improve output in lower-resourced languages like Maltese itself. The AI-Renderer successfully synthesized human-like audio-visual content, with avatars accurately reflecting linguistic and cultural nuances as validated by internal reviewers. System stability was evaluated through stress-testing and error-logging protocols. The framework maintained high uptime and responsiveness, with latency for content generation and rendering consistently within acceptable thresholds for educational applications. These results suggest that ACCLAIMED's modular architecture is technically robust and scalable, supporting future integration with external learning management systems. To ensure pedagogical validity, subject-matter experts and instructional designers participated in structured walkthroughs of the generated content. Feedback highlighted the system's strengths in producing logically structured lessons, appropriate scaffolding, and adaptive feedback mechanisms. Notably, the Guardrail module's human-in-the-loop oversight effectively identified and corrected factual inaccuracies, cultural mismatches, and inappropriate content, demonstrating the practical value of embedding ethical review within the workflow (Montebello, 2021). Qualitative feedback from internal testers indicated that the audio-visual materials enhanced learner engagement and comprehension, particularly for complex or abstract topics. These findings are consistent with broader research on AI-driven educational tools, which have shown improvements in student engagement and learning outcomes when adaptive and multimedia elements are incorporated (Mallia-Milanes & Montebello, 2021). Initial user experience trials involved the project team that is made up of numerous educators and learners that interacted with the prototype. The majority of participants found the system intuitive and the workflow for content co-creation straightforward. Educators appreciated the ability to review, edit, and approve AI-generated materials, reinforcing their role as pedagogical authorities. Learners responded positively to the diversity of avatars and languages, noting increased relatability and motivation. Iterative refinements continue to refine ACCLAIMED as they were based on user feedback that led to enhancements in navigation, customisation options, and accessibility features. These adjustments mirror findings from other AI education pilots, where continuous user-centered design has been critical for adoption and efficacy (Heung & Yim, 2024). While this initial internal testing phase yielded promising results, several limitations were identified. Language coverage provides particular challenges as further work is needed to improve accuracy and naturalness in underrepresented languages like Maltese. Cultural adaptation also has its challenges as ensuring deep cultural relevance remains a complex challenge, particularly for content intended for diverse global audiences. Finally, automated moderation through the Guardrail module presented some edge cases indicating it still requires manual intervention, underscoring the need for ongoing human oversight. These findings align with other recent proof-of-concept initiatives in educational AI, which have similarly highlighted the importance of iterative development, user feedback, and ethical safeguards in achieving practical and scalable solutions (DoE, 2024). The ACCLAIMED proof-of-concept demonstrates that generative AI and audio-visual cloning can be harnessed to produce high-quality, inclusive,

and ethically sound educational content. The modular, educator-centered design supports both scalability and adaptability, making ACCLAIMED a compelling candidate for broader pilot studies and eventual real-world deployment. These initial results reinforce the transformative potential of AI in education, particularly for addressing linguistic and cultural barriers and supporting underserved populations. However, the experience also underscores the necessity of embedding robust ethical, legal, and pedagogical oversight at every stage of development and deployment. Building on the success of internal trials, the next phase will involve pilot deployments in partnership with educational institutions, with a focus on diverse linguistic and cultural settings. Quantitative and qualitative data will be systematically collected to evaluate learner outcomes, educator workload, and system impact. Further research will also address the scalability of the Guardrail module and the ongoing refinement of language and cultural adaptation capabilities.

5. Conclusion and Future Work

ACCLAIMED represents a significant step forward in leveraging generative AI and audio-visual cloning for equitable, inclusive, and ethical digital learning. By foregrounding multilingualism, cultural adaptation, and robust ethical safeguards, it offers a scalable blueprint for the future of education technology. However, ongoing vigilance is required to ensure these technologies serve all learners, uphold privacy, and foster digital sovereignty. As the ACCLAIMED platform matures, several key areas have been identified to guide future research and development. These avenues aim to strengthen the platform's pedagogical robustness, enhance system autonomy and flexibility, and extend its adoption across varied educational contexts. Future work will look into integration with Learning Management Systems (LMS) to manage not only the distribution of generated content, but also to collect learner analytics and feedback. This integration would enable the coupling of ACCLAIMED with student modelling frameworks such as Knowledge Tracing and Cognitive Diagnosis Modelling, thereby creating an adaptive learning environment. Such an environment would support the dynamic adjustment of instructional content in response to individual learner needs, thus realising the project's ambition of personalisation at scale to improve accessibility. To further close the adaptive feedback loop, the alignment of assessment mechanisms with Bloom's Taxonomy will be deepened. Prior work has demonstrated the effectiveness of Bloom-aligned assessments in differentiating cognitive skill levels and informing instructional design. By enhancing the taxonomy mapping in ACCLAIMED's assessment generation tools, a more granular understanding of learner capabilities can be derived and used to guide the generation of tailored content that meets learners at their demonstrated level of mastery. To accommodate a broader range of educational and training contexts, especially those outside traditional academic environments, future iterations of the platform will incorporate alternative assessment techniques. This includes integrations with branching scenario platforms and virtual reality (VR) simulation environments to support Scenario-Based Learning (SBL). Such modalities are particularly relevant for vocational training, where experiential and performance-based evaluation methods are more pedagogically appropriate than conventional quiz-based assessments. The platform's export functionalities will be expanded to include Microsoft Forms and Microsoft PowerPoint, ensuring compatibility with institutional ecosystems that rely on Microsoft 365 infrastructure. This will enhance usability for educators in institutions where Office licenses are predominant, thereby lowering the barrier to adoption. To support institutional-level deployments, ACCLAIMED will be extended with capabilities for collaborative course creation. This will allow educators, including teaching assistants and co-instructors, to jointly author and refine course materials. The ability to support multi-author workflows is essential in contexts where course delivery is a distributed effort across teams, ensuring consistency, version control, and efficient division of labour in large-scale educational programs. Future versions could also allow for the sharing of educational content between courses, allowing educators to pull from their institutions content library and re-use to fit their needs. The current reliance on third-party AI rendering services presents limitations in terms of flexibility, cost, and control. A proposed future direction involves implementing the AI Renderer using recent open-source techniques for talking head generation. This would not only eliminate third-party dependencies but also allow fine-grained access control and local deployment. A qualitative study will be undertaken to compare the output quality of open-source renderers with that of proprietary solutions, incorporating metrics such as realism, engagement, and educator satisfaction. In parallel, the content generation pipeline will undergo two major comparative evaluations. First, a comprehensive benchmarking of Guardrail libraries will be conducted to assess their effectiveness in enforcing ethical, cultural, and pedagogical constraints. Second, the performance of various large language models (LLMs) will be compared in their ability to generate educational content. This comparison will be executed as a controlled study involving both educators and students, who will be asked to rate and rank content produced by different LLMs and by expert human authors. These evaluations will provide empirical grounding for model selection and configuration in future platform release. A series of pilot studies will be conducted in collaboration with educational institutions to assess both the technical and pedagogical

performance of each platform component, as well as the system as a whole. In addition to performance metrics, a user experience (UX) study will be carried out to evaluate the intuitiveness and usability of the educator-facing interface. Complementing these efforts, rigorous empirical studies will quantify the reduction in content authoring time achieved through ACCLAIMED. By measuring time savings in real-world instructional design tasks, the platform's value proposition for educators can be substantiated with evidence-based metrics.

Ethics declaration

No ethical clearance was needed for the research referred to in this paper.

AI declaration

A number of Generative engines were used responsibly to assist with language refinement, structure, and editing during the preparation of this paper. All content was critically reviewed, verified, and edited by the authors who employed Gemini, Co-Pilot, ChatGPT and Perplexity to ensure accuracy, originality, and strict compliance with academic integrity standards.

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Professional/Educational Characteristics of Children of Employed Parents During a Crisis Period

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Abstract: The article examines the professional and educational characteristics, as well as the e-competence, of children of workers in the Ostrava coal region of the Czech Republic during the early 21st century. This work represents a component of the REFRESH project, which is dedicated to enhancing research excellence in the Moravian-Silesian Region. The overarching aim of this initiative is to foster the development of a smart region through the transfer of technology in fields such as sustainable energy, the digitalisation of industrial production, environmental technologies, and smart materials technologies. The researchers from the Faculty of Education at the University of Ostrava conducted a questionnaire survey targeting a research cohort comprising disadvantaged and vulnerable social groups. This focus stems from the anticipated significant adverse effects of regional transformation on these groups, who may possess attitudes that could hinder the effective transition of the coal industry in alignment with contemporary European developments. The primary objective of this research was to delineate the professional and educational characteristics of children of miners during a crisis phase of their parents' careers. As part of the investigation into the professional orientation of these employees' children, the study identified the working personality types of participating pupils. It assessed their self-efficacy beliefs regarding career preparedness, particularly in relation to their interest in digital technologies. This evaluation also encompassed the development of their digital literacy, reading, and technical competencies, alongside their preparedness for life in Society 4.0. Findings from the research indicated that children of workers in the mining sector who were enrolled in primary school utilised computers for academic purposes in an irregular manner. Notably, nearly 29% of respondents reported a lack of access to a fast Internet connection at home, and a mere 2% expressed interest in reading scientific and technical electronic texts. This contribution is part of a research initiative within the framework of the Just Transition Operational Programme, project REFRESH (Research Excellence for Region Sustainability and High-tech Industries), registration number CZ10.03.01/00/22_003/0000048.

Keywords: REFRESH project, vulnerable social groups of children, professional and educational characteristics of children, digital competences, transformation of the coal region, Society 4.0

1. Introduction

In the contemporary European and global context, there are significant transformations in the lifestyles of individuals across various age groups, principally driven by technological advancements associated with what is commonly referred to as the Fourth Industrial Revolution. This current phase of industrial evolution is initiating fundamental shifts within the labour market, resulting in the obsolescence of certain professions while simultaneously fostering the emergence of new ones. Specifically, in the Polish border region of the Moravian-Silesian Region of the Czech Republic, energy and heavy industries have been evolving for over two centuries, with a predominant focus on mining activities. However, as we enter the third decade of the 21st century, this sector is experiencing a period of decline that threatens the continued existence of mining-related professions.

As part of the REFRESH project, researchers from the Faculty of Education at the University of Ostrava are dedicated to investigating strategies that contribute to the region's transformation, emphasising the adoption of technologies in sustainable energy, the integration of digital strategies in production processes, and the implementation of innovative environmental technologies and smart materials.

The community of industrial and mining workers, along with their families, represents a specific demographic within the Moravian-Silesian region, particularly pertinent to this research, considering the ongoing industrial transition. This group is characterised as a vulnerable social segment at risk, enduring both psychologically and physically demanding work conditions.

Numerous external and internal factors influence an individual's life satisfaction, including challenges related to lifestyle choices, career adaptability, optimism about life, the spectrum of life needs, and motivation for lifelong learning and professional flexibility. The Briefing of the European Parliament (2016, p. 1) characterises vulnerable social groups as "those presumed to be at risk of poverty or social exclusion due to physical disability, age, ethnic origin, lack of housing, or substance abuse." Furthermore, the OSF Foundation (2021, p. 11) delineates a vulnerable adult as an individual over the age of 18 who may be incapable of protecting themselves from potential harm or abuse due to various factors, including disability, age, illness, situational contexts, or social inequalities.

Janus-Sitarz and Nowak (2014, pp. 9–14) emphasise the significance of enhancing cultural capital, which is influenced by educational opportunities, language competencies, and reading habits within the framework of lifelong professional development. They state, "Language competencies represent the cultural capital of every person and have a substantial impact on their educational opportunities, job prospects, and social status."

2. Reading and digital literacy as part of critical thinking and interpersonal communication

Reading literacy is increasingly recognised as a fundamental right and necessity for individuals, facilitating the development of various literacy components, including reading, digital, media, visual, communicative, mathematical, scientific, and environmental literacy. These components collectively form the foundation of functional literacy, comprising an essential set of knowledge, skills, and competencies necessary for navigating everyday life effectively in the 21st century. In the context of the rapidly evolving landscape marked by robotisation, automation, and digitalisation associated with Society 4.0, there is a pressing need to comprehend information presented in diverse text formats—ranging from artistic and non-artistic to electronic, digital, multifunctional, and hybrid texts. This comprehension is vital for fostering critical thinking and transversal competencies among individuals across various age groups, framed within the parameters of lifelong education.

Grecmanová and Urbanovská (2007, p. 15) articulate critical thinking as the process of curiosity-driven inquiry, employing diverse information-gathering strategies, posing relevant questions, and systematically seeking informed answers. This approach is guided by a healthy scepticism, enabling individuals to explore alternatives, form opinions, and defend these opinions rationally while critically engaging with the arguments of others and evaluating their logical consistency. Engagement with a variety of text types serves to advance both reading and digital literacy among educated individuals. International assessments, notably the PISA and PIRLS, are responsive to the imperative of addressing diverse text formats in the context of digitalisation. For instance, the PIRLS (2021) assessment included traditional written texts alongside electronic and internet-based texts, featuring excerpts of information from simulated websites enriched with multimedia elements. In artistic texts, pupils analysed literary works, while informational texts, biographical data, advertisements, and current events further supplemented the test tasks. The PIRLS (2021) framework encompasses four strategic approaches to ensure comprehension of texts: information retrieval, drawing conclusions, interpretation, and text evaluation, aimed at enabling individuals to gain experience and effectively utilise information from various informational texts. An important element influencing these processes is the dynamics of internal motivation within educated individuals, which plays a crucial role in securing a sustainable future for families as integral components of society, facilitating personal and career growth, and enhancing interpersonal communication skills. Katrňák (2006, pp. 174–177) emphasises the significance of a family's social status, which influences both the quantity and quality of resources available to individuals. Moreover, UNICEF (2025) emphasises the critical importance of digital literacy, which encompasses a broader context that includes not only technical knowledge and skills but also the attitudes and competencies necessary for ensuring safety in the digital realm. Numerous factors affecting the level of digital literacy are discernible, categorised into external and internal influences. Through familial, educational, and extracurricular activities, alongside other experiential and knowledge-driven environments, individuals undergo socialisation processes that shape their perceptions of safety and risk in both the tangible and digital realms. Children progressively learn to navigate the nuances of the immediate and the distant, the real and the digital, each offering a plethora of stimuli and digital experiences that reflect historical, contemporary, and future contexts. Digital literacy is integral to the UNICEF framework, which aims to equip children and adolescents with the skills necessary for success in school, the workforce, and their broader lives. Consequently, digital literacy is a pivotal intersection for acquiring essential and transferable skills necessary for thriving within Society 4.0.

3. Occupational inheritance as a phenomenon

The ability to determine the trajectory of one's future profession in conjunction with aspirations for further education and orientation is termed professional-career competence. Hřebíček (2003, p. 22) conceptualises this competence as "a complex ability, representing a person's potential readiness to address the tasks, roles, and challenges frequently encountered in the interplay between individuals and the world of work." The professional-career competence of an individual evolves through various stages, influenced by growing awareness of one's possibilities, talents, interests, risks, consequences, impacts, and advantages inherent in the selected professional path. Hřebíček (2003, pp. 40-48) emphasises the significance of three factors shaping the strategies leading to professional choices: professional-career awareness, professional-career motivation, and the capacity for professional decision-making.

The occupational decisions of fifteen-year-old pupils at the conclusion of primary education are swayed by both internal and external influences, which may include health status, individual interests and skill profiles, innate abilities and talents, family dynamics, financial constraints, proximity to educational institutions, as well as the influence of peers, siblings, educators, and professional role models. Holland's research into personality typologies identified six categories of work personality types: practical, investigative, artistic, social, enterprising, and conventional (Holland, 1997, p. 1). This selection process is further influenced by various motivational factors, both external and internal, that shape pupils' aspirations for continued education.

In the context of Czech mining families, the phenomenon of intergenerational occupational transfer, predominantly from father to son, is notable. Ožanová (2018, pp. 23–26) investigated the impact of parental influence on children's career decisions and professional orientation, findings regarding the pivotal role played by family social and cultural capital in this intergenerational transfer of occupations.

Průcha, Walterová, and Mareš (2003, p. 274) define occupational choice as "a process involving decisions related to the selection of educational pathways or professional preparation, encompassing the entirety of an individual's professional career." This choice is inherently linked to an individual's professional orientation, which the authors describe as "the formation and development of a concrete professional goal and vision for a young person, encompassing the characteristics and abilities essential for the profession-selection process, its execution, and potential retraining" (p. 181).

Various factors, including family, educational institutions, peers, and individual interests, significantly influence the occupational choices of fifteen-year-old pupils. While personality traits primarily dictate career decisions, the necessary competencies for performing specific occupations also play a critical role. According to Hlaďo (2008, p. 9), the educational institution is tasked with equipping pupils with "the competencies essential for self-awareness and knowledge of the world of work.

Ožanová (2018, p. 29) highlighted the significant transformation in the social context and institutional frameworks following 1989, particularly emphasising the concept of social origin in relation to the diminishing prominence of blue-collar professions and the contemporary standing of the mining sector. She further posits that "certain common values characterise families with lower socioeconomic status, characteristics, approaches to upbringing and education, through which they convey their socioeconomic status to their offspring" (Ožanová, 2018, p. 31). This suggests a noticeable shift in the influence of familial socioeconomic status on child education, moving towards an emphasis on individual capability and parental valuation of education. Children from blue-collar families, therefore, often exhibit a propensity towards manual labour and vocational professions. Rabušicová et al. (2011, cited in Ožanová, 2018, p. 34) advocate for differentiating intergenerational learning within family structures into two levels: peer (for instance, among siblings) and intergenerational (such as that between grandparents, parents, and children). This familial dynamic is particularly evident within the mining industry, where members spanning diverse ages and family roles frequently found employment, thereby underscoring the generational transmission of mining professions.

The educational foundations for mining careers in the Czech Republic trace back to the late 19th century, marked by the establishment of specialised mining schools. The aftermath of World War II marked the emergence of new avenues for mining education through a network of apprenticeships, industrial schools, and programs offered by the Faculty of Mining and Geology at VŠB in Ostrava. The Moravian-Silesian Region boasts a rich mining heritage that dates back to the Middle Ages. Miners continue to uphold their cultural traditions, customs, language, and the collective identity that generations of miners have shaped. The profession has historically been inherited across generations; however, a noticeable decline in mining activities is anticipated in the years 2025-2026. This decline is closely associated with the transformation of the OKD company (Ostravsko Karvinské Doly) as it pivots towards new ventures infused with digital capabilities. Coal mining is gradually diminishing, and the OKD company is preparing to cease operational activities at the ČSM Mine (Důl Československé mládeže) by early 2026. On a positive note, OKD is actively facilitating the transition for its laid-off employees through the establishment of the New Shift department, which aims to help them secure new employment opportunities. Nevertheless, the OKD brand will not be entirely phased out; it will continue to engage in the production of industrial mixtures, the leasing of industrial facilities, the utilisation of mine gas, and the execution of various other business initiatives, all directed towards a systematic transformation of the company that is expected to last until 2050.

4. Research Methodology

This research aimed to explore the professional and educational characteristics of children of miners and other employees of the OKD mining company during a crisis in their parents' careers. It focused on aspects such as

professional orientation, student personality types, self-efficacy, interest in reading, proficiency with digital technologies, development of various competencies, and interest profiling for life in Society 4.0. Additionally, the study examined the children's relationship to the Moravian-Silesian region of the Czech Republic. To guide this investigation, the research problem was structured into a set of specific research questions.

1. Is there a connection between the student's interest in the energy industry and their interest in education in the field of technology, focusing on machines, cars, and IT? (E11/ D2)
2. Is there a connection between pupils' enjoyment of computer activities in their free time and their increased interest in future careers focused on digital technologies? (A8/ E12)

In our research, we administered questionnaires to pupils across three primary schools in the Moravian-Silesian region of the Czech Republic. The study was conducted from October 2024 to January 2025 by staff from the Faculty of Education at the University of Ostrava. We collected data from 318 respondents, consisting of lower secondary school pupils aged 13 to 16, specifically children of OKD employees attending schools in the Moravian-Silesian region. The semi-structured questionnaire included 42 semi-open questions organised into six categories labelled A through F.

A Leisure interests, activities (6 items)

B Interest in reading various types of texts (5 items)

C Educational competences and electronic/digital competences (4 items)

D Professional competences (digital technologies, machines, cars, etc.) (8 items)

E Professional competences (economy) (11 items)

F. Interest in transforming life in the Moravian-Silesian Region (12 items)

4.1 Results

The research objectives and research questions led to the formulation of hypotheses, which are presented together with the results of their statistical verification.

4.1.1 Results of descriptive data analysis

Descriptive data more closely characterise the selected professional, educational, leisure, and reading activities and preferences of individuals, as well as their relationship to the Moravian-Silesian Region.

Question A8: "Do you enjoy engaging in computer activities during your free time? (PC/NB)?" (yes/ no)

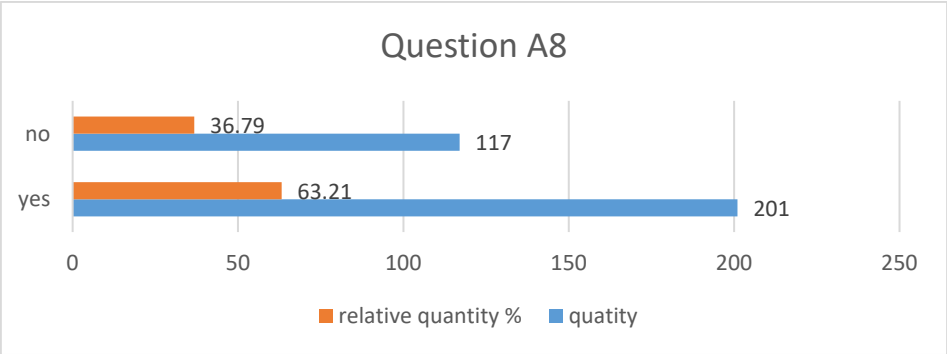


Figure 1. Utilising free time for computer-related activities.

In response to item A8, "Do you enjoy engaging in computer activities during your free time?", nearly two-thirds of respondents (201, or 51.93%) indicated that they prefer computer (PC/NB) activities during their free time.

Question E11: "Are you interested in pursuing a career in the energy industry? (yes/ no)

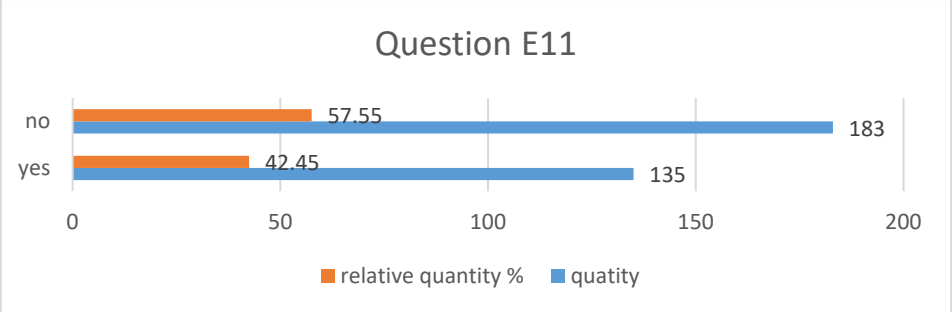


Figure 2. Interest in working in the energy industry.

The responses to item E11, "Are you interested in pursuing a career in the energy industry?" revealed that over half of the participants (183, or 57.55%) expressed interest in working in the energy sector. Conversely, more than two-fifths of the respondents (135, or 42.45%) indicated that they are not interested in pursuing a career in this field.

Question D2: "Are you interested in learning about technology?" (yes/no)

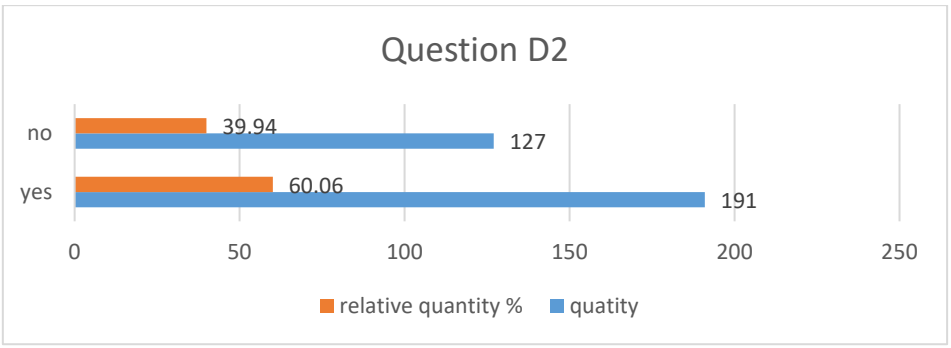


Figure 3. Interest in learning about technology.

The responses to item D2, "Are you interested in learning about technology?" revealed that three-fifths of the participants (191, or 60.06%) are interested in learning about technology. In contrast, 127 respondents (39.94%) stated that they are not interested in pursuing education in this field.

Question E12: "Are you interested in a professional profile/work focused on digital technologies?" (yes/ no)

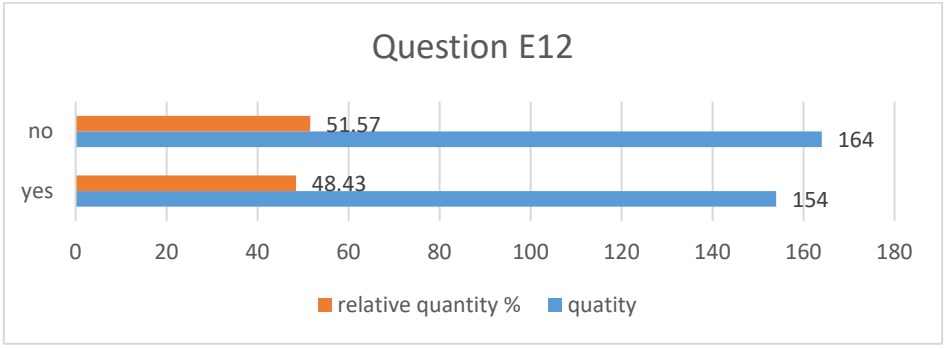


Figure 4. Interest in working with a focus on digital technologies

From the pupils' responses to item No. E12 "Are you interested in a professional profile/work focusing on digital technologies?" it was found that a larger half of the respondents (i.e. 164, 51.57%) are interested in a work focusing on digital technologies and that almost half of the respondents (i.e. 154, 48.43%) are not interested in a work focusing on digital technologies.

Research conducted in the realm of leisure interests and activities has yielded significant insights. The findings indicate that 48% of respondents perceive their leisure activities as varied, while 29% characterise theirs as narrowly focused. Alarmingly, 18.8% of participants reported experiencing boredom during their free time; moreover, the data highlights varying preferences for specific types of leisure activities. Notably, 41% of

respondents favour physical activities during their leisure time, 32% engage in practical home activities such as DIY projects, 15% enjoy spending time in nature, 7% prioritise relaxation, and 5% dedicate time to school-related preparations. Regarding the perceived variety of leisure pursuits, an overwhelming 69.5% of respondents believe their activities to be diverse, whereas 27.8% view them as monotonous. Storytelling emerges as a prominent leisure activity; 48.9% of respondents reported enjoying storytelling with friends, 25% with classmates, and 24.5% with friends through social media platforms. Remarkably, 45% of respondents indicated a preference for sharing life stories with their grandparents, while 36% valued narratives from parents and grandparents concerning family traditions and memories. A particularly noteworthy finding is that 46% of respondents actively explore locations connected to their ancestral heritage with their grandparents. Meanwhile, 28% reported undertaking such explorations with their parents, whereas 24.1% indicated that they do not participate in these ancestral explorations.

A significant portion of respondents, specifically 46%, indicated a preference for reading artistic texts, such as short stories and novels. In comparison, 38.9% expressed a lack of interest in non-artistic texts, including professional and journalistic writings. Regarding the format of text, 58% of respondents favoured printed materials, while 38.2% preferred digital formats.

When examining interest in various text types, only 12% confirmed an interest in scientific and technical electronic texts; conversely, 55% preferred reading printed materials centred on technical and scientific themes. Additionally, 35% showed general interest in diverse text types, while 64.4% did not. Notably, 32.5% of respondents appreciated texts that can be accessed in both printed and digital forms, with 38.2% favouring printed books compared to 28.1% who preferred digital texts.

In the context of educational competencies related to digital technologies, 55% of respondents reported having a permanent, high-speed Internet connection at home, while 29% did not. Close to half (47%) used digital technologies and PCs regularly for school preparation, although 35.5% reported irregular usage. Regarding computer ownership, 49% possessed their own laptop or PC, 23% shared a computer with siblings, and 9.8% borrowed one from school. Notably, 12% shared a computer with both parents and siblings. Regarding leisure activities, 67.6% prioritised working with a PC during their free time, while 31.2% did not.

A noteworthy interest in developing professional competencies in digital technologies was observed in 51% of respondents, whereas 49.3% reported a lack of interest in this area. A third (32%) expressed a strong interest in enhancing their competencies in technology fields, including automotive and IT sectors. More than half (59.8%) exhibited average interest in technology-related professional growth, while only 6.1% expressed no interest. Concerning economic activity as a professional competence, 11% confirmed a strong interest, and 79% showed average interest, with 7.1% indicating no interest. Interest in future professions revealed that 26.2% were inclined towards mechanical engineering, 21.8% towards healthcare, and 30.1% towards social services. Only 12.4% indicated an interest in economic-focused professions, and 6.4% aspired to enter the same field as their parents, while 2.1% were uncertain about their professional aspirations. When asked about parental employment in mining, 72.5% confirmed positive responses, while 21.8% indicated that their parents did not work in this field.

4.1.1 Relational research results

Two research hypotheses were tested using Pearson's Chi-square for a contingency table. The relevant source data and results of the statistical procedure are presented in the following tables.

H1: Pupils who are interested in technical education (e.g. cars, machinery, IT) are more interested in working/profiling in the energy industry than pupils who are not interested in technical education. (E11 x D2)

Table 1. Detected and expected frequencies for H1

Pearson´s chi-square = 13,59183	degree of freedom = 1	significance *p*= 0,002272	
Q E11	**Q D2 -yes**	**Q D2 - no**	**Line totals**
yes	97 (81,08)	38 (53,92)	135
no	94 (109,92)	89 (73,08)	183
Column totals	191	127	318

The results indicated a statistically significant relationship between pupils' interest in education in the field of technology and their interest in working in the energy industry. This supports our hypothesis.

Consequently, we accept hypothesis H1 at the 0.05 significance level.

H2: Pupils who enjoy spending their free time with computer activities are more interested in work focused on digital technologies than pupils whose priority is not to spend their free time with computer activities. (A8 x E12)

Table 2. Detected and expected frequencies for H2

Pearson´s chi-square = 0,097163	degree of freedom = 1	significance *p*= 0,75526	
Q A8	**Q E12 -yes**	**Q E12 - no**	**Line totals**
yes	96 (97,34)	105 (103,66)	201
no	58 (56,66)	59 (60,34)	117
Column totals	154	164	318

The analysis did not confirm a statistically significant relationship between pupils' interest in spending their free time on computer activities and their interest in work related to digital technologies. As a result, we reject hypothesis H2 at the 0.05 significance level.

5. Discussion and conclusion

The research outcomes, obtained through the questionnaire method, present an objective perspective on the leisure and reading activities, as well as the educational and professional competencies, of children whose parents work for OKD in the Moravian-Silesian Region.

The hypothesis H1 was confirmed, indicating a statistically significant relationship between the responses to both queries (E11 and D2). Conversely, the research did not substantiate the validity of hypothesis H2, which posited a statistically significant relationship between the responses to both questions (A8 and E12).

A noteworthy finding from the research is that nearly half (48%) of the respondents categorise their leisure activities as varied; however, 29% perceive their leisure pursuits to be one-dimensional, highlighting a significant concern. Alarmingly, 18.8% of participants acknowledged experiencing boredom during their leisure time. Additionally, an intriguing result emerged, wherein almost half (48.9%) prefer face-to-face storytelling with friends, while engagement in storytelling via social networks is favoured by over a third (34.5%). In contrast, only 14% indicated a preference for storytelling with classmates. Regarding reading preferences, nearly half (46%) of participants demonstrated a preference for artistic texts, whereas 38.9% favoured non-artistic texts. Furthermore, over one-eighth (15.1%) of respondents indicated a lack of preference for both artistic and non-artistic reading materials. Notably, 18.1% of respondents expressed an interest in pursuing a future career in the energy sector, while a substantial majority (81.6%) showed no inclination toward employment in this industry.

Katrňák (2006, p. 183) examined the educational attainment of parents of fifteen-year-old Czech pupils, highlighting its significance as a factor influencing their children's career choices. His findings indicated that “a higher level of education among both parents correlates with increased aspirations for their children’s future endeavours,” with maternal education exhibiting a more pronounced impact on educational aspirations than paternal education—particularly in the context of higher education.

Similarly, Swapnil Lange (2024) explored the dynamics of intergenerational occupational mobility, focusing on how parental occupations shape children’s career trajectories and contribute to income disparities. His research revealed a palpable influence of occupational inheritance on the perpetuation of income levels, as well as a concerning trend of negative self-selection among children from low-income backgrounds in their career decision-making processes.

Through semi-structured interviews, Ožanová (2018, p. 60) investigated the intergenerational transmission of the mining profession within a cohort comprising five parents who are miners and a community of nine children from mining families. The study aimed to investigate the impact of familial context on individuals' professional choices, the motivating factors behind their decision to pursue a career in mining, and the implications of this transmission within the family unit. The findings indicate that the intergenerational passage of mining professions is significantly shaped by the family environment, parental influence, and broader social contexts, all of which emerge as pivotal factors guiding children's professional orientation towards the mining industry. Moreover, other salient elements contributing to a favourable inclination towards the mining profession include academic performance, the advantages associated with mining employment (such as bonuses), the accessibility of educational opportunities and job placements, public perceptions, the inherent risks associated with the profession, as well as the distinctions between mining and surface employment profiles. From the conducted

interviews, two predominant characteristics emerged regarding individuals' perceptions of their relationship to mining: "I am a miner, who is more" and "I am a miner, what else should I do." In addition, Ožanová delineated two archetypes of typical mining families: (a) an ambitious family that aspires for their offspring to attain the highest possible levels of education and social status, and (b) a static family that exhibits a passive approach to child-rearing. The research identified a correlation between the transmission of mining professions in families and factors such as lower academic performance during compulsory education and the accessibility of relevant studies. Ultimately, the author affirmed that the intergenerational transmission of the mining profession remains an ongoing phenomenon within mining families.

Kuijpers (2025) conducted research concentrated on the Dutch context regarding the integration of career competencies as a compulsory component of pre-vocational and secondary school curricula. The primary objective of this study was to highlight the role of the educational environment in facilitating the development of pupils' career competencies. This was approached through the lens of two international meta-studies that emphasise two prominent theoretical frameworks: Intelligent Career Theory (ICT) and Social Cognitive Career Theory (SCCT).

In a different context, Siddiky and Akter (2021) examined the factors that influence career choice among 120 university pupils at Noakhali Science and Technology University in Bangladesh. Utilising a snowball sampling method, their findings indicate that the decision to pursue a particular professional career is shaped by a complex interplay of social, cultural, and economic influences; however, social class does not appear to affect career preferences significantly. The study also highlighted the effectiveness of self-education strategies as instrumental in guiding pupils towards their chosen professions. Moreover, although completing training programs in career development is integral to enhancing pupils' professional competencies, it was observed that a considerable proportion of pupils demonstrated little interest in enrolling in such courses. Consequently, the research highlighted the need to enhance career guidance for pupils, particularly in light of contemporary labour market dynamics.

Additionally, the International Reading Literacy Research (PIRLS 2021) identified significant issues within the educational landscape, particularly in primary schools, regarding the insufficient competencies of educators. Many teachers reportedly do not integrate digital devices into their instructional practices, even in an era characterised by Society 4.0, thereby restricting pupils' opportunities to cultivate digital and technically oriented competencies. "Approximately three-quarters of pupils have teachers in whose classrooms they never encounter digital devices during individualised activities" (PIRLS, 2021, p. 61).

The problem of different types of teaching texts in educational practice was addressed by research by Ivic (2029), Carpenter, Bullock and Potter (2006) or Van den Ham and Heinze (2018).

Blanc et al. (2025) identified a significant relationship between student autonomy and the utilisation of digital tools and technologies in addressing real-world problems. Their research demonstrated that primary and secondary school pupils from four European countries—Slovenia, Portugal, Spain, and Greece—exhibited a heightened comprehension of the text, evidenced by their understanding of the questions posed in the research questionnaire.

In a methodologically rigorous study, Sowa et al. (2025, pp. 1-2) examined the challenges of supporting children's career aspirations amidst the evolving landscape of career conditions. Their work provides a systematic overview of various intervention approaches by analysing the methodologies of 45 different authors. This study provides valuable insights into the interplay between scientifically grounded approaches and the underlying principles that may help predict the career aspirations of adolescents, thereby influencing their future career trajectories and decisions. It encompasses a broad spectrum of trends, including shifts in career prospects and the impact of job automation, which complicate intervention strategies concerning career aspirations. The authors compile alternative approaches that foster a deeper understanding of occupational transitions, contextualised within the realities of the 21st-century societal evolution influenced by digitalisation and robotic advancements.

The anticipated advantages of this research can be interpreted as factors rooted in both socioeconomic and administrative frameworks. The relevant data derived from research into human resources and their professional prospects holds potential to enhance the retention of qualified workers in the Moravian-Silesian Region, thereby influencing their choices to remain locally rather than pursuing opportunities elsewhere.

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Ethics declaration

I did not need ethical clearance for the research referred to in this paper.

AI declaration

I did not use an artificial intelligence tool to create the presented article.

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Enhancing Higher Education Learning through Blackboard: Impact on Student Learning and Diversity

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Abstract: The increasing reliance on digital learning platforms in higher education necessitates an exploration of how Learning Management Systems (LMS) like Blackboard influence student learning experiences and accommodate learning diversity. This study examines the effectiveness of Blackboard in promoting inclusive and engaging learning experiences at the University of Fort Hare. The purpose of this research was to investigate how students interact with Blackboard, the challenges they face, and the extent to which the platform supports diverse learning needs. This study is guided by the Community of Inquiry (CoI) framework, which examines cognitive, social, and teaching presence in online learning. By applying this framework, the research evaluates how Blackboard fosters meaningful engagement, supports diverse learning needs, and enhances instructional effectiveness, contributing to a more inclusive and student-centered digital learning environment. This study adopts a mixed-methods approach. This methodology allows for a comprehensive analysis of students' perceptions, engagement levels, and barriers to the optimal use of Blackboard. The findings indicate that while Blackboard enhances accessibility to learning materials and fosters asynchronous engagement, students encounter challenges related to digital literacy, navigation complexities, and limited interactive elements. Additionally, variations in students' technological proficiency and learning preferences highlight the need for adaptive instructional strategies. The above findings indicate the importance of integrating student centered design principles into Blackboard's usage, ensuring that learning experiences cater to diverse student backgrounds. Providing training for both students and lecturers is important in addressing technical challenges, improving digital literacy, and ensuring seamless navigation of Blackboard. The study's relevance lies in informing institutional strategies for improving Blackboard's pedagogical effectiveness, fostering student engagement, and promoting digital inclusivity. By addressing these concerns, the University of Fort hare can enhance student learning experiences and bridge digital disparities, ultimately contributing to a more equitable and responsive higher education environment.

Keywords: Blackboard, Learning Management System, Student Engagement, Learning Diversity

1. Introduction and Background

In recent years, universities have made a big shift towards using online learning tools to support teaching and learning. At the University of Fort Hare (UFH). Blackboard is the Learning Management System (LMS) used to give students access to learning materials, sharing of announcements, and allowing interaction between students and lecturers. This shift has been especially important during and after the COVID-19 pandemic, which pushed many institutions to rely more on digital platforms , (Czerniewicz at el, 2020). While Blackboard makes it easier for students to access learning content at any time, it also comes with practical challenges that affect how students learn and engage with their studies (Uziak,at et, 2018). Many UFH students come from disadvantaged backgrounds, and not all of them have the same level of digital skills. Some students struggle to use Blackboard because they are not familiar with technology, while others face problems like poor internet connection or difficulty in navigating the system. Alokluk (2018) states that effective implementation of Blackboard must address a number of barriers, including institutional culture, pedagogical and technical support, teacher's familiarity with technology and pedagogical content knowledge, students' technical knowledge, and resources. These challenges make it hard for all students to benefit equally from online learning. Some also find the content on Blackboard not interactive enough, which can make learning feel lonely or boring.

The central problem addressed in this study is the disconnect between the intended functionality of Blackboard as an inclusive learning platform and the actual experiences of students at UFH. While Blackboard is designed to support a wide range of learning needs through its digital tools and flexible content delivery mechanisms, in practice, it does not always meet the diverse requirements of all students. According to Yu at el (2024) many students encounter barriers such as limited digital literacy, inconsistent access to reliable devices or internet connectivity, and difficulties in navigating the platform's interface. Additionally, the way in which learning content is structured and delivered on Blackboard often fails to consider students' varied learning preferences, linguistic backgrounds, and levels of prior exposure to digital learning environments (Raza at el, 2022). These challenges contribute to unequal learning experiences and hinder full participation in the academic process for some students.

At UFH, first-year students are supported through structured Blackboard training sessions designed to introduce them to the platform's key features, including course navigation, accessing learning materials, submitting assignments, and participating in online discussions. These trainings are conducted during the first week of the academic year as part of the student orientation programme. The training runs over a full week, with two sessions held daily, each lasting two hours. Following the initial training week, additional refresher sessions are scheduled every Wednesday for the first term to reinforce learning and address any challenges students may encounter as they begin engaging with their online courses.The TeL Student Assistants play an important role in providing hands on guidance, answering student queries, and offering one-on-one consultations to ensure that first-year students develop the digital skills needed to effectively engage with their courses on Blackboard. This support system is crucial in helping new students transition into the digital learning environment with confidence.

2. Literature Review

2.1 The Role of Learning Management Systems in Higher Education

The LMS play an important role in higher education by enhancing teaching and learning processes. These platforms facilitate the creation, delivery, and management of educational content, making learning materials easily accessible to students (Thangavel, 2024). In addition to supporting academic delivery, LMS streamline administrative functions such as documentation storage and report generation, thus improving institutional efficiency (Madyatmadja et al., 2023). The integration of LMS into higher education institutions has transformed traditional educational practices, supporting more organized, centralized, and efficient workflows.

The LMS also contributes significantly to teaching and learning by promoting student engagement and supporting a variety of learning preferences. The LMS faciliatates the creation of interactive learning environments that encourage active participation, leading to improved student satisfaction and learning outcomes (Madyatmadja et al., 2023). Moreover, LMS offer flexible and accessible learning opportunities, allowing students to learn at their own pace and from any location (Ebbini, 2023). By accommodating various pedagogical approaches, these systems help lecturers address diverse learning needs and styles, ultimately enriching the overall educational experience.

Despite their numerous advantages, the implementation of the LMS is not without challenges. Issues such as system complexity, infrastructure limitations, and the need for skilled personnel can hinder effective integration (David et al., 2022). Nevertheless, the transformative potential of LMS in higher education remains substantial. Continued investment in training, system development, and technological innovation is essential to fully leverage the benefits of the LMS and ensure they contribute meaningfully to the advancement of teaching, learning, and institutional effectiveness.

2.2 Digital Literacy and Access in the South African Higher Education Context

Digital literacy and access in South African higher education are pressing concerns, shaped by persistent socio-economic disparities and rapid technological advancements. While the integration of digital tools has the potential to enrich learning experiences, many students continue to face significant obstacles in both access and skill development. Research shows that a considerable number of students lack the digital and information literacy skills necessary for academic success and meaningful participation in the digital world (Shibambu & Mojapelo, 2024). As the demands of the Fourth Industrial Revolution grow, there is a rising need for inclusive digital practices, especially in multilingual educational settings where technology can serve as a tool to improve learning outcomes (Ndebele, 2022).

Despite efforts to promote digital inclusion, many students still experience inconsistent access to digital resources. This tension is often felt as students navigate between technologically enriched environments and under-resourced ones, reflecting broader inequalities in the South African education system (Kajee & Balfour, 2011). The digital divide in this context is not simply about having or lacking technology, but rather about the quality, consistency, and context of access. As such, it is important to move beyond simplistic understandings of digital inequality and recognize the nuanced, uneven experiences of students across different institutions and communities (Liebenberg et al., 2012).

The educational implications of these disparities are significant. Multimodal pedagogies offer a promising response, allowing lectures to tap into the diverse resources that students bring with them and to create more inclusive learning environments (Archer, 2016). At the same time, there is a growing recognition of the need for curricula to incorporate digital competencies to better prepare students for the evolving demands of the digital age (Shibambu & Mojapelo, 2024). Although the challenges remain considerable, there are ongoing efforts

through policy, pedagogy, and institutional reform to bridge digital gaps and promote greater equity in South African higher education.

2.3 Theoretical framework

The study employs the Community of Inquiry (CoI) framework developed by Garrison, Anderson, and Archer (2000). This model guides the design of effective online and blended learning environments by emphasizing the interplay of three core elements: cognitive presence, social presence, and teaching presence. Below on figure 1 is the Community of Inquiry framework diagram that illustrates the interrelatedness of the three elements of the framework.

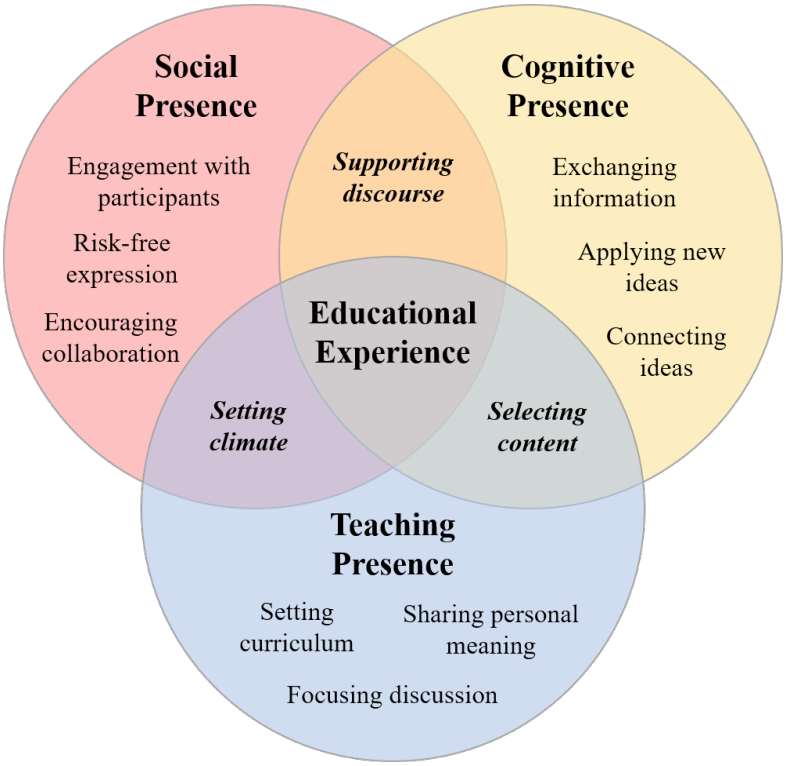


Figure 1: Community of Inquiry framework.

The framework looks at three key areas: cognitive presence (how students make sense of the content), social presence (how students connect with others), and teaching presence (how lecturers guide the learning process). The study explores how well these areas are working on Blackboard and what can be improved. The aim is to help the university make better decisions about how to use Blackboard in ways that support all students, especially those with limited digital access or learning support.

3. Methodology

3.1 Research Design

The parallel mixed-methods design was employed in the study to effectively capture undergraduate students' perceptions, engagement levels, and barriers to using Blackboard. In this approach, quantitative data was collected through structured surveys, allowing for statistical analysis of students' usage patterns, satisfaction levels, and technical challenges. At the same time, qualitative data was gathered using open-ended survey questions, providing deeper insight into students' personal experiences and contextual factors influencing their use of the LMS. The data from both strands were collected independently but analyzed together to draw comprehensive conclusions. As Hashemi et al (2013) highlight, this concurrent design ensured that both numeric trends and individual voices were equally considered. The combination of closed- and open-ended items strengthened the study's validity, offering both breadth and depth in understanding students' interactions with Blackboard. This design is particularly useful in educational research where multiple forms of evidence enrich interpretation and application (Mislevy,, Behrens, Dicerbo,& Levy, 2012).

3.2 Sampling

In this study, one academic bootcamp was conducted for the faculty of Social Sciences first year students in UFH. The bootcamp aimed to support students' transition into university learning by covering key academic and digital skills, including a dedicated session on digital literacy, which focused on effective use of Blackboard and other online learning tools. It is mandatory for all students to attend from the faculty of Social Sciences. Following the academic boot camp, a questionnaire was distributed to the students through Google forms to collect their responses and perceptive. Out of 650 students who attended the bootcamp, 276 students completed and submitted the questionnaire. This resulted in a response rate of approximately 42%. The collected responses were then used to anaylse the effectiveness of Blackboard in promoting inclusive and engaging learning experiences at the university.

3.3 Data Collection

In this study, the data collection process used both quantitative and qualitative methods to capture a comprehensive set of responses from participants. Quantitative data were gathered through numerical responses, which involved the use of surveys with closed- ended questions and rating scales. This type of data provides measurable results that facilitate the identification of trends, patterns, and correlations within the dataset.

In addition, qualitative data was collected through narrative responses, which involved open ended questions with prompts that encouraged participants. This approach captures the experiences, opinions, and insights offering context and elaborating beyond numerical scores. Participants shared their personal reflections on the effectiveness of Blackboard in promoting inclusive and engaging learning.

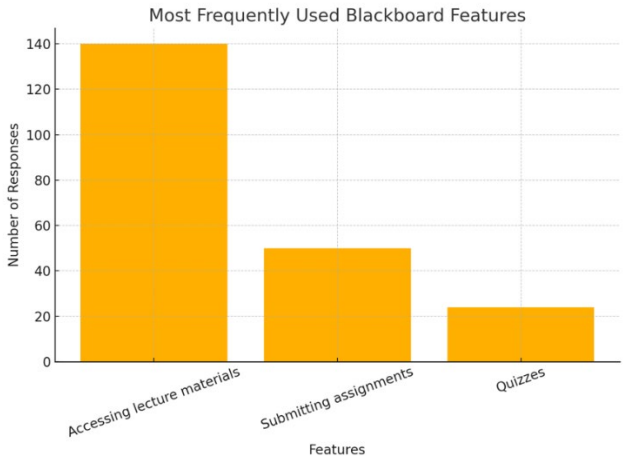
3.4 Data Analysis

The analysis is structured using the Community of Inquiry (CoI) framework, which evaluates the learning environment through three key presences: Cognitive, Social, and Teaching. The goal is to identify strengths and areas of improvement in Blackboard usage to support all students, especially those with limited digital access or learning support.

4. Results and Discussion

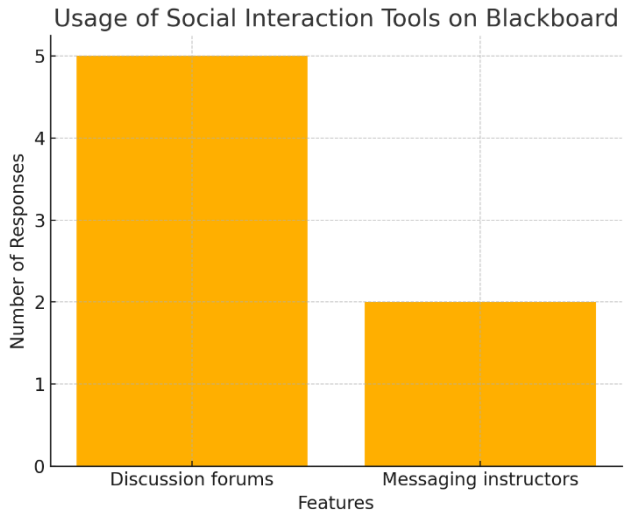
4.1 Cognitive Presence Analysis

Cognitive presence refers to the extent to which students can construct and confirm meaning through sustained reflection and discourse. Within the Blackboard learning environment, it is demonstrated by how students engage with academic content, particularly in ways that support understanding, inquiry, and knowledge building. Based on the survey data, the most frequently used feature was accessing lecture materials, which received the highest number of responses (140), indicating its central role in students' use of the platform. This was followed by submitting assignments, with 50 responses, highlighting its importance in managing coursework. Quizzes were also commonly utilized, with 24 responses, suggesting that they are a valued tool for assessment and engagement in the learning process. These findings indicate that students are consistently using Blackboard to engage in academic activities that foster independent learning and understanding of course content. The high usage of content delivery and assessment features shows that students are utilizing Blackboard not just for administrative tasks but as a core component of their academic learning.



4.2 Social Presence Analysis

Social presence involves the ability of students to project themselves socially and emotionally within a digital learning environment. In the context of Blackboard, this presence is fostered through tools that enable interaction, collaboration, and communication among students and lecturers. Based on the survey data collected, discussion forums were used by only 5 respondents, indicating limited engagement with peer-to-peer interaction features. Similarly, messaging lecturers was the least utilized feature, with only 2 respondents reporting its use, suggesting minimal direct communication between students and lecturers through the platform. These low usage numbers suggest that Blackboard's interactive features are underutilized for fostering community and connection. This minimal engagement indicates a gap in peer-to-peer and student instructor interaction, which can negatively impact students' sense of belonging and engagement. There is a clear need for targeted interventions to encourage and support meaningful online interactions through these tools to build a more connected and supportive learning community.

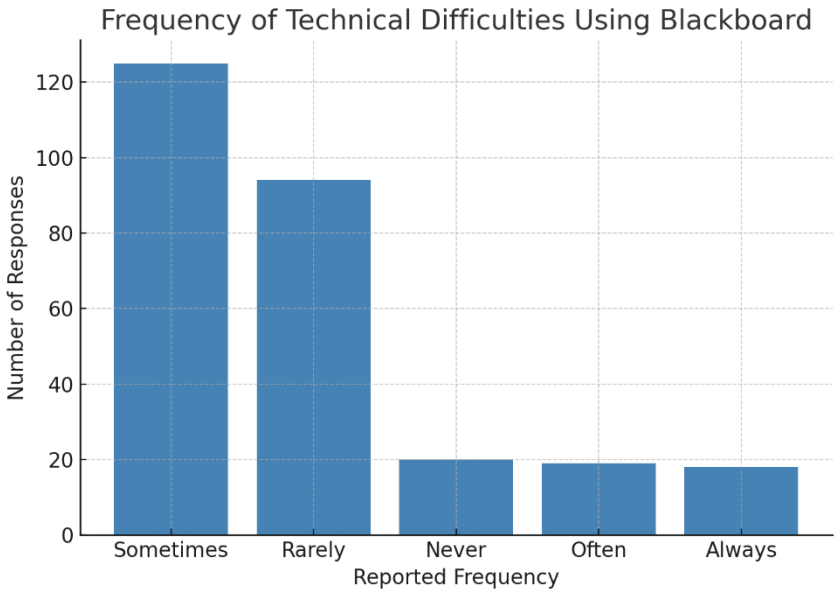


4.3 Teaching Presence Analysis

Teaching presence refers to the design, facilitation, and direction of cognitive and social processes to realize meaningful learning outcomes. Within the Blackboard platform, teaching presence is reflected in how well the platform is structured, how clearly course instructions are communicated, and the degree to which lecturers guide and support students through their learning journey. Based on the survey results, students expressed a high level of satisfaction with their learning experience, as reflected in the following, the average score for confidence in using Blackboard for academic activities was approximately 4.1 out of 5. The average score for ease of navigation on the platform was approximately 4.2 out of 5. These results suggest that the instructional design within Blackboard is generally well executed. The high ease of use scores implies that course structures, learning paths, and access to academic resources are automatically laid out. Similarly, the high confidence levels indicate that students feel adequately prepared and supported when engaging with Blackboard’s academic tools.

4.4 Barriers and Challenges

Technical difficulties emerged as a significant barrier to effective engagement with the Blackboard platform. When asked about the frequency of these issues, most students indicated they experienced them sometimes (19% responses), followed by rarely (14% responses), suggesting that while not constant, technical problems were a recurring concern. A smaller number of students reported never encountering issues (20), while others experienced them more frequently, with often (19) and always (18) responses, highlighting that for a subset of students, technical challenges were persistent and potentially disruptive. This distribution shows that while a considerable number of students face occasional issues, technical barriers are a consistent concern for a large portion of users. Such interruptions can affect students’ ability to attend classes, complete assessments, or access materials on time Open-ended responses revealed specific challenges such as poor internet connectivity, difficulty logging into the system, and problems with accessing or submitting online tests. These technical limitations disproportionately affect students with limited digital infrastructure and undermine the overall effectiveness of Blackboard as a learning tool.



5. Conclusion

This study has demonstrated that Blackboard plays an important role in enhancing access to learning content and promoting independent academic engagement among students at the University of Fort Hare. Guided by the Community of Inquiry (CoI) framework, the research revealed strong cognitive and teaching presences on the platform, particularly in terms of content accessibility, assignment submission, and course navigation. However, social presence remains significantly underdeveloped, with limited use of discussion forums and communication tools, thereby weakening the potential for peer collaboration and community building. Challenges such as inconsistent digital literacy, unreliable internet access, and technical glitches disproportionately affect students from disadvantaged backgrounds, undermining the inclusive potential of Blackboard. While training interventions such as bootcamps and the support of TeL Assistants have begun to address these gaps, sustained institutional efforts are needed to optimize Blackboard's pedagogical impact. Ultimately, the findings emphasize the importance of responsive digital learning environments that are not only technologically functional but also pedagogically inclusive. Addressing the structural and technical barriers identified in this study will be crucial to ensuring that Blackboard truly supports diverse learning needs and contributes meaningfully to equitable and transformative higher education in South Africa.

6. Recommendation

Based on the study's findings, it is recommended that the University of Fort Hare strengthen digital literacy support for both students and lecturers through continuous training and expanded access to TeL Assistants. Greater emphasis should be placed on enhancing social presence by encouraging the use of interactive features such as discussion forums and peer collaboration tools within Blackboard. To improve accessibility and user experience, the university should address technical issues related to platform reliability and ensure offline or low-bandwidth alternatives for students with limited connectivity. Furthermore, institutional policies should prioritize digital inclusion by aligning resources toward device provision, internet access, and pedagogical innovation. Ongoing monitoring and student feedback mechanisms are essential to ensure that Blackboard continues to meet the diverse and evolving needs of the student body.

Ethics Declaration

This research was carried out in line with established ethical standards and institutional protocols governing studies involving human participants. Approval for the study was granted by the Inter-Faculty Human Research Ethics Committee (Reference Number: IFHREC-25/08/0008). Participants were provided with full information regarding the study's purpose and procedures, and their voluntary involvement was obtained through signed informed consent. Measures were taken to safeguard participants' privacy, confidentiality, and anonymity, with all data managed in accordance with relevant data protection requirements.

AI Declaration

This paper was prepared with the assistance of artificial intelligence tools, namely ChatGPT (OpenAI), which was used to improve language clarity and support the development and refinement of ideas during the writing

process. The author remains fully responsible for all critical analysis, content decisions, and the overall structure of the work. The use of AI was conducted in alignment with relevant ethical and institutional guidelines.

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The Impact of an AI-Based Educational Platform on Student Teachers' Self-Regulated Learning

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Abstract: This study investigated the effectiveness of an AI-based lesson planning platform in enhancing self-regulated learning (SRL) skills among student teachers at Sultan Qaboos University. To address a critical gap in AI–SRL integration within Middle Eastern teacher education contexts, this research developed a culturally adapted, Arabic-enabled platform aligned with national curriculum standards. Utilizing a quasi-experimental pre-test/post-test design, the SRL skills of an experimental group (n=14) using an AI-based lesson planning platform were compared with those of a control group (n=15) who followed traditional lesson planning methods. During a four-week intervention, the AI-based platform was utilized to streamline the planning process by providing ready-made lesson plans that adapt to teachers' objectives, strategies, and evaluation methods. The platform enables teachers to customize and modify each section of their plan by offering personalized suggestions tailored to the instructional needs of each teacher. An SRL questionnaire was constructed and validated for data collection. This instrument comprised 20 items across four dimensions: short-term planning, real-time self-monitoring, rapid self-evaluation, and adjustment of strategies. The questionnaire demonstrated excellent psychometric properties, exhibiting good overall internal consistency (Cronbach's $\alpha = 0.89$), with individual dimension reliabilities ranging from 0.79 to 0.87, and good test–retest reliability ($r = 0.84$). Content validity was established by a review conducted by six expert faculty members specializing in educational psychology and teacher education, while construct validity was confirmed using an exploratory factor analysis that revealed a four-factor structure explaining 68.5% of total variance. The statistical analysis indicated a significant improvement in the SRL dimensions for the experiential group, rising from a pre-test mean of 75.07 (SD=10.5) to a post-test mean of 102.20 (SD = 12.5), $t(13) = -6.93$. $p = 0.005$. This yields an average gain of 26.93. In contrast, the control group exhibited no significant increase, with only a slight mean improvement of 6.87 (pre-test: M = 78.8, SD = 11.5; post-test: M = 85.67, SD = 13.0; $t(14) = -1.8$, $p = 0.438$). The positive effect was evident across all four SRL sub-dimensions, highlighting the inclusive impact of the AI-based platform. This research advances the field of AI in education, with substantial implications for curriculum design for teacher education and professional development.

Keywords: self-regulated learning, student teachers, AI-based educational platform, teacher education, lesson planning

1. Introduction

In an increasingly complex and rapidly evolving educational landscape, students' ability to control their own learning has become more critical than ever (Zimmerman, 2002). Self-regulated learning (SRL) is a cornerstone of this educational autonomy, empowering students to become active, engaged, and effective learners (Pintrich, 2000). SRL is a multifaceted construct that encompasses the thoughts, feelings, and actions individuals generate to attain their learning goals (Schunk & Zimmerman, 2008). It is, therefore, not merely a set of academic skills; it is a proactive process that enables students to manage their learning experiences, adapt to challenges, and ultimately achieve academic success (Winne & Hadwin, 1998). The development of SRL skills is a key objective of modern education, as it equips students with the necessary tools to become lifelong learners who can navigate the demands of higher education and the professional world. While some students naturally develop SRL strategies, many require explicit instruction and support to cultivate these essential competencies. The adoption of artificial intelligence (AI) in teacher education is rapidly transforming pedagogical practices, offering new opportunities for teaching and learning (Mutiga, 2024). Academics and innovators have developed AI-powered tools to support student teachers in improving crucial skills, such as lesson planning (Van den Berg & Du Plessis, 2023). Existing systematic reviews have demonstrated that AI applications can be used in higher education to successfully support SRL (Lan & Zhou, 2025).

The present research explores how an AI-based platform helps student teachers at Sultan Qaboos University (SQU) in the process of designing their lessons. The study examines the effectiveness of this platform in improving teachers' SRL skills, which are essential for quality teaching and continuous professional development (Sakamoto et al., 2024). Lesson planning is a core competency for teachers that requires multifaceted interaction among content knowledge, pedagogical strategies, and awareness of student needs (Kehoe, 2023). Recent advances in SRL facilitated by AI applications have produced multilayer taxonomies (Grüneke et al., 2024). Students can find traditional lesson planning methods time-consuming and demanding as they continue to build their pedagogical expertise. AI-driven platforms provide a promising solution by structuring support, generating ideas, and delivering feedback to scaffold students' lesson planning process (Wong & Viberg, 2024). This study

argues that leveraging such platforms can enhance the quality of lesson plans while improving SRL, practical goal setting, self-reflection and time management skills. Meta-analyses show that SRL scaffolds in computer-based environments enhance academic performance (Zheng et al., 2016). This study therefore explores how AI tools can be used to improve teacher preparation and support the development of competent, self-regulated teachers at SQU. As a key institution for teacher education, SQU is particularly well-positioned to benefit from this research, as its teacher preparation programs can directly apply the study's insights to enhance student teachers' self-regulated learning and integration of AI tools in lesson design.

2. Research Gap and Problem Statement

The concept of SRL has its foundations in social cognitive theory, which emphasises the dynamic interplay among personal, behavioural, and environmental factors (Zimmerman & Schunk, 2018). Zimmerman (2002) defined SRL as a cyclical process involving learners setting goals, applying strategies, monitoring progress, and evaluating outcomes, reflecting the metacognitive, motivational, and behavioural dimensions of active learning (Panadero, 2017; Schunk & Greene, 2018). Research has consistently demonstrated strong positive correlations between SRL and academic achievement across age groups and disciplines (Theobald, 2021; Jansen et al., 2019). Students with effective SRL skills show higher achievement, stronger motivation, and improved self-efficacy, which are essential qualities for navigating today's information-rich environments (Wong et al., 2019; de Ruig et al., 2024). Despite the established benefits, there are several gaps in the SRL literature. Methodologically, it is dominated by correlational designs, rather than experimental or quasi-experimental methods, which limits the ability to make causal claims (Dignath & Büttner, 2008; Panadero, 2017). Reviews reveal that fewer than one-third of interventions employ rigorous control-group designs, and many use small samples, reducing statistical power (Cleary et al., 2021; Vilkova, 2022). Culturally, most SRL studies are conducted in Western contexts, limiting the generalizability of findings across diverse educational settings (McClelland & Wanless, 2015; McInerney & King, 2018; Xu et al., 2023). Traditional frameworks often fail fail to reflect the collective values, social norms, and learning strategies that characterize non-Western cultures (Anyichie et al., 2023; Haslam et al., 2019). Moreover, limited integration of co-regulation processes involving teachers, peers, and caregivers has left the social and collaborative dimensions of SRL largely underexplored in teacher education, particularly within non-Western contexts such as Oman (Bransen et al., 2022; Tauber et al., 2023) and insufficient attention to the sustainability of SRL strategies, with few studies examining long-term adoption (Akdeniz, 2022; Suhandoko & Hsu, 2020; Lobos et al., 2024). Additionally, despite the strong influence of peer and social learning contexts on adolescent development, these areas remain underexplored (Wu et al., 2023; Fan et al., 2022). These shortcomings highlight the urgent need for research on the development of rigorous, culturally responsive, and sustainable SRL. interventions, particularly in underrepresented contexts such as the Middle East. The present study is guided by the following research questions:

1. Does a participation in an AI-based lesson planning intervention lead to a significant improvement in students' overall academic performance?
2. Does use of an AI-based lesson planning platform have a differential impact on the four sub-dimensions of SRL?

3. Literature Review

3.1 AI in Teacher Education

Research on the role of AI in teacher education has grown rapidly alongside the development of AI-powered technologies to support various aspects of teachers' professional development, such as automated feedback on instructional practices, virtual reality for developing class management skills, and AI tutoring systems for improving content knowledge (Cruz et al., 2024). Generative AI has created new possibilities for developing personalised and adaptive learning frameworks that efficiently enhance SRL (Prasad & Sane, 2024). A key area of inquiry is the use of AI for lesson planning. Tools such as ChatGPT have demonstrated significant potential in helping teachers produce well-structured and engaging lesson plans (Van den Berg & Du Plessis, 2023). These tools can empower teachers to brainstorm ideas, integrate activities with curricula goals, and differentiate instruction to address learner diversity (Wong & Viberg, 2024). More research on the impact of these tools is therefore needed, particularly in the context of pre-service teacher education programs (Kehoe, 2023).

3.2 Self-Regulated Learning in Student Teachers

SRL is a multi-dimensional construct involving the ability of learners to formulate goals, monitor their advancement, assess their performance, and request help when needed (Zimmerman, 2008). Recent research has highlighted the importance of evaluating SRL and understanding how AI tools support these processes (Prasad & Sane, 2024). SRL skills enable student teachers to become reflective and committed to their ongoing

advancement (Panadero, 2017) and have been associated with improved teaching effectiveness and professional longevity (Theobald, 2021). The synergy between AI and SRL thus represents a promising opportunity for enhancing educational outcomes (Zhang & Fan, 2025). AI-driven platforms provide adaptive scaffolding, personalised feedback and real-time monitoring to help develop SRL skills. Research has revealed that when AI tools are designed with SRL principles in mind, they can effectively support learners in developing metacognitive awareness and self-regulatory strategies (Wong & Viberg, 2024). Teachers who are effective self-regulated learners are more inclined to establish professional development goals, seek feedback and reflect on their teaching (Zimmerman, 2008). SRL skills can be developed through direct instruction and support (de Ruig et al., 2024), and various methods, such as peer coaching, reflective journals and technological tools, can be used to provide opportunities for student teachers to develop SRL skills that are aligned with their pedagogical competencies (Zee & de Jong, 2024).

3.3 AI and Self-Regulated Learning

The interconnection of AI and SRL is a promising area of research. AI-driven tools have the potential to support SRL by scaffolding complex tasks, providing customised feedback and enhancing self-reflection (Bonilla et al., 2025). For instance, an AI-based platform could be used for lesson planning, providing input on the alignment of the objectives and activities. It could also prompt student teachers to reflect on and enhance their pedagogical choices. By providing such support, AI tools can help student teachers strengthen their self-regulation across their learning and teaching practices (Zhang et al., 2025). However, additional research is needed to understand the best ways of integrating AI tools into teacher education programs to improve student teachers' SRL skills (Mutiga, 2024).

4. Methodology

4.1 Research Design

This study employed a quasi-experimental design to investigate the impact of an AI-driven lesson planning platform. This design enabled the comparison of experimental and control groups, with participants assigned to each group in a manner that ensured comparability. Pre- and post-test measures were used to evaluate changes in SRL skills over time. The participants recruited for this study were 29 student teachers enrolled in the Science Teacher Education program at SQU. They were divided randomly into an experimental group (n = 14) and a control group (n = 15). Over a four-week period, the experimental group employed the AI-based lesson planning platform for lesson preparation, while the control group utilised traditional lesson planning methods. Prior to the intervention, both groups attended a brief workshop on the Ministry's lesson preparation framework. Both groups were in the final year of the program and had the same teaching experience.

4.2 The AI-Based Lesson Planning Platform

The AI-driven lesson planning platform developed for this research was utilized to support student teachers in creating high-quality lesson plans. The platform delivered a range of features, including:

- **A structured lesson plan template**: The platform integrated all Grade 8, Term 2 learning outcomes from the Teacher's Guide, including content, experiments, activities, and questions from both the Student's Book and the Activity Book, ensuring comprehensive consistency with the official curriculum outlined by the Ministry of Education in Oman.
- **AI-driven suggestions**: The platform, powered by ChatGPT, complied with learning outcomes and official assessment methods. Additionally, it generated suggestions for activities and assessment methods, based on the grade level and subject matter.
- **Feedback and reflection prompts**: The platform provided feedback based on interactions between the student and the system, offering a range of innovative and interactive instructional strategies and assessment methods.
- **Integrated time efficiency:** The platform was designed for efficiency, providing student teachers with instant access to necessary resources with just one click. Participants accessed the platform via laptops and mobile devices, receiving instant AI-generated text feedback to guide lesson design aligned with the Omani science curriculum.

4.3 Data Collection and Analysis

The Self-Regulated Learning (SRL) questionnaire was developed by the researcher based on Zimmerman (2000) and Pintrich (2004). It included 24 items across four dimensions: planning, self-monitoring, quick evaluation, and strategy adjustment. Validated by experts, the scale showed strong reliability ($\alpha = 0.89$; subscales = 0.79–0.87; $r = 0.84$). Sample items included "I plan learning tasks in advance" and "I adjust strategies when facing challenges".

The SRL questionnaire was administered to the experimental and control groups, once at the beginning and once at the end of the intervention period. The data were analysed using SPSS software, performing independent and paired samples t-tests to compare the SRL scores of both groups.

5. Results

5.1 Descriptive Statistics

The descriptive statistics for the pre-test and post-test scores of the experimental and control groups are presented in Table 1.

Table 1: Descriptive statistics for pre-test and post-test SRL scores

Group	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	Mean Change
Experimental	14	75.07	10.5	102.0	12.5	+16.93
Control	15	78.8	11.5	85.67	13.0	+6.87

5.2 Pre-Test Group Equivalence

An independent samples t-test was conducted to compare the pre-test SRL scores of the experimental and control groups. The results revealed no statistically significant differences between the two groups at the pre-test assessment ($t(27) = -0.95$, $p = 0.351$). This finding indicates that the SRL skills of the two groups were equivalent at the start of the study, providing a solid foundation for comparing post-intervention outcomes.

5.3 Main Effects of the Intervention

A paired samples t-test was conducted to compare the experimental group's pre-test and post-test SRL scores. The results revealed a statistically significant improvement in the group's SRL performance from pre-test ($M = 75.07$, $SD = 10.5$) to post-test ($M = 102.0$, $SD = 12.5$), $t(13) = -6.93$, $p = 0.005$. The intervention resulted in a substantial mean SRL score increase of 26.93 points, with a confidence interval ranging from -35.5 to 18.3. A paired samples t-test was also conducted to compare the control group's pre- and post-test scores. The results revealed no statistically significant change in the control group's SRL performance from pre-test ($M = 78.8$, $SD = 11.5$) to post-test ($M = 85.67$, $SD = 13.0$), $t(14) = -1.8$, $p = 0.438$, with only a modest mean increase of 6.87 points.

An independent samples t-test was conducted to compare the post-test scores of the experimental and control groups. The results indicated a statistically significant difference between the two groups in terms of their post-test scores ($t(27) = 3.85$, $p = 0.001$), with the experimental group demonstrating superior SRL performance.

Our results suggest that AI-driven platforms may be significantly effective, as our effect size exceeds the average reported in previous meta-analyses. In contrast, the control group showed no significant increase in SRL scores from pre-test ($M = 78.8$, $SD = 11.5$) to post-test ($M = 85.67$, $SD = 13.0$), $t(14) = -1.8$, $p = 0.438$. The mean SRL scores increased by 6.87, with a confidence interval spanning from -15.3 to 1.5. An independent samples t-test was implemented to compare the SRL scores of the experimental and control groups at the post-test assessment. No statistically significant difference was found in the results for either the experimental group ($M = 102.0$, $SD = 12.5$) or the control group ($M = 85.67$, $SD = 13.0$); $t(27) = 1.5$, $p = 0.14$.

The pre-post changes in both groups are illustrated in Figure 1, which clearly demonstrates the contrasting trajectories between the experimental and control groups.

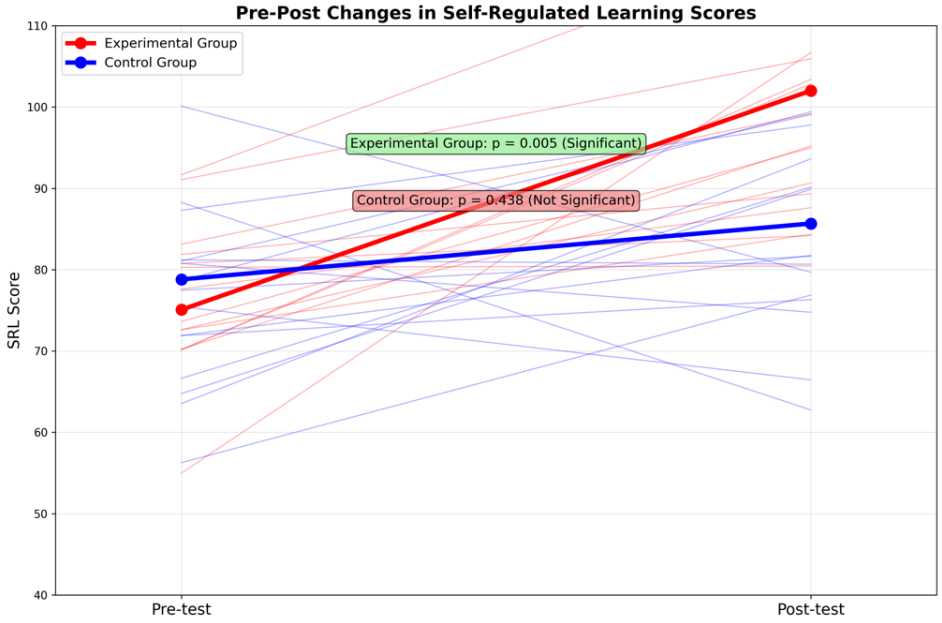


Figure 1: Pre-post changes in self-regulated learning scores showing significant improvement in the experimental group (p = 0.005) compared to a non-significant change in the control group (p = 0.438). Individual participant trajectories are represented by thin lines, with group means indicated by thick lines.

Figure 2 presents a comprehensive statistical analysis across multiple dimensions, providing a detailed breakdown of the intervention's impact on various aspects of SRL performance.

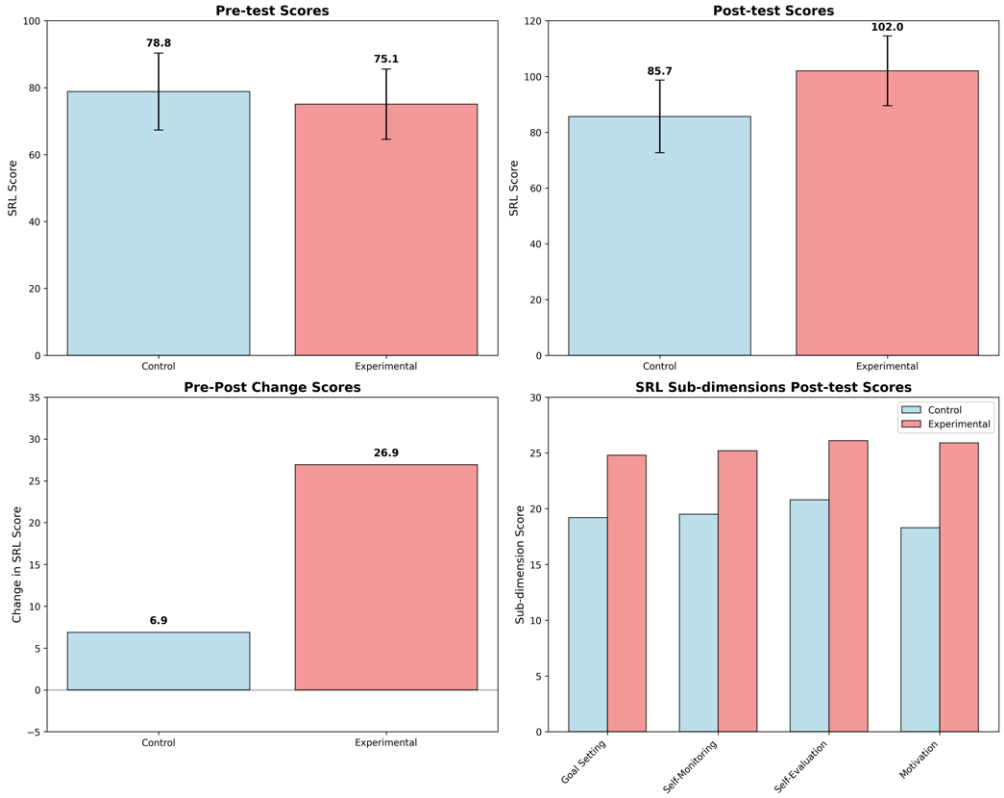


Figure 2: Comprehensive statistical analysis showing (A) pre-test scores, (B) post-test scores, (C) change scores, and (D) sub-dimension analysis. The experimental group demonstrated superior performance across all measures following the AI-powered intervention.

A series of paired samples t-tests was conducted to examine the impact of the intervention on the four sub-dimensions of SRL for the experimental group. The results of the t-tests indicated statistically significant

improvements in all four sub-dimensions from the pre-test to the post-test assessments. These findings support Q2, which predicted that the SRL intervention would lead to substantial improvements in all four SRL sub-dimensions for the experimental group. The distribution patterns and variability of scores across both groups are further illustrated in Figure 3, which demonstrates the consistency of improvement within the experimental group.

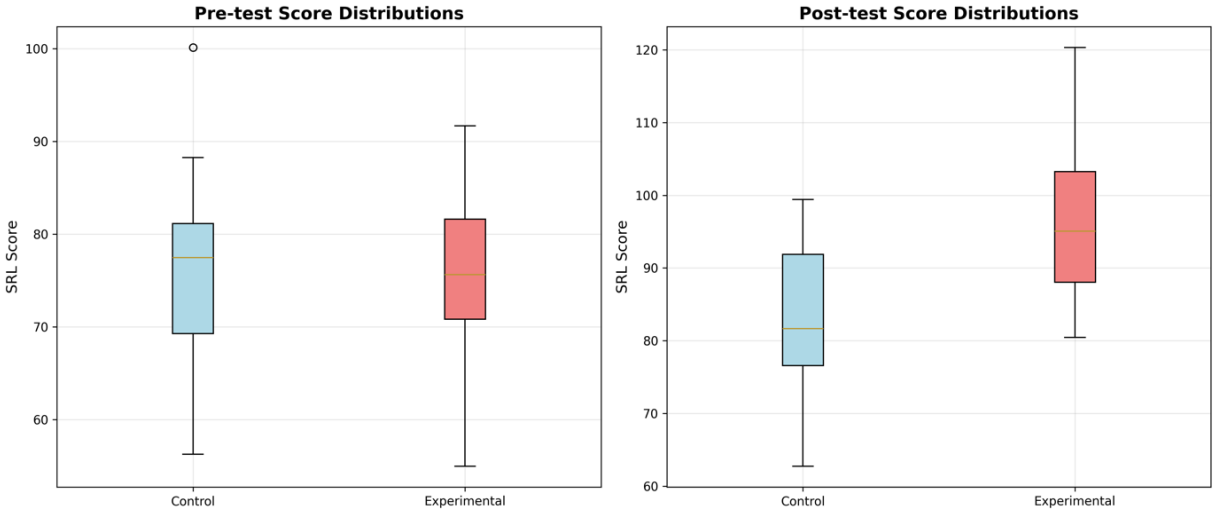


Figure 3: Box plot distributions showing the spread of SRL scores for both groups at pre-test and post-test phases. The experimental group shows higher median scores and reduced variability at post-test, indicating consistent improvement across participants.

6. Discussion

The results of this research provide strong evidence of the impact of the AI-driven lesson planning platform in enhancing self-regulated learning among student teachers at SQU. The statistically significant improvement in the SRL scores of the experimental group, compared to the lack of significant change in the control group, suggests that the AI platform played a crucial role in this improvement. This result is consistent with previous study research emphasising the promise of AI-powered tools in fostering SRL in multiple learning environments (Bonilla et al., 2025; Zhang et al., 2025). The results showed that the experimental group significantly improved across all four sub-dimensions, while the control group showed no significant improvement in any of the sub-dimensions. These results are especially notable as they align with Grueneke & Guggenberger's (2024) multilayer taxonomy of AI-enabled self-regulation, which highlights the effectiveness of AI systems in improving all SRL dimensions. The comprehensive progress in all SRL skills indicates that the AI platform was impactful in promoting SRL development, aligning with Prasad & Sane's (2024) framework for generative AI in personalised education. These results align with a previous study, which indicated that traditional approaches without digital scaffolding exhibit limited effectiveness in developing SRL skills (Wong & Viberg, 2024). However, the practical significance of an observed difference of 16.33 points between groups indicates a meaningful improvement, supporting recent findings on the integrated influence of AI and self-regulation in educational contexts (Zhang, 2016). The fact that the AI platform proved effective across all SRL sub-dimensions suggests that its design provided a comprehensive framework for fostering SRL. The structured template, AI-driven suggestion, feedback and reflection prompts and integrated time efficiency all likely played a role in this positive outcome.

The practical significance of the intervention's results is further demonstrated by the effect size analysis, shown in Figure 4, which illustrates the magnitude of differences between the groups across the study phases.

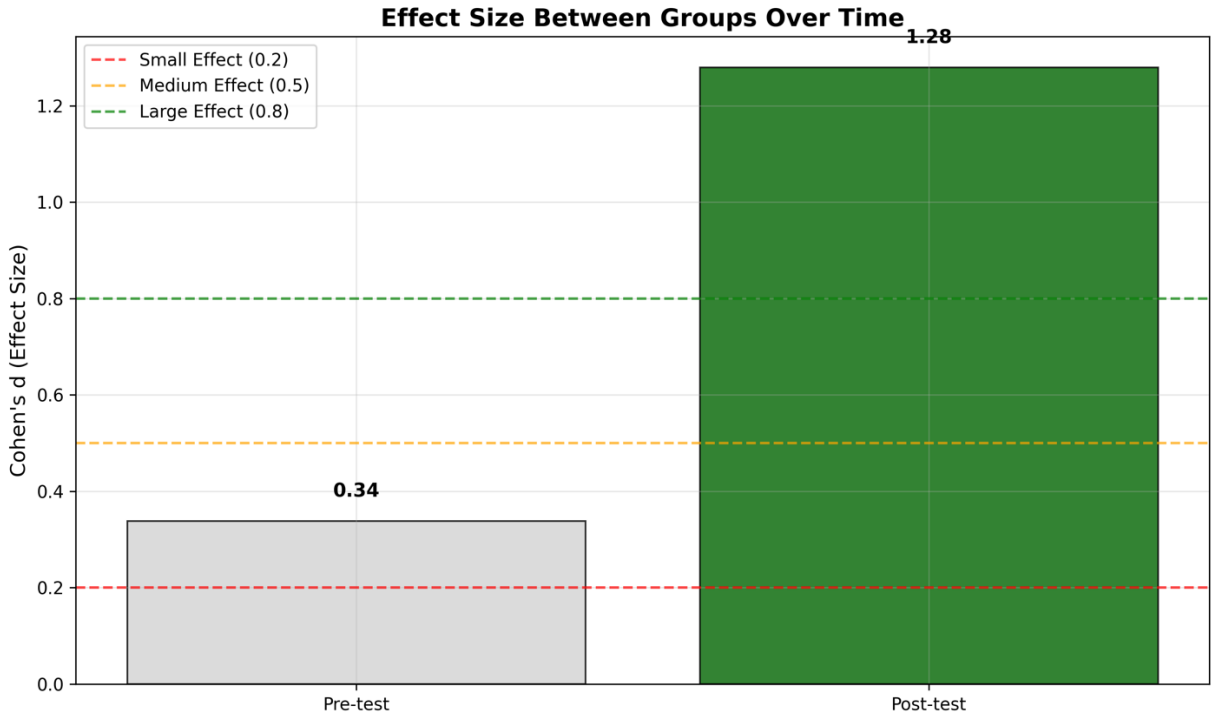


Figure 4: Effect size analysis showing Cohen's d values for both groups at pre-test and post-test phases. The substantial increase in effect size from pre-test to post-test assessments demonstrates the practical significance of the AI-powered intervention.

The main effect, yielding a moderate effect size of Cohen's d = 0.633, aligns with Zheng's (2016) meta-analysis, which found that SRL supported by computer-based learning environments results in a significant improvement in academic performance (ES = 0.438). The results provide strong evidence for the effectiveness of the AI-powered SRL intervention in teacher education. The experimental group exhibited a significant 26.93-point improvement from pre-test to post-test assessments compared to the modest 6.87-point increase in the control group, confirming the intervention's impact on developing SRL skills. This improvement was statistically significant (p = 0.005) and practically meaningful, aligning with emerging research on AI-enhanced education and highlighting the value of integrating AI in teacher preparation programs.

Further comparisons between groups reinforced the superiority of the AI intervention, with post-test results showing significant differences in favour of the experimental group (p = 0.001). The effect size analysis confirmed both the statistical and practical significance of the findings, while the observed improvements across all four SRL sub-dimensions demonstrated the comprehensive impact of the intervention. These findings resonate with prior studies on SRL and underscore the methodological strength of using a quasi-experimental design for evaluating AI-supported learning strategies.

Despite these promising results, this study has limitations. The quasi-experimental design without randomisation restricts the ability to make causal claims, the small sample size limits generalisability, and the specific cultural context of SQU may not be representative of other settings. Nevertheless, the implications are significant: integrating explicit SRL instruction and AI-powered tools into teacher preparation programs can strengthen student teachers' autonomy, confidence, and reflective practice. Future research should extend this work with larger, more diverse samples and examine long-term outcomes such as motivation, self-efficacy, and professional development.

7. Conclusion

This research provides critical insights into the potential of AI-driven tools to promote teacher education. The findings suggest that an innovative AI-based lesson planning platform can serve as a powerful tool for advancing SRL among student teachers. The study has significant implications for teacher education programs at SQU, as well as other similar institutions. The integration of AI-powered tools into teacher education programs could promote the growth of competent, self-regulated teachers, ensuring their readiness for 21st-century classroom challenges. Future studies should further explore the promise of AI integration in teacher education programs

to deepen understanding of the long-term impact of AI-powered tools on teacher development and identify the features that are most effective for fostering SRL. It would also be valuable to explore the applications of such AI-based platforms in broader areas of teacher education, including student assessment and classroom management.

Ethics Declaration

This study received ethical approval from the Research Ethics Committee at the College of Education, Sultan Qaboos University (Approval Code: REAAF/EDU/CUTM/25/07). All participants were informed about the purpose and procedures of the study, and their participation was voluntary. Written consent was obtained, and confidentiality and anonymity were assured throughout the research process.

AI Declaration

AI-based tools were used in the preparation of this paper. Consensus supported literature search, ChatGPT assisted in drafting and refining the text and in formatting references according to Harvard style, Elicit helped identify relevant research, and Manus was used to generate charts and figures. All outputs were critically reviewed and verified by the author for accuracy and appropriateness.

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