Proceedings of the

2nd International Conference on Education Research

Hosted by ISCTE-IUL University Institute of Lisbon, Portugal

6-7 November 2025



Florinda Matos, Isabel Flores and Susana Martins

A conference managed by ACPI, UK

Proceedings of the

2nd International Conference on Education Research

ICER 2025

A Conference Hosted By

ISCTE-IUL University Institute of Lisbon, Portugal

6-7 November 2025

Edited by Florinda Matos, Isabel Flores and Susana Martins

Copyright the authors, 2025. All Rights Reserved.

No reproduction, copy or transmission may be made without written permission from the individual authors.

Review Process
Papers submitted to this conference have been double-blind peer reviewed before final acceptance to the conference. Initially, abstracts were reviewed for relevance and accessibility and successful authors were invited to submit full papers. Many thanks to the reviewers who helped ensure the quality of all the submissions.

Ethics and Publication Malpractice Policy
ACIL adheres to a strict ethics and publication malpractice policy for all publications – details of which can be found here:
http://www.academic-conferences.org/policies/ethics-policy-for-publishing-in-the-conference-proceedings-of-academic-conferences-and-publishing-international-limited/

Self-Archiving and Paper Repositories
We actively encourage authors of papers in ACIL conference proceedings and journals to upload their published papers to university repositories and research bodies such as ResearchGate and Academic.edu. Full reference to the original publication should be provided.

Conference Proceedings
The Conference Proceedings is a book published with an ISBN and ISSN. The proceedings have been submitted to a number of accreditation, citation and indexing bodies including Thomson ISI Web of Science and Elsevier Scopus.

Author affiliation details in these proceedings have been reproduced as supplied by the authors themselves.

The Electronic version of the Conference Proceedings is available to download from
https://papers.academic-conferences.org/

The Conference Proceedings for this year and previous years can be purchased from
http://academic-bookshop.com

E-Book ISBN: 978-1-917204-64-4
Print version ISBN: 978-1-917204-65-1
Print Version ISSN: 3049-5636

Published by Academic Conferences and Publishing International Limited
Reading, UK
+44 (0) 118 324 6938
www.academic-conferences.org
info@academic-conferences.org

Contents

Preface v

Committee vi

Biographies vii

Academic Papers

Designing an Impact-Focused Entrepreneurship Course: Insights from a Europe - India Collaboration
Bogdanova, Maitrayee Mukerji , Taina Vuorela, Eva Sørum Poulsen , Nansi Van Geetsom , Arpita Amarnani 1-9

Perceived Risk of Generative AI Adoption in Initial Teacher Education Programmes
Marian Carcary, Patrick Bucklan 10-17

Algorithmic Teaching, Fading Thought? Rethinking Engagement in the AI Era
Melisa Chawaremera 18-25

Efficacy of Detecting AI Plagiarism in Higher Education
Henry Collier 26-30

Play, Learn, Empower: A Design Model of Student Engagement in Environmental Education
Julia DeVoy, Qingwan Cheng, Natalie Pedley, Carter Frato-Sweeney, Sophia Ferrone, Mary O'Brien, Mia Cresti 31-41

Modeling the Role of Graphical and Textual Complexity in Geometry Problem-Solving Using SEM
Farshid Farzan, Canwen Wang, Rachel L Ankney, Paulo Carvalho 42-49

Rethinking Generative AI in Human-Computer Interaction: Review of Affordances, Constraints, and Implications
Niklas Humble, Åsa Cajander 50-58

A Study of Preservice Teachers Developing Teaching Competencies with VEX GO Robotics
Kamini Jaipal-Jamani 59-68

A Large-Scale Study on the Effects of Motivation on Academic Test Performance
Michael Kickmeier-Rust, Katharina Richter 69-77

Educational Paradigm Shifts Among Generation Z University Students
Peter Krajčovič, Vladimíra Jurišová 78-86

Lecture Capture in Finnish High Schools: Teachers' Perspectives
Ilkka Kukkonen, Outi-Maaria Palo-oja 87-94

Bridges to the Future – The Case of Business Mill
Emma Latvala, Pasi Rantanen 95-102

Reskilling and Upskilling in Portugal Amidst Digital and Green Transformation
Carolina Marques, Florinda Matos 103-111

Investigating Ethical Issues for Workplace Lifelong Learning Digital Technologies: A Survey Study
Kadri Mettis, Abiodun Afolayan Ogunyemi, James Sunney Quaicoe 112-121

The Changing Trends in Higher Education: Lecturertainers' Pedagogy and Personality Blending
Sky Mkuti, Wiza Munyeka 122-129

Internationalization of African Universities: South African Student-Centred Transformational Agenda
Sky Mkuti 130-137

The Importance and the Role of Technology in the Education of Generation Z
Igor Piatrov, Peter Krajčovič 138-146

Formative Assessment in Digital Classrooms: Comparison through Bar Model Representations
Claire Poh 147-156

Analysing Virtual Reality Applications in Built Environment Education: A Study of Existing Research
Ockert Rudolf Pretorius, Herman Myburgh 157-165

The PCC Model in Online Teaching: A Framework for Effective Practice
Md Mizanur Rahman 166-175

Building Information Modelling (BIM) Issue Introduced in Master Academic Level
Alcinia Zita Sampaio 176-184

Academic One-Day Course Offered to Improve Engineers' BIM Skill
Alcinia Zita Sampaio 185-193

Integrating the Hidden Curriculum into an Edu-Socio Model for Student Success
De Wet Schutte 194-201

AI in Higher Education: IRIS and Turnitin Challenges and Opportunities
Nothando Shiba , Ilunga Masego, Linda Jewel 202-210

Introducing C++20 Modules in First-Year Computer Science: A Pedagogical Case Study
Siphesihle Sithungu 211-218

Strategic Coherence and AI-Enabled Personalization: Drivers of Motivation in Corporate Learning
Olga Tunkevichus, Arseniy Kovalerchik, Dr. Konstantin Bagrationi 219-227

Strategic Coherence under Turbulence: How Corporate Universities Balance Exploration and Exploitation
Olga Tunkevichus, Irina Plaunova, Konstantin Bagrationi 228-236

An Automated Feedback System for Written Exams
Stefan Ullmann, Mareike Schoop 237-246

Leveraging Scientific Research for Business Improvement: A PRISMA Review
Jaani Väisänen 247-255

Research Writing, Ghostwriting and Academic Cheating in the Age of AI: A Scoping Review
Brenda Van Wyk, Lesego Makhafola 256-264

TalkPro: A Multimodal Language Learning and Evaluation System
Johannes Wirth, René Peinl 265-273

Non-Academic Papers

Build-A-Cyber-Attacker: Simulating Attackers to Reflect Myth and Folklore in Cyber Threat Analysis
Tim Pappa 275-282

Work in Progress Papers

Simulation of Postpartum Hemorrhage Maneuvers Using an Educational Biomodel for Low-income Countries
Israel Garnica-Bohórquez, Clara Isabel López-Gualdrón, Adriana Inés González-Quitían, Jesús Alexis Machuca Gelvez, Silvia Isabel Gómez-Gualdrón, Luis Eduardo Bautista Rojas 284-289

Education for Sustainable Development through Maker Education: Visions, Concepts And Experiences
Diana Pereira, Cristina Sylla, Ute Massler, Fabian Pettig, Holger Weitzel, Claudia Bergmüller-Hauptmann , Kerstin Hansson, Moritz Wagner, Philipp Wilfinger, Sandra Palhares, Orlanda Tavares, Eva Lopes Fernandes 290-294

About the International Conference on Education Research, 2025

The Proceedings of the 2nd International Conference on Education Research, 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 ICER 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 International Conference on Education Research (ICER) is an opportunity for academics, practitioners and consultants from around the world who are involved in the study, management and development of education research related issues to come together and exchange ideas. There are several strong strands of research and interest that are developing in the area including the use of technology in teaching and learning, active learning and student engagement, assessment and feedback, curriculum design and delivery, inclusive teaching and learning and teaching for social justice to mention only a few.

The aims of the conference now not only include sharing academic research but also fostering dialogue among practitioners, policymakers, and scholars to address pressing issues facing organizations and institutions today. The 2025 call for papers for the ICER is interested in contributions that consider the following topics. In addition, the committee welcomed papers on a number of specialist mini-tracks which can be seen at the end of this list.

1. **The Use of Technology in Teaching and Learning**
    - Blended Learning Environments
    - Educational Technology Tools
    - Impact of Virtual Reality in Education
    - E-learning Platforms and Accessibility
2. **Active Learning and Student Engagement**
    - Cooperative Learning Strategies
    - Gamification in Education
    - Role of Discussion in Active Learning
    - Engaging Diverse Learners
3. **Assessment and Feedback**
    - Formative vs. Summative Assessment Techniques
    - Peer Assessment Approaches

- Importance of Timely Feedback
- Digital Tools for Assessing Student Work

4. **Curriculum Design and Delivery**
    - Integrating Interdisciplinary Approaches
    - Developing Culturally Relevant Curriculum
    - Online Curriculum Development Strategies
    - Monitoring and Evaluating Curriculum Effectiveness
5. **Inclusive Teaching and Learning**
    - Universal Design for Learning (UDL)
    - Strategies for Supporting Diverse Learners
    - Addressing Implicit Bias in Education
    - Creating Inclusive Learning Environments
6. **Teaching for Social Justice**
    - Critical Pedagogy Approaches
    - Curriculum for Social Change
    - Empowering Marginalized Voices
    - Community Engagement in Education
7. **Assessment Practices and Strategies**
    - Authentic Assessment Methods
    - Designing Rubrics for Effective Assessment
    - Using Analytics to Inform Assessment Practices
    - Continuous Improvement in Assessment Strategies
8. **Constructive Feedback on Completed Assessments**
    - Best Practices for Providing Feedback
    - Balancing Critique and Encouragement
    - Feedback Loops in Learning Cycles
    - Using Technology to Enhance Feedback
9. **Module Development in the New Digital Era**

- Best Practices for Online Module Design
- Incorporating Multimedia in Course Content
- Student-Centered Approaches to Module Development
- Evaluating Online Learning Modules

10. **Curriculum Development, Implementation, and Monitoring**
    - Strategies for Effective Curriculum Implementation
    - Feedback Mechanisms for Curriculum Improvement
    - Engaging Stakeholders in Curriculum Development
    - Evaluating Learning Outcomes
11. **Module Throughput and Success**
    - Factors Influencing Student Success
    - Strategies to Improve Module Completion Rates
    - Analyzing Dropout Rates in Modules
    - Support Systems for Struggling Students
12. **Teaching and Learning Pedagogies**
    - Innovative Teaching Strategies

ICER Preface

These proceedings represent the work of contributors to the 2nd International Conference on Education Research (ICER 2025), hosted by ACPI and ISCTE-IUL University Institute of Lisbon, Portugal, on 6-7 November 2025. The Conference Chairs are Florinda Matos and Isabel Flores, and the Programme Chair is Susana da Cruz Martins all from ISCTE-IUL University Institute of Lisbon, Portugal.

ICER is in its 2nd year as an established event on the academic research calendar. The conference provides an opportunity for participants to share ideas and connect with fellow researchers across diverse fields. The scope of submitted papers promises two engaging days of academic exchange. 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 delivered by Dr. Jon-Hans Coetzer, from United Nations Institute for Training and Research (UNITAR) who will talk about *Reimagining Higher Education: Building Future-Ready Skills for a World in Transition*. The second day of the conference will begin with an address from Prof. António Lopes, ISCTE-Instituto Universitário de Lisboa, Portugal who will discuss *Generative AI in Teaching: Challenges and Opportunities*.

With an initial submission of 91 abstracts, after the double blind, peer review process there are 31 Academic research papers, 1 Non-Academic paper, and 2 work-in-progress papers published in these Conference Proceedings. These papers represent research from Australia, Canada, Colombia, Cyprus, Czechia, Estonia, Finland, Germany, Greece, India, Ireland, Mexico, Nigeria, Poland, Portugal, Slovakia, South Africa, Sweden, Switzerland, Turkiye, UK, USA, and Zimbabwe.

We hope you enjoy the conference.

Florinda Matos and Isabel Flores
Lisbon, Portugal
November 2025.

ICER Conference Committee

Assc Sara Abdoh, Faculty of Applied Arts, Egypt; Paula Abola, University of Jamestown, Germany; Prof Adrian Adascalitei , Technical University Gh Asachi from Lasi, Romania; Prof Megha Ainapurkar , Padre Concicao College of engineering Verna Goa, India; Prof Hamid AlAsadi, University of Basrah, Iraq; Prof Abbas Aljuboori, University of Information Technology and Communications, Iraq; Prof Antonios Andreatos, Hellenic Air Force Academy, Greece; Dr Stavroula Andreopoulos, University of Toronto, Canada; Prof Mohamed Arteimi, Libyan Academy for Graduate Studies, Libya; Prof Lina Artemenko, National Technical University of Ukraine Igor Sikorsky Kyiv Politechnic Institute, Ukraine; Dr Migle Baceviciene, Lithuanian Sports University, Lithuania; Prof Joan Ballantine, Ulster University, UK, Northern Ireland; Prof Ana Barata, Instituto Superior de Engenharia do Politécnico do Porto, Portugal; Dr Andrew Blake, University of Brighton, UK; Dr Chaytanya Bora, Tinsukia Commerce College , India; Prof Piedade Carvalho, ISEP-Instituto Superior de Engenharia do Porto, Portugal; Prof Ana Chankvetadze, Kutaisi Akaki Tsereteli State University, Georgia; Prof George Chiladze, The University of Georgia, Georgia; Dr Caroline Crawford, University of Houston-Clear Lake, USA; Dr Sara Cruz, Polytechnic University of Cávado and Ave, Portugal; Moffat David, Glasgow Caledonian University, UK; Dr Antonio De Nicola, ENEA, Italy; Dr Ayanda Pamella Deliwe , Nelson Mandela University , South Africa; Dr Souad Demigha , University of Paris1 Sorbonne Paris, France; Dr YiFei Dong, Data Science Institute, University of Technology Sydney, Australia; Prof David Edgar, Glasgow Caledonian University, Scotland, UK; Dr Wily Engelbrecht, The Independent Institute of Education, South Africa; Dr Samson Fabiyi, University of Leeds, UK; Dr Samuel Faloye, IIE Varsity College, South Africa; Prof Marta Ferreira Dias, GOVCOPP, University of Aveiro, Portugal; Dr Prof. Georgios Fesakis, University of the Aegean, Greece; Prof Rachel Fitzgerald, University of Queensland, Australia; Dr Lisa Gjedde, Dept. for Culture and Learning, Denmark; Prof Sofia Gomes, Portucalense University, Portugal; Dr Sue Greener, University of Brighton, UK; Prof Md. Fokhray Hossain, Daffodil International University (DIU), Bangladesh; Prof Eunice Ndeto Ivala, Cape Peninsula University of Technology, South Africa; Prof Majeed Jadwe, University of Anbar, Iraq; Dr Dinesh Jain, SAGE University, Indore, India; Dr Kanthi Jayasundera, Simon Fraser University, Canada; Dr Amor Jebali, The Applied College, Saudi Arabia; Dr Matthew Jones, University of Salford, United Kingdom; Dr Matshemo Khumalo, The Independent Institute of Education, South Africa; Prof Jesuk Ko, Gwangju University, Republic of Korea; Dr Kuo-Ying Lee, Music College of Zhaoqing University, China; Prof Felipa Lopes dos Reis, Lusofona University, Portugal; Prof Ana Loureiro , Polytechnic University of Santarém, Portugal; Dr Ayanda Magida , University of the Witwatersrand , South Africa; Prof Dianne Manning, Foundation for Professional Development, South Africa; Maode Linda Joy Mesh, Università degli Studi di Siena, Italy; Assc Lina Morgado, Universidade Aberta, Portugal; Prof. Doutor Pedro Ribeiro Mucharreira, UIDEF, Institute of Education, University of Lisbon | ISCE - Instituto Superior de Lisboa e Vale do Tejo, Portugal; Dr Annie W.Y. Ng, The Hong Kong University of

Science and Technology, Hong Kong; Prof Piotr T. Nowakowski, Institute of Pedagogy, Rzeszów University, Poland; Dr Catalina Olivas, Tecnologico de Monterrey, Mexico; Dr ISAAC GBENGA OLUKOTUN, Shekinah Educational Services, UK; Prof Sónia Pais, Polytechnic of Leiria, Portugal; Prof Stamatios Papadakis, University of Cret, Greece; Dr Francesca Pozzi, Institute for Educational Technology - CNR, Italy; Ockert Pretorius, University of Johannesburg, South Africa; Prof Sandra Ribeiro, ISCAP-IPP, Portugal; Prof Pedro Neves Rito, Instituto Politécnico de Viseu, Portugal; Dr Joanna Rosak-Szyrocka , Częstochowa University of Technology, Poland; Prof Jože Rugelj, University of Ljubljana, Faculty of Education, Slovenia; Dr Denada Selfo, University of Vora, Albania; Dr Paulino Silva, ISCAP - Porto Polytechnic University, Portugal; Prof Chrysanthi Skoumpourdi, University of the Aegean, Greece; Dr Deena Slockett, AdventHealth University, USA; Dr Souad Slyman, University of Roehampton, UK; Dr Imene Soussi, University of Sharjah, United Arab Emirates; Arvin Sto. Domingo, Taliptip National High School, Philippines; Prof Tiago Trancoso, IPVC, Portugal; Dr Aristides Vagelatos, Computer Technology Institute, Greece; Brenda Van Wyk, The University of Pretoria, South Africa; Prof Carlos Vaz de Carvalho, Porto Polytechnic, Portugal; Prof Isabel Vieira, Polytechnic of Porto - ISCAP, Portugal; Prof Alf Inge Wang, Norwegian University of Science and Technology (NTNU), Norway; Prof Sheryl Williams, Loughborough University, United Kingdom; Dr Justyna Żywiołek, Czestochowa University of Technology, Poland.

Conference and Programme Chairs



Florinda Matos is a Professor of General Management at ISCTE Business School, ISCTE – University Institute of Lisbon, and an associate research fellow at DINÂMIA'CET – IUL – Centre for Socioeconomic and Territorial Studies, where she leads several international projects, including the relevant CoVE Future Skills Factory. As the editor of several journals and books, she has authored numerous works on knowledge and intellectual capital management, resilience, sustainability, and digital transformation. She is a distinguished conference chair for numerous conferences in the fields of intellectual capital and knowledge management, as well as innovation. Additionally, she is a board member of the Institute of Public and Social Policies at Iscte, the founder and president of the ICAA – Intellectual Capital Association, and Portugal's ambassador for The New Club of Paris.



Isabel Flores graduated in Economics and holds a PhD in Public Policy. Researcher at CIES-Iscte, Executive Director of the Institute of Public and Social Policies at Iscte, and guest lecturer in the Master's in Education at FSCH Universidade Nova de Lisboa and in the PhD in Public Policy at Iscte. Currently represents Portugal on the OECD's Centre for Educational Research and Innovation (CERI). Her main research areas focus on education topics, particularly Evidence-Based Decision Making. Recently has worked on the characterization of the teacher profession and policy development to minimize the lack of teachers crisis.



Susana da Cruz Martins, PhD in Sociology. She is an associate professor at Iscte – Instituto Universitário de Lisboa and a researcher at the Centre for Research and Studies in Sociology (CIES) in the Department of Political Science and Public Policy. She is co-coordinator of the Education and Science Research Group at CIES-Iscte. She is a member of the Inequalities Observatory and Director of the Doctorate in School Administration and Management Policies (at CIES-Iscte). She was awarded a post-doctoral scholarship by the Foundation for Science and Technology and a Gulbenkian Professorship by the F. C. Gulbenkian. She has coordinated and participated in national and international research projects. Of particular note is the national coordination (in Portugal) of the European project EUROSTUDENT – Social and Economic Conditions of Student Life In Europe (II, III, VI, and VII) and the national external evaluation of the Global Schools2030 Programme, implemented by the Aga Khan Foundation. She is the author of a number of national and international publications, mainly in the areas of education and higher education policies, comparative education systems, school performance and success, evaluation of public policies and social inequalities.

Keynote Speakers



António Lopes has a PhD in Artificial Intelligence (2011) and is currently a professor at the Department of Information Science and Technology at Iscte-Instituto Universitário de Lisboa and a researcher at the Iscte's group of Instituto de Telecomunicações. His research activities focus mainly on the areas of Applied AI, Machine Learning, Generative AI and Agents, in which he has participated in multiple national and international projects since 2000, published several papers and gave several talks, lectures and training sessions on these topics. He has also been the Director of the Information Systems Development Services at Iscte since 2015, where he is responsible for the team that develops and manages the information systems at the university level.



Jon-Hans Coetzer is a senior higher education manager with over 25 years of experience in higher education. Focusing on instructional design and programme management, delivery and assessment practices, and academic and quality assurance management in the ever-changing landscape of higher education. He also worked as Project Coordinator in Strategic Crisis Management Training for the Swiss Federal Presidency in Bern from 2010 – 2015. Jon-Hans has also worked as senior delegate of the International Committee of the Red Cross (ICRC) responsible for training the armed forces in the Law of War and the Geneva Conventions and the Additional Protocols, during 1995 – 2002, in more than fifteen countries at war. He currently serves as Team Leader for the United Nations Institute for Training and Research (UNITAR), including establishing collaborative partnerships with institutions of higher education and universities focusing on Inclusive Pedagogy, Business, Conflict, Peace and Sustainable Development Studies. Jon-Hans' research interests focus on the cross-cultural challenge of framing attuned leadership in the international classroom for positive change in higher education for sustainable development in the 21st century, including developing transformational learning for delivering results within the UN 2030 Agenda-framework through advocating for more inclusive pedagogical practices. He continues to publish academic papers and essays, including participating in conferences. Jon-Hans led the planning of UNITAR's First International Research Conference hosted at the UN Bonn Campus in November 2023 focusing on the Climate Security: Peace and Security Consequences of Climate Change.

Mini Track Chairs



Adrian A. Adascalitei is Professor at Technical "Gh. Asachi" University, Iasi, Romania. His specialist area is Blended STEM Teaching and Learning. He is a certified student teachers' trainer, reviewer in international journals and conference proceedings and member of scientific associations. He has authored and co-authored various papers in International and European conferences and journals. His research focuses on blended learning and use of virtual laboratories in STEM Education.



Ockert R. Pretorius is a lecturer at the Department of Urban and Regional Planning, University of Johannesburg, South Africa. His research interests include regional policy and economic resilience, and he has an industry background in development economics.

Designing an Impact-Focused Entrepreneurship Course: Insights from a Europe - India Collaboration

Olga Bogdanova[1], Maitrayee Mukerji[2], Taina Vuorela[3], Eva Sørum Poulsen[4], Nansi Van Geetsom[5] and Arpita Amarnani[6]

[1]LAB University of Applied Sciences, Lappeenranta, Finland
[2]Indian School of Development Management, Noida, India
[3]Laurea University of Applied Sciences, Uusimaa region (Greater Helsinki), Finland
[4]Aarhus University, Herning, Denmark
[5]Thomas More University of Applied Sciences, Mechelen, Belgium
[6]Goa Institute of Management, Goa, India

olga.bogdanova@lab.fi
maitrayee.mukerji@isdm.org.in
Taina.Vuorela@laurea.fi
eva@btech.au.dk
nansi.vangeetsom@thomasmore.be

Abstract: This paper presents the design, implementation, and evaluation of a nine-week pilot course in Impact-Focused Entrepreneurship (IFE), developed within the Erasmus+ Capacity Building for Higher Education-funded project Co-LIFE. The pilot, conducted by a consortium of eight Higher Education Institutions from Europe and India, aimed to foster entrepreneurial competencies, intercultural collaboration, and real-world problem-solving through a blended curriculum developed in collaboration with stakeholders. The course combined a MOOC, an in-person kick-off week in Goa, seven weeks of virtual team-based project work, and a closing week in Mumbai. Students worked in international, interdisciplinary teams on four live impact entrepreneurship cases provided by Indian companies. These cases were deeply embedded in the local context and supported by company visits, mentorship, and Design Thinking workshops. Each week, students engaged in theoretical and practical content delivered through a MOOC platform. Topics included sustainability principles, circular economy models, impact measurement, business model innovation, theory of change, and user-centred design. The content was delivered through online lectures, interactive assignments, quizzes, and case readings. Students were expected to apply this content directly to their live case projects. A comprehensive course evaluation collected feedback through weekly surveys, peer evaluations, and structured interviews with students and staff. Findings highlight strong student motivation, high engagement with real-world content, and development of entrepreneurial and intercultural competencies. Key areas for improvement included pacing, assignment clarity, and enhanced mentoring alignment. The study contributes to multiple theoretical domains. It extends Learning by Development into a cross-cultural, digitally mediated context; enriches Experiential Learning Theory through its application in international, real-world settings; and advances the theory and practice of blended learning by demonstrating its effectiveness in a transnational, Impact-Focused Entrepreneurship course. Furthermore, the study contributes to entrepreneurship education theory by demonstrating how interdisciplinary, impact-oriented, real-life projects enhance opportunity recognition, entrepreneurial self-efficacy, and value creation within diverse student teams. This paper also offers a replicable model for transnational, impact-driven education that aligns with global trends in active learning, digital pedagogy, and curriculum co-design with external stakeholders.

Keywords: Erasmus+, Impact-Focused Entrepreneurship, Learning by Development, Experiential Learning, Blended Learning

1. Introduction

Globally, alongside economic growth and progress, there are growing challenges to the economy, society, and environment. Climate change and sustainable human development are now core global concerns (World Economic Forum, 2023). Against this backdrop, the 77th UN General Assembly session in December 2022 adopted a resolution acknowledging the pivotal role of entrepreneurship in sustainable development. It recognized that entrepreneurship can contribute by "creating jobs, promoting decent work, driving inclusive economic growth and innovation, improving social conditions, and addressing economic, social, and environmental challenges in the context of the 2030 Agenda" (United Nations General Assembly, 2022).

In response to this global shift, higher education institutions across the world have begun incorporating sustainability principles into their curricula, research agendas, and pedagogical methods (Ploum et al., 2017). There is growing recognition of the need to equip students with the mindset and competencies necessary to address pressing societal and environmental challenges. The concept of impact-focused entrepreneurship, defined as entrepreneurial activity that produces positive societal, economic, and environmental outcomes

aligned with the UN Sustainable Development Goals (SDGs), has gained attention. Yet, in many higher education systems, including India's, this concept remains underdeveloped in both theory and institutional practice.

Existing literature on entrepreneurship education in India tends to emphasize technical training, job creation, and economic development, with limited attention to sustainability, social impact, or interdisciplinary problem-solving (Chatterjee & Das, 2016; Rao, 2018). Moreover, studies highlight the fragmented nature of entrepreneurship education, the absence of experiential models, and weak linkages with social enterprises or community-based learning (Agarwal et al., 2020; Hota, Mitra, & Qureshi, 2019). While Indian HEIs have taken steps to integrate innovation and entrepreneurship initiatives (e.g., Atal Incubation Centres, Entrepreneurship Development Cells), there is little evidence of structured curricula that embed sustainability-driven entrepreneurship in a project-based, intercultural format.

Furthermore, much of the entrepreneurship education literature is rooted in Western theoretical paradigms, which may not translate seamlessly into contexts like India, where entrepreneurs often face structural constraints such as limited capital, regulatory ambiguity, and low digital penetration (Mair et al., 2012). This points to a clear need for locally relevant, practice-driven pedagogies that not only teach entrepreneurial skills but also engage students in solving complex social and environmental problems in contextually grounded ways.

To address this pedagogical gap, the Co-LIFE project draws on several well-established theoretical foundations. The Learning by Developing (LbD) model (Raij, 2007) emphasizes real-world relevance, co-creation of knowledge, and the integration of teaching, research, and development through authentic collaboration. Although rooted in Finnish higher education, LbD offers a valuable framework for applied, interdisciplinary learning. Complementing this is Kolb's Experiential Learning Theory (1984), which outlines a cyclical process—concrete experience, reflective observation, abstract conceptualization, and active experimentation—that supports learners in transforming experience into knowledge. Blended learning theory (Garrison & Vaughan, 2008) provides a third pedagogical lens, focusing on the intentional combination of face-to-face and online learning to enhance flexibility, engagement, and depth of learning. Finally, within the domain of entrepreneurship education, scholars have emphasized the value of interdisciplinary, impact-oriented, and project-based approaches for enhancing opportunity recognition, entrepreneurial self-efficacy, and systems thinking (Fayolle & Gailly, 2008; Pittaway & Cope, 2007).

The Co-LIFE project thus seeks to operationalize these pedagogical principles in the Indian higher education context through the design and delivery of an Impact-Focused Entrepreneurship course. This international collaboration between HEIs in India and Europe aims to support local communities through two-way knowledge exchange, stakeholder-driven project learning, and the development of socially conscious entrepreneurs. This becomes particularly relevant given that social enterprises in India often operate under persistent resource constraints and institutional uncertainty (Agarwal et al., 2020; Hota, Mitra, & Qureshi, 2019). By co-developing live cases with local enterprises and embedding students in authentic problem-solving environments, the project addresses a critical void in Indian entrepreneurship education: the absence of real-world, sustainability-driven learning models that are locally relevant yet globally informed.

This paper presents the design, implementation, and evaluation of a nine-week pilot course in Impact-Focused Entrepreneurship, developed within the Erasmus+ Capacity Building for Higher Education–funded project Co-LIFE. The study investigates how an internationally co-designed course can contribute to sustainability-oriented entrepreneurial education, specifically in contexts where traditional curricula fall short of addressing the intersection between enterprise, equity, and environmental responsibility.

2. Methodology

This study employs Participatory Action Research (PAR), recognized as a valuable pedagogical approach in university settings (Dancis, Coleman & Ellison 2023); it ideally involves companies, educators and students working together to identify and address real-world issues e.g. through critical thinking. PAR's application in higher education aims to promote inclusive, democratic practices within educational settings; hence, participatory action research typically employs a variety of data collection methods, such as interviews of focus groups, surveys and questionnaires, as well as participant observation (ibid.).

3. Data Collection

To evaluate the pilot course in Impact-Focused Entrepreneurship, a mixed-methods approach was employed to capture the multifaceted nature of student experiences within a cross-cultural and interdisciplinary context (Creswell & Plano Clark, 2018). The data collection process unfolded through three interconnected layers:

3.1 Weekly Surveys

Structured online questionnaires were distributed to all students through the MOOC platform at the end of each week. These surveys provided timely insights into student engagement, workload, team dynamics, and the perceived relevance of course content. The regularity of responses enabled the research team to monitor evolving trends and identify emerging concerns throughout the nine-week programme.

3.2 Individual and Group Interviews

Semi-structured interviews were conducted with selected participants at three key stages: following the in-person kick-off in Goa, midway through the online phase, and during the final week in Mumbai. These interviews allowed students to reflect more deeply on their personal learning journeys, cultural interactions, and collaborative challenges. Complementing these were group interviews held during the on-site sessions, providing teams with the opportunity to share collective experiences regarding course structure, mentorship, and engagement with live case projects.

3.3 Informal Conversations and Thematic Analysis

Additional insights were drawn from informal conversations during coaching sessions, virtual meetings, and breaks. These spontaneous interactions added contextual depth to the formal data and helped validate findings from the surveys and interviews. All qualitative data were analysed using thematic analysis (Braun & Clarke, 2006), enabling the identification of recurring themes across individual, team, and institutional levels.

4. Results

4.1 Learning Materials Development

4.1.1 Cases and Cooperation With Companies

Learning by Developing (LbD) is a pedagogical approach developed at Laurea University of Applied Sciences, Finland, in the early 2000s (LbD Guide, 2024). It is rooted in workplace collaboration, typically originating from partnerships between universities and external organizations (see What is Laurea's Learning by Developing model? Video, 2024). When adapting LbD for the Co-LIFE project and the 6 ECTS Impact-Focused Entrepreneurship (IFE) course within Indian universities, it became evident that the case-providing companies, posing challenges for international student teams, would need to be locally embedded. This ensured that the course would deliver tangible regional impact, socially, economically, and environmentally, both during the pilot and as part of its continued integration into university curricula (Vuorela & Lehtosaari, 2024).

With its foundations in Problem-Based Learning (PBL) (Wells, Warelow, & Jackson, 2009), the LbD model encourages presenting students with open-ended, loosely defined problem statements, or "fuzzy" triggers, that simulate real-world complexity. This deliberate ambiguity is intended to foster critical thinking, ownership, and initiative, as students must collaboratively define the scope and nature of the problem themselves. However, during Pilot 1, this approach posed difficulties due to differences in academic culture. Some students, especially those in international and interdisciplinary teams expressed discomfort with the ambiguity and struggled to independently define their project scope.

To address this challenge in the cross-cultural context of the course, the instructional team incorporated several support mechanisms. To ensure consistent implementation across the consortium, the eight participating universities co-developed a shared case template. This framework guided local companies from the two Indian regions hosting the course pilots to provide comparable and relevant background information about their sustainability challenges for students to address. During the pilot week, informative visits to the case companies were organized, along with coaching sessions involving company representatives and university lecturers through team teaching by both Indian and European staff. These components helped students interpret the

problem space, negotiate shared understanding across cultural and disciplinary lines, and develop actionable, context-sensitive solutions, while preserving the productive ambiguity central to the LbD approach.

A recurring challenge that emerged during implementation was the perception among some students that their tasks were a "moving target," with the scope appearing to shift over time. This highlights the need for clearer early-stage communication, better expectation setting, and stronger alignment between academic mentors and case companies to ensure that students can maintain focus within the open-ended structure of the course.

4.1.2 The Role of the Digital Learning Platform

A central component of the Co-LIFE Impact-Focused Entrepreneurship course was its digital learning platform, which served as the program's informational backbone and collaborative workspace. Built on the Moodle MOOC infrastructure, the platform offered the flexibility, security, and functionality necessary for a transnational, blended learning experience.

Beyond hosting the course structure and content, the platform facilitated continuous interaction, reflection, and assessment throughout the nine-week pilot. Initially developed using shared OneDrive folders, course materials were curated and reorganized into a user-friendly digital environment. The MOOC supported various media formats, including videos, PDFs, slide decks, and recorded lectures, alongside interactive elements such as exercises, quizzes, and peer assessments.

Each weekly module followed a consistent format. This included a thematic introduction (e.g., circular economy, impact measurement), optional pre-readings, digital presentations, interactive tasks, reflective blog entries, and evaluation questionnaires. This structure ensured pedagogical coherence and scaffolded student learning. The platform also enabled team-based collaboration by offering tools for case study coordination and weekly peer and team evaluations. These features supported effective cross-cultural teamwork among students from eight institutions across Europe and India.

Practical logistics, including agendas for in-person sessions in Goa and Mumbai, were also integrated into the MOOC. This allowed students to prepare in advance for field visits and workshops. A guided orientation familiarized both students and staff with the platform, which subsequently served as the primary channel for asynchronous learning and inter-institutional communication. Lecturers monitored engagement, reviewed submissions, and tracked progress, while students used the platform to manage tasks, reflect on their learning, and navigate the broader IFE curriculum.

4.2 The Co-LIFE Pilot Course: A Nine-Week Impact-Focused Entrepreneurship Program

The first Co-LIFE pilot was a nine-week hybrid educational program designed to equip students with competencies in Impact-Focused Entrepreneurship through collaborative, cross-cultural, and multidisciplinary learning. It brought together 32 students from four Indian higher education institutions and four European HEIs, with six and two students participating per institution respectively. These students represented diverse disciplinary backgrounds, including the creative industries, entrepreneurship, service design, business, and engineering. Students were organized into four transnational and multidisciplinary teams of eight. Each team was supported by one Indian and one European coach and tasked with addressing real-world sustainability challenges in India.

4.2.1 Program Structure and Pedagogy

The course employed a Learning by Developing (LbD) approach and Design Thinking methodology across three phases (Table 1).

Table 1: Structure and Activities of the Co-LIFE Impact-Focused Entrepreneurship Course.

Phase	Location and Duration	Key Activities
Pre-Kick-off Phase	Online (Pre-Weeks 1 and 2)	Virtual team formation, institutional introductions, foundational concepts in Impact-Focused Entrepreneurship and sustainability, team exercises for intercultural collaboration
Week 1	Onsite (Goa Institute of Management)	Orientation sessions and site visits, team-building workshop, immersive workshops and field visits to local impact-oriented enterprises, introduction of four real-world R&D challenges, roundtable discussions with practitioners, intensive Design Thinking session, finalization of

Phase	Location and Duration	Key Activities
		work plans and selection of digital collaboration platforms (e.g., Miro, Microsoft Teams, Google Meet)
Weeks 2-8	Online	Weekly sessions covering: Sustainability (CSR, ESG, circular economy), Impact-Focused Entrepreneurship (global and Indian contexts), Legal and regulatory frameworks, Service design, impact measurement, and business modelling Two interim presentations, weekly coaching sessions, use of MOOC platform for content delivery and resource sharing
Week 9	Onsite (École Intuit Lab, Mumbai)	Final project refinement and mentorship, formal presentations to peers, faculty, and industry stakeholders, cultural activities, graduation ceremony

4.2.2 Live Projects and Setting the Context for the Students

As the course was based on the Learning by Developing (LbD) methodology, students worked on live projects throughout the nine-week program. These projects were defined by local impact-oriented enterprises in Goa, India, and focused on social and environmental sustainability. The cases were selected by the partner university in Goa based on four consortium-defined criteria: (1) alignment with the Sustainable Development Goals (SDGs), (2) potential for community-level impact, (3) relevance to pressing regional challenges (e.g., water and waste management), and (4) compatibility with the interdisciplinary composition of student teams, which included backgrounds in business, design, and technology.

The first project addressed the need for household rainwater harvesting to counter groundwater depletion in Goa. Despite high rainfall, the region suffers from seasonal shortages due to poor storage and overdependence on municipal supply (Goa Rainfall, 2023; World Bank, 2021). The entrepreneur asked students to develop a scalable solution and support a shift from a B2B to a B2C model. Using Design Thinking, market research, and stakeholder interviews, students created user personas, mapped customer journeys, and proposed a roadmap for market entry (Euro Guard, 2024; Van Geetsom et al., 2025).

In the second project, students supported a startup that had developed an IoT-enabled device for real-time, decentralized water quality monitoring. The team was tasked with developing a commercialization strategy. Limited public awareness and stakeholder skepticism were identified as barriers (Gangadharan et al., 2025). The team proposed a multi-layered outreach plan and identified key partnerships with regulatory agencies to build trust and scale adoption.

The third project focused on addressing Goa's high per capita plastic waste, which tripled from 12,000 to 35,000 tonnes between 2014–2024 (GWMC, 2014–15; GSPCB, 2023–24). Students assessed the effectiveness of regulations and proposed a multilingual mobile app to drive citizen engagement. They also suggested collaborations with industries and municipalities to upcycle plastic, framed within a circular economy model (Lehtosaari et al., 2025; Shefali et al., 2025).

The final project aimed to improve the efficiency and transparency of local waste collection. After mapping friction points across the current system, students proposed digitization via a real-time dashboard to track participation, waste volume, and payments. Their solution included reward systems for compliant households and penalties for non-segregation, alongside community engagement strategies (Hansen et al., 2025).

Table 2: Summary of student projects in the Co-LIFE Course.

Project Number	Focus Area	Challenge	Key Student Contribution
1	Water conservation and business design	Low adoption of RWH; transition from B2B to B2C	Market research, user personas, roadmap for B2C implementation
2	Safe drinking water and technology	Commercialization barriers; stakeholder skepticism	Outreach strategy, stakeholder mapping, scaling framework
3	Waste management and policy	High per capita plastic waste; weak public engagement	Multilingual mobile app, policy gap analysis, circular partnerships
4	Urban services and digital governance	Inefficiencies and low transparency in collection processes	Digital dashboard, route optimization, incentive-based community engagement

These projects required students to deeply engage with local contexts while applying global frameworks. The interdisciplinary teams co-developed implementable, context-sensitive solutions through field visits, stakeholder meetings, and iterative design. Entrepreneurs appreciated the feasibility and relevance of the proposed interventions.

4.2.3 Assessment and Outcomes

The assessment comprised both individual and group elements aligned with ECTS standards. The individual evaluation included oral presentations, peer assessments, and weekly module tasks. The group assessment focused on process quality and project deliverables for the 4 real-life challenges, including a ~20-page report, end-of-course presentation, and weekly blog reflections.

The Co-LIFE pilot demonstrated the value of experiential, impact-driven entrepreneurship education in fostering cross-disciplinary collaboration and addressing local sustainability challenges. It offers a replicable model for international HEI partnerships aiming to enhance student engagement in socially and environmentally responsive innovation.

4.3 Evaluation of the Course

The evaluation of the Co-LIFE pilot course highlights its strong potential while revealing several critical areas for improvement. Overall, students valued the experiential, interdisciplinary, and cross-cultural nature of the programme, though certain structural and pedagogical aspects limited their ability to fully benefit from the course.

4.3.1 Engagement With Live Case Projects

Students consistently cited the live case work with Indian companies as a major strength. These projects helped them apply theoretical knowledge to complex, real-world problems and fostered a strong sense of purpose. Working closely with enterprises tackling water scarcity, waste management, and circular economy issues gave students hands-on experience in designing solutions for social and environmental impact.

4.3.2 Interdisciplinary and Cross-Cultural Collaboration

Teamwork across disciplines and nationalities was described as both rewarding and demanding. Students valued the exposure to diverse perspectives and knowledge systems, which contributed to their learning and professional development. However, several teams struggled with coordination, especially in larger groups. Challenges included uneven contributions, language barriers, and differing levels of commitment. Students recommended forming smaller, more balanced teams (ideally five to six members) and ensuring that each group included a local student familiar with the context of the assigned case.

4.3.3 Workload and Institutional Support

Particularly among students from Indian institutions, balancing the course with ongoing academic responsibilities proved difficult. Many reported limited support from their home universities, which impacted their ability to engage fully with the programme. This points to a need for better institutional alignment and clearer expectations regarding course workload.

4.3.4 Timing and Use of Tools and Frameworks

Several students noted that important frameworks and tools, such as those related to sustainability, impact measurement, and design thinking, were introduced too late in the course. Early access to these resources would have allowed teams to incorporate them more meaningfully into their project work. Students suggested frontloading core content to enhance its practical application across all phases of the programme.

4.3.5 Blended Delivery and Digital Learning Environment

The hybrid format, combining online and in-person learning, received mixed reviews. While the flexibility of online learning was appreciated, many students found the experience fragmented. The MOOC platform was perceived as disconnected from other components of the course, and content was often delivered in long, dense video lectures. Students recommended shorter videos, simplified language, increased interactivity, and regular live sessions to encourage dialogue and maintain motivation.

4.3.6 Reported Learning Outcomes

Despite the challenges, students reported meaningful personal and academic development. Many described the course as transformative, citing improvements in confidence, creativity, and collaborative skills. The experience helped them better understand impact-focused entrepreneurship and increased their ability to work effectively in diverse, real-world contexts.

5. Discussion and Conclusion

The Co-LIFE pilot course in Impact-Focused Entrepreneurship offers a theoretically grounded and practically tested model for transnational, interdisciplinary, and impact-driven higher education. Through its integration of real-world problem-solving, digital platforms, and cross-cultural collaboration, the course contributes to and extends several key educational theories, while also illuminating areas for refinement in future iterations.

5.1 Extending Learning by Developing in Cross-Cultural Contexts

The pilot course significantly extends the Learning by Developing (LbD) model beyond its Finnish origins by embedding it within a multicultural, digitally mediated, and impact-focused learning environment. By collaborating with Indian social enterprises to co-design live projects, the course preserved LbD's emphasis on real-world relevance and co-creation of knowledge. However, the results also reveal that such a model, when applied across differing academic cultures, requires nuanced facilitation. In particular, students unfamiliar with open-ended, exploratory learning found it challenging to navigate the "fuzziness" of the project briefs. This highlights a need for more structured onboarding and culturally sensitive scaffolding to ensure all learners can engage productively.

5.2 Enriching Experiential Learning through International Practice

The course operationalizes Experiential Learning Theory by placing students in high-stakes, socially relevant projects where they cycle through experience, reflection, conceptualization, and action. The live projects—including those focused on rainwater harvesting, waste management, and water quality monitoring—enabled students to apply theory in dynamic real-world settings. This not only deepened their understanding of sustainability challenges but also enhanced their self-efficacy and reflective capacity. Interdisciplinary collaboration enriched this cycle further by exposing students to diverse problem-solving approaches and knowledge systems.

5.3 Advancing Blended Learning in Transnational Education

The MOOC-based digital platform exemplified a meaningful application of blended learning theory, facilitating both asynchronous content delivery and synchronous collaboration across eight institutions. The platform functioned as a pedagogical hub, integrating learning materials, reflections, assessments, and teamwork tools. However, student feedback points to the need for greater coherence between the digital and live components. Content was sometimes perceived as dense, disconnected, or delivered too late to support project work effectively. This reinforces the importance of intentional instructional design and early introduction of core tools in blended learning environments.

5.4 Contributing to Entrepreneurship Education Theory

The Co-LIFE course contributes to evolving entrepreneurship education theory by demonstrating how interdisciplinary, impact-oriented, and real-life projects cultivate opportunity recognition, entrepreneurial self-efficacy, and systems thinking. Rather than focusing narrowly on venture creation, students explored how entrepreneurship can drive social and environmental transformation. This broader framing aligns with contemporary calls for entrepreneurship education to support sustainability, inclusivity, and cross-sector innovation. Furthermore, the transnational and multicultural setup of student teams exposed learners to complex collaborative dynamics—challenging yet ultimately enriching their professional growth.

5.5 Toward a Scalable Model of Impact-Driven Education

In conclusion, the Co-LIFE pilot illustrates a replicable and adaptable model for international, impact-focused higher education. It demonstrates how universities can collaborate to deliver experiential, digitally supported, and socially relevant curricula that address global challenges through local action. While future iterations should

address the pacing of content, mentor alignment, and team coordination, the core structure of the course is sound. Its integration of LbD, experiential learning, and blended delivery provides a strong foundation for expansion across contexts and disciplines.

5.6 Limitations of the Study

While the study provides valuable insights into the design and implementation of a transnational, impact-focused entrepreneurship course, several limitations should be noted. The findings are based on a single pilot with a relatively small and context-specific sample, limiting generalizability. Student feedback was primarily self-reported, introducing potential biases such as social desirability and cultural interpretation differences. Additionally, the selection of case enterprises may have been influenced by existing institutional partnerships, potentially limiting diversity in project types. Variability in digital access and institutional support across participating institutions may also have affected student engagement in ways not fully captured. Future studies could address these constraints through larger samples, longitudinal tracking, and comparative designs across different regions.

Ethics Declaration

This study involved educational course design, implementation, and evaluation as part of the Co-LIFE project. As it did not involve sensitive personal data or clinical research, formal ethical clearance was not required. However, all participating institutions followed their internal guidelines for responsible conduct of research, and informed consent was obtained from all student and staff participants involved in data collection activities.

AI Declaration

As English is not the authors' first language, Grammarly was employed to ensure grammatical accuracy and improve stylistic consistency.

References

Agarwal, N., Chakrabarti, R., Prabhu, J. and Brem, A. (2020) "Managing dilemmas of resource mobilization through jugaad: A multi-method study of social enterprises in Indian healthcare", *Strategic Entrepreneurship Journal*, Vol *14, No.* 3, pp. 419-443.

Braun, V. and Clarke, V. (2006) "Using thematic analysis in psychology*", Qualitative Research in Psychology*, Vol 3 No. 2, pp.77–101.

Chatterjee, N., & Das, N. (2016) "A Study on the Impact of Key Entrepreneurial Skills on Business Success of Indian Micro-entrepreneurs: A Case of Jharkhand Region", *Global Business Review*, Vol. *17*, No. 1, pp. 226-237.

Creswell, J.W. and Plano Clark, V.L. (2018) *Designing and Conducting Mixed Methods Research*, 3rd ed., Thousand Oaks, CA: Sage.

Dancis, J. S., Coleman, B. R., & Ellison, E. R. (2023) « Participatory Action Research as Pedagogy: Stay Messy", *Journal of Participatory Research Methods*, Vol. 4, No. 2.

EuroGuard, (2024) *An introduction to rainwater harvesting in India,* [online], https://www.euroguardhysquare.com/news-blogs/rainwater-harvesting-in-india.

Fayolle, A. and Gailly, B. (2008) "From craft to science: Teaching models and learning processes in entrepreneurship education", *Journal of European Industrial Training*, Vol. 32, No. 7, pp.569–593.

Gangadharan, G., Bogdanova, O., Rai, A., Naringe, A., Pontan, M., Lalwani, J., Desai, M. B., Sharma, M., & Aglave, P. (2025), *SaafWater: Real-time water quality monitoring for public health impact*, Co-LIFE Pilot Project Report.

Garrison, D.R. and Vaughan, N.D. (2008) *Blended learning in higher education: Framework, principles, and guidelines*, San Francisco: Jossey-Bass.

Goa rainfall (2023) *User analysis of rainfall and water simulation scenarios*, Unpublished Jupyter Notebook.

Goa State Pollution Control Board (2024) *Annual report on plastic waste generation and management in Goa*, Government of Goa.

Goa Waste Management Corporation (2015) *Annual report on plastic waste management in Goa*, Government of Goa.

Hansen, A. H., Poon, C., Thakur, D., Barla, G., Paramasivam, H., Sharma, M., George, N. N., & Sharma, T. (2025), *Research report of the Co-LIFE case YIMBY*.

Hota, P.K., Mitra, S. and Qureshi, I. (2019) "Adopting bricolage to overcome resource constraints: The case of social enterprises in rural India", *Management and Organization Review*, Vol. 15, No. 2, pp.371–402.

Kolb, D.A. (1984) *Experiential learning: Experience as the source of learning and development*, Englewood Cliffs, NJ: Prentice Hall.

LbD Guide (2024) [online], Laurea, https://libguides.laurea.fi/lbd/english.

Lehtosaari, T., Kmetec, T., Wunnava, A., Jaiswal, V., & Sristava, B. (2025) *Case study: Saahas Zero Waste*. Co-LIFE Pilot Project Report.

Mair, J., Battilana, J., & Cardenas, J. (2012) "Organizing for society: A typology of social entrepreneuring models", *Journal of Business Ethics*, Vol. 111 No.3, pp. 353-373.

Mukesh, H. V., Rao, A. S., & Rajasekharan Pillai K. (2018) "Entrepreneurial Potential and Higher Education System in India", *The Journal of Entrepreneurship*, Vol. *27, No.* 2, pp. 258-276.

Pittaway, L. and Cope, J. (2007) "Simulating entrepreneurial learning: Integrating experiential and collaborative approaches to learning", *Management Learning*, Vol. 38, No. 2, pp.211–233.

Ploum, L., Blok, V., Lans, T. and Omta, O., (2017; "Toward a validated competence framework for sustainable entrepreneurship", *Organization & Environment*, Vol. 31, No. 2, pp.113–132.

Poulsen, E.S. (2025) *Continuous Evaluation*, Co-LIFE project report.

Poulsen, E.S. (2025) *Evaluation Results,* Co-LIFE project report.

Poulsen, E.S. (2025) *Final Interviews Report: Co-LIFE Pilot Programme*, Co-LIFE project report.

Poulsen, E.S. (2025) *Improvement Recommendations Report: Work Package 7, Impact-Focused Entrepreneurship Course*. Co-LIFE project report.

Poulsen, E.S., Rezac, F. and Møberg, J.E. (2025) *Interviews Mumbai,* Co-LIFE project report.

Raij, K., (2007) *Learning by Developing,* Vantaa: Laurea University of Applied Sciences.

Shefali, Wankhade, A., Mustonen, T., Bhardwaj, B., & Khandhar, M. (2025) *Circular Goa*, Co-LIFE Project Report.

United Nations General Assembly (77th Session), (2022) *Entrepreneurship for sustainable development: Resolution adopted by the General Assembly*.

Van Geetsom, N. and Wilkinson, A. (2025) *Project Pilot and results*, Co-LIFE project report.

Van Geetsom, N., Amarnani, A., Gupta, S., Hansen, M. F. N., Dange, N., Agasthya, A., Borkar, S., Harsha, R., Verbiest, A., and Natekar, P. (2025) *Report-roadmap book of Lila Digital and Environmental Solutions*, Co-LIFE Pilot Project Report.

Vuorela, T. and Lehtosaari, T. (2024) "Kicking off Co-LIFE Project: Co-designing Learning for Impact-Focused Entrepreneurship (IFE) in India", *Blog, Laurea UAS: Laurea Journal*, [online], http://urn.fi/URN:NBN:fi-fe2024090969810

Wells, S., Warelow, P. and Jackson, K. (2009) "Problem Based Learning (PBL): A Conundrum", Contemporary Nurse, Vol. 33, No. 2, pp. 191–201.

What is Laurea's Pedagogical Model? Laurea UAS, (2024), YouTube. What is Laurea's Learning by Developing model?

World Bank (2021) *Managing water scarcity through sustainable solutions*.

World Economic Forum (2023) *Global Risks Report 2023*.

World Resources Institute (2022) *The role of rainwater harvesting in sustainable urban water management*.

Perceived Risk of Generative AI Adoption in Initial Teacher Education Programmes

Marian Carcary and Patrick Buckland
Mary Immaculate College, Thurles, Ireland

marian.carcary@mic.ul.ie
patrick.buckland@mic.ul.ie

Abstract: Generative AI (GenAI) is reshaping the paradigms of learning and creativity in higher education environments, presenting a host of benefits but also considerable concerns and challenges. One such challenge is that of perceived risk. This is a function of the extent to which an individual senses there to be potential threats or unfavourable outcomes, giving rise to varying apprehensions towards new technology use. New technology adoption involves a fine balance between confidently leveraging the technology's functionalities to deliver practical benefits and between weighing the potential risks of adoption. Previous studies investigating the impact of perceived risk on GenAI adoption in higher education have yielded mixed results, but overall limited empirical evidence exists. Some studies have found that perceived risk has a significant negative influence on the attitudes of higher education students' towards GenAI and consequently acts as a deterrent towards their behavioural intention to adopt. Others indicate that perceived risk is not a significant barrier to GenAI adoption intention, with the practical advantages of academic support, increased productivity, and ease of use outweighing student risk-related concerns such as data privacy, content authenticity and misinformation, academic misconduct, skill degradation, and the stifling of intellectual development. This study offers a more nuanced investigation of perceived risk in the context of students enrolled in undergraduate initial teacher education programmes in Ireland. This is an intriguing context given such students play a dual role – they not only need to consider the perceived risks of AI chatbot use within their own academic studies but also in the context of acting as student teachers within an external school environment. The paper presents a quantitative and qualitative assessment of 290 student responses in relation to the varying dimensions of perceived GenAI risk. It offers a number of theoretical and practical implications; from a theoretical perspective, it highlights the rationale to extend existing technology adoption models with perceived risk as a key exogenous variable, while from a practical perspective it offers a number of recommendations to mitigate perceived risks and shape more effective student engagement with GenAI in educational environments.

Keywords: Generative AI, AI Chatbots, AI Adoption, Perceived Risk, Initial Teacher Education.

1. Introduction

Ongoing developments in GenAI are reshaping the context of the higher education landscape (Bennett and Abusalem 2024), offering the potential to significantly enhance teaching and learning processes whilst also threatening existing learning paradigms and academic integrity (Le and Metzger 2024; Mao et al, 2023). From a beneficial perspective, GenAI offers students a personalised, interactive and dynamic learning experience that caters for diverse learning needs and modalities and thereby improves student learning outcomes (Bennett and Abusalem 2024; Cotton et al, 2023; Gundu 2023; Harry and Sayudin 2023; Wang et al. 2023). Acting as a learning companion or personalised tutor/dialogic partner that provides students with tailored explanations and real-time feedback enhances student learning autonomy (Schön et al. 2023) and their retention and understanding of complex concepts (Bennett and Abusalem 2024; Hadi Mogavi et al, 2024; Williams 2024). Application of GenAI within the classroom also supports collaborative problem solving, teamwork, student interactivity, engagement, and learning satisfaction, among other benefits (Mao et al, 2023). However, across higher education stakeholders, there are concerns that GenAI may diminish student motivation, critical thinking and writing skills, and their overall understanding of and engagement with subject matter; in essence the student learning process becomes bypassed in favour of quick results (Chan 2023; Duah and McGivern 2024). The impact of AI misinformation and encoded biases can also negatively affect students' understanding and their worldview (Mao et al, 2023). However, given GenAI's capabilities to produce sophisticated output in a fraction of the time it would take a student, the greatest concern centres on maintaining academic integrity and the challenges of academic misconduct (Cotton et al, 2023; Mao et al, 2023; Moorhouse et al, 2023). Beyond the impact of academic misconduct on individual students, there is a concern that GenAI may deplete trust and credibility in the higher education system, thereby eroding the value of academic awards (Bennett and Abusalem, 2024; Eke 2023; Moorhouse et al, 2023). Thus, from a student's perspective, while GenAI offers significant transformative benefits for their learning journeys, there are many risks associated with its adoption that need to be carefully evaluated.

Adoption of any new technology involves a fine balance between confidently leveraging the technology's functionalities to deliver practical benefits and between weighing the potential risks associated with adoption.

This paper explores GenAI adoption from the perspective of student teachers – students enrolled in undergraduate initial teacher education programmes in Ireland. It presents a quantitative and qualitative assessment of 290 student responses in relation to the varying dimensions of perceived GenAI risk and its impact on their behavioural intention to adopt GenAI. The context investigated is intriguing given that such students not only need to consider the perceived risks of GenAI use within their own academic studies but also in the context of acting as student teachers. The research questions addressed are as follows:

- What risks do students enrolled in undergraduate initial teacher education programmes in Ireland perceive in relation to GenAI adoption?
- To what extent do these risks impact their behavioural intention to adopt?

This paper is structured as follows: Section 2 provides an overiew of the literature centred on GenAI risks within the context of higher education. Sections 3 details the methodological approach adopted. Section 4 provides an analysis and discussion of both quantiative and qualitative findings, while section 5 presents both theoretical and practical implications and recommendations from the study. Section 6 draws the paper to a conclusion.

2. Literature Overview

Perceived risk refers to the degree to which individuals sense potential threats, uncertainties, unfavourable outcomes, or negative events when adopting new technologies (Oc et al, 2024; Sharma and Singh, 2024; Zhu et al, 2024), and may be linked to a blending of behavioural insecurity (the lack of familiarity with how the technology works) and environmental insecurity (the unpredictable nature of the technology itself) (Chatterjee and Bhattacharjee, 2020; Sharma and Singh, 2024). Studies investigating the impact of perceived risk on GenAI adoption in higher education have yielded mixed results, but overall limited empirical evidence exists (Oc et al, 2024; Sharma and Singh, 2024). Some studies (e.g. Acosta-Enriquez et al, 2024; Oc et al, 2024; Kasneci et al, 2023) have found that perceived risk has a significant negative influence on the attitudes of higher education students' towards GenAI and consequently on their behavioural intention to adopt, with students reducing their AI usage when they perceive the associated risks to be high. Perceived risk was found to be the most significant negative effect on Chinese pre-service teachers' intention to use GenAI in their future teaching due to concerns over data security and privacy, stability of the technology, authenticity of content, and impact on their teaching effectiveness (Hu et al, 2025). Similarly, Chatterjee and Bhattacharjee (2020) found that perceived risk has a significant negative impact on the attitudes of higher education stakeholders in India towards AI adoption. Fu et al (2024) and Hsu and Silalahi (2024) investigated the related concept of perceived severity (defined as 'the potential harms individuals might experience') in the context of ChatGPT in Indonesia and Taiwan respectively. They found that high perceived severity is a deterrent towards ChatGPT's use in academic settings particularly when it is perceived to impede academic integrity, critical thinking, and soft skills development.

Contrary to these studies, Gulati et al (2024) found that perceived risk does not deter students' behavioural intention to use GenAI, despite recognition of the potential risks. In a study of Chinese journalism students, the impact of perceived risk on AI adoption within their course was negligible, indicating their perceived value from AI use is not impacted by perceived risk (Zhu et al, 2024). Similarly, Al-kfairy (2024) highlighted that perceived risk has a minimal impact on the adoption of ChatGPT, possibly implying that its perceived practical benefits outweigh its perceived risks. Nonetheless, they also note that perceived risk does play a role in understanding anxieties and apprehensions pertaining to new technology adoption.

In general, perceived GenAI risks relate to academic misconduct; misinformation and bias; confidentiality and data privacy; and overreliance – linked with the stifling of creativity (Chan and Tsi, 2024; Hu et al, 2025). These risks need to be balanced in order for potential benefits to be effectively harnessed (Hsu and Silalahi, 2024). The perception of risk is also often a function of the nature of the AI tool – for example, text generators may increase academic dishonesty and plagiarism anxiety, while image generators may have a greater impact on creative authenticity anxiety (Oc et al, 2024). We discuss key literature findings in relation to these specific risk categories in section 4, in comparison with the key findings from this study.

3. Methodology

This study employed a quantitative research approach through the development and administration of an online survey instrument using Microsoft Forms. The survey constructs were informed by a systematic review of existing literature (Okoli, 2015) pertaining to the adoption of AI within higher education; these constructs were pilot tested with a sample of senior academics and students and refined to ensure their relevance within the

higher education environment. The survey gathered responses to a series of closed questions using 5-point Likert scales. A numerical score was associated with each response reflecting the degree of attitudinal favourableness, with 'strongly agree' associated with number '1' and 'strongly disagree' associated with number '5' on the scale. The survey also included a series of open-ended questions that provided a richer, more multifaceted understanding of the issue investigated. Purposive stratified sampling was employed (Silverman, 2021); the sampling frame was stratified according to the following criteria: 1) Respondents must be students enrolled in undergraduate initial teacher education programmes, and 2) Respondents must be located in Ireland. The study's sample consisted of 600 students. Data collection resulted in 290 usable responses, achieving a 48% response rate. Analysis of the quantitative closed questions was performed using SPSS, while the qualitative open-ended questions were coded and thematically arranged using N-Vivo.

4. Findings

4.1 Profile of Respondents

The survey provided 290 usable responses. Each student respondent was enrolled in a discipline specific initial teacher education programme in Ireland with a view towards qualifying to teach specific subjects in the Irish post primary school setting (catering for students ranging from 12-18 years of age). The majority of respondents (74 percent, n=215) were female, while 26% (n=74) were male (Figure 1). This break down is reflective of the profile of students who were enrolled in initial teacher education programmes at the time of survey administration. In terms of 'year of study' (Figure 2), the majority of student respondents were in their 4th and final year (39 percent, n=113), 25% percent (n=72) were enrolled in 3rd year, 35% percent (n=101) were enrolled in 2nd year, while a significant minority of 1% (n=4) were 1st year students. The low response rate from 1st year students is likely a function of the time of survey administration during a period when they were transitioning to university life and perhaps their limited exposure to GenAI within the university setting.

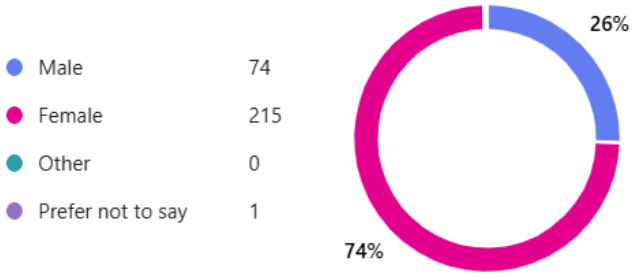


Figure 1: Profile of respondents – gender

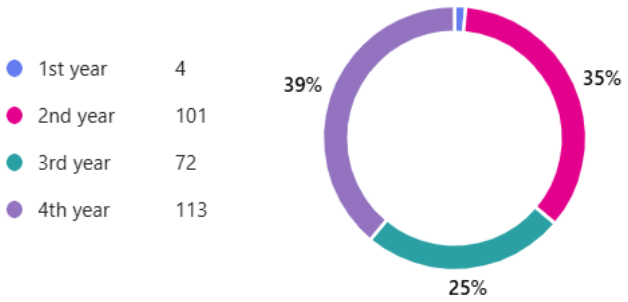


Figure 2: Profile of respondents – year of study

Among the survey respondents, there was a significant awareness of GenAI. 96% of respondents (n=279) had heard about AI chatbot technology; 75% (n=218) had observed the use of AI chatbots as demonstrated by their lecturers or peers; while 78% (n=225) had experimented with AI chatbots. However, only a significant minority (17%, n=49) were regular users of AI chatbots in their academic studies.

4.2 Perceived Risk of GenAI Adoption and Impact on Behavioural Intention – Findings and Discussion

83% of respondents (n=241) reported that use of AI chatbots for answering their academic queries was risky. The pivotal concerns surround academic misconduct, misinformation and bias, and confidentiality and data privacy (Figure 3). A further risk category of 'overreliance on AI' was uncovered through qualitative comments. Further exploration of the data collected indicates varying degrees of relationships between perceived GenAI risks and students' behavioural intention to adopt GenAI tools. The degree of correlation between such variables was investigated using the non-parametric Spearman Rank Order correlation coefficient which is deemed appropriate in exploring relationships between two ordinal or ranked variables (Pallant, 2020). Characterisation of the relationship's strength was interpreted according to Cohen's (2013) guidelines on correlation coefficient size. The data indicates a negative correlation of moderate strength (r= -.31, p < .001) between students' perceptions that using AI for academic queries is risky and their intention to use AI chatbots in their academic studies. This implies that when their perception of risk is high, their intention to adopt GenAI tools is reduced.

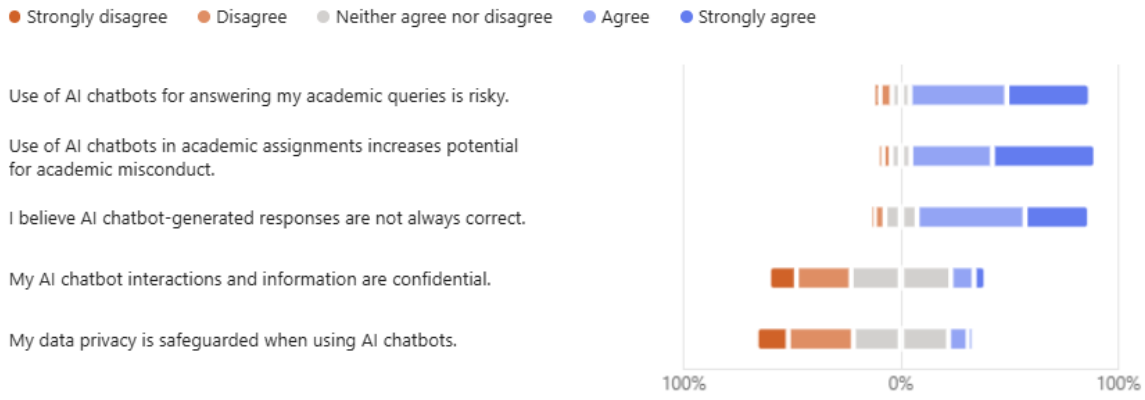


Figure 3: Perceived risk of GenAI use

4.2.1 Risk of Academic Misconduct

85% of respondents (n=247) suggested that use of AI chatbots in their academic assignments increased potential for academic misconduct. Respondents mention 'plagiarism', 'using work that is not your own', and 'not referencing' as key perceived risks. The unethical nature of this is recognised by some respondents. However, the majority of comments pertain to the consequences of academic misconduct and the severity of penalties or disciplinary action. Students discuss the 'fear of repercussions', the possibility of 'getting caught', 'getting done for cheating', and 'detection by anti-plagiarism software'. The primary concerns include 'the risk of failing a module, assignment, or course'; 'the risk of having to repeat an assignment; 'the risk of action by the school board'; and 'the risk of getting kicked out of college'. One student commented that 'the chances of getting in trouble outweigh the reward of using it'. The data indicates a negative but weak correlation (r= -.25, p < .001) between students' perception that AI increases potential for academic misconduct and their intention to use GenAI in their studies. This implies that when their perception of academic misconduct is high, their intention to adopt GenAI tools is reduced. This finding is in line with a study by Oc et al (2024) which suggests that academic dishonesty and authorship were pivotal concerns with some students particularly concerned that AI-assisted work may not be judged by assessors and academic institutions as being authentic, thereby impacting student grades and feedback and their intention to adopt AI tools.

4.2.2 Risk of Misinformation and Bias

79% of respondents (n=230) believed that AI chatbot generated responses were not always correct. Respondents cite 'unreliable information', 'incorrect/inaccurate information', 'false/fake information', and 'misleading information' to reflect potential outcomes from GenAI use. The possibility of 'relying on information that hasn't been verified' is recognised as a further risk. The data indicates a negative but weak correlation (r= -.22, p < .001) between students' perception that AI chatbot generated responses are not always correct and their intention to use AI chatbots in their academic studies. This implies that when their perception of misinformation and bias is high, their intention to adopt GenAI tools is reduced. The literature supports this

finding - the 'AI hallucination effect' associated with inherent AI biases in training data and delivery of misleading information is widely discussed potentially resulting in unfair educational outcomes (Omughelli et al, 2024; Hsu and Silalahi, 2024). Oc et al (2024) highlight that lack of transparency surrounding AI algorithms and how AI content is generated can increase student mistrust and reduce their intention to adopt AI tools; while a study by Hsu and Silalahi (2024) suggests that the inaccurate or misleading nature of some AI generated content may compromise academic integrity.

4.2.3 Risk of Confidentiality and Data Privacy Issues

A significant minority, 16% of respondents (n=47) believed that AI chatbot interactions were confidential, while only 11% (n=33) believed their data privacy was safeguarded when using AI chatbots. Respondents mention the issue of 'data privacy breaches' and 'online safety'. They note that they are 'unsure of what data is being accessed' and 'not sure about the privacy of using AI and how information is stored'. The data indicates a negative but weak correlation ($r = -.23$, $p < .001$) between students' perception that their AI chatbot interactions weren't confidential and their intention to use AI chatbots in their academic studies. Similarly, there is a negative but weak correlation ($r=-.19$, $p <.001$) between students' perceptions that their data privacy is not safeguarded when using AI chatbots and their behavioural intention to adopt (note wording of original scales reversed). This implies that when their perception of confidentiality and data privacy breaches is high, their intention to adopt GenAI tools is reduced. Other studies have found that perceived risks surrounding personal data collection and processing, data privacy breaches, and data security deter students from engaging effectively with GenAI tools (Acosta-Enriquez et al, 2024; Irfan et al, 2023; Salloum, 2024). Given the strength of the relationships uncovered, our study's findings largely concur with those of Menon and Shilpa (2023), who found that privacy concerns were not a significant barrier impacting ChatGPT use in India despite study participants demonstrating caution in terms of what personal information they revealed. The authors suggest that this may be due to lower privacy expectations among individuals when using chatbots and a perception of the technology's benefits outweighing its risks – a trade-off referred to as the 'privacy paradox'. Similarly, Zhao et al (2024) findings suggest that within educational contexts, privacy concerns are less critical since the interactions with GenAI do not typically disclose sensitive information.

4.2.4 Risk of Overreliance on AI

Overreliance on AI is associated by respondents with 'lack of originality', 'lack of creativity', and 'lack of imagination', giving rise to 'student laziness' and a lack of 'authenticity' in students' work. Overreliance is also associated with 'poor grasp of a topic' and 'lack of student learning', where students 'don't understand the generated text provided by AI' and 'are not able to brainstorm ideas' or 'come up with answers/solutions on their own'. This is particularly so in disciplines such as mathematics: 'When using it for logical purposes (e.g. Mathematics) I may rely on AI help before engaging the problem-solving side of my brain for long enough' and 'I think that it does not improve my critical thinking'. Some students mention that 'AI gives a false representation of abilities'. These findings are in line with some previous studies that highlight students' recognition of the risks of overdependence on GenAI, including a negative impact on their problem-solving skills, critical thinking skills, and creativity (Habib et al, 2024). Chan and Hu (2023) suggested that the potential negative impact on students' ability to independently analyse academic challenges may be a concern for their overall skill development. While Oc et al (2024) regard AI as useful for routine tasks, its potential to stifle intellectual development was found to be a key concern.

5. Implications and Recommendations

The insights gleaned through the data analysis present a number of practical and theoretical implications. Notably, the perceived risks of GenAI adoption need to be effectively managed in order to enable the value of such tools to be realised. The groundwork for student teachers' adoption of GenAI in their professional practice lies within their university academic courses. In this regard, university educators need to be conscious of the role they play in terms of influencing students' perceptions. Previous research has found that supportive educators who adopt the technology in their work practices and provide sound educational guidance on its use instil confidence, while less supportive educators increase student anxiety and scepticism of GenAI tools (Oc et al, 2024). With respect to the risk categories identified, the following practical recommendations are proposed:

To mitigate risks of academic misconduct, academic institutions need to clearly define acceptable GenAI use and AI-facilitated behaviours (including student disclosure of AI assistance) in an unambiguous, institution-wide policy. Such a policy should be co-created by all university stakeholders to foster shared ownership and

responsibility. To embed this policy, academic institutions need to rethink their educational approaches towards the use of GenAI, where AI is coherently integrated within course content within a supportive guiding framework that educates students on GenAI features and provides practical guidance/tutorials on its acceptable, ethical, and responsible use. While this may be achieved on a module-by-module basis, a university-wide programme on GenAI literacy and academic integrity education is recommended as foundational to enable successful leveraging of the technology within students' academic courses and professional teacher practice. Educators need to model ethical GenAI practice and discuss misuse in order to demystify GenAI tools and build student confidence in tool adoption. They should also consider reducing opportunities for academic misconduct by rethinking their assessment approaches with a focus on more AI-resistant formats that necessitate higher-order thinking and authenticity in their performance e.g. reflective commentary, problem-based tasks. The boundaries of acceptable GenAI use on every assignment should be clearly stated.

To mitigate risk of misinformation and bias, as part of a GenAI literacy programme, academic institutions need to educate students on verification strategies, bias detection, triangulation, and so on. Educators should design tasks to force verification such as critiques of AI outputs and reflective commentaries on accuracy and bias. Students may be requested to annotate AI outputs and document details of AI assistance including tools used, prompts, use cases, and verification approaches and steps.

Because AI systems can handle large volumes of personal data, robust and trustworthy security measures are needed. To mitigate risk of confidentiality and data privacy issues, academic institutions require clear privacy notices regarding the processing of personal data by GenAI tools. Institution-wide GenAI literacy programmes and role specific training to comply with the EU AI Act need to be established and embedded. Educators need to select tools with privacy-preserving defaults and be explicit with their students about what is uploaded to third-party tools.

To mitigate risk of overreliance on AI, academic institutions need to embody a culture where human judgement, creativity, and independent learning are at the forefront of all academic programmes. GenAI should be positioned as a supplemental tool as opposed to a substitute for these graduate attributes. Institution-wide GenAI policies need to be continually reviewed to discourage unhealthy dependence and keep the boundaries of acceptable use in line with new developments. Educators can design assessments that focus on both process and end product, with requests for staged drafts, think-alouds, and reflective commentaries that link to sources used. Authentic tasks such as oral defences, live problem-solving, and artefacts linked to personal experience ensure GenAI use does not replace independent thinking.

This study also offers recommendations from a theoretical perspective. The findings detail the various categories of perceived GenAI risks and their impact on students' behavioural intention to adopt such tools. Within the education context, GenAI-enabled academic misconduct, misinformation, privacy issues, and overreliance are very real threats to the quality of students' education and the reputation of academic institutions. Thus, from a theoretical perspective, this study presents a rationale for the inclusion of perceived risk as an exogenous variable in technology adoption models e.g. UTAUT (Venkatesh et al, 2003) in order to present a more complete understanding of GenAI adoption and risk mitigation approaches.

6. Conclusion

This paper has presented a detailed exploration of the various categories of risks perceived by student teachers in terms of GenAI adoption. The analysis highlighted that students reduce their intention to adopt GenAI in their academic studies when they perceive use of GenAI for academic purposes is risky, increases potential for academic misconduct, gives rise to misinformation, or leads to confidentiality and data privacy issues. It should be noted, however, that the strength of each of these respective relationships are moderate or weak in nature. Nonetheless, the recognition of GenAI risks by students necessitates that effective strategies are considered by academic institutions to effectively mitigate.

Ethics Declaration

Ethical clearance for this research was obtained from MIC's Joint Faculty Research Ethics Committee.

AI Declaration

AI was not used in the paper's writing.

References

Acosta-Enriquez, B.G., Ballesteros, M.A., Jordan, C.L., and Tirado, K.S. (2024). Analysis of college students' attitudes toward the use of ChatGPT in their academic activities: effect of intent to use, verification of information and responsible use. *BMC Psychology,* 12:255.

Al-kfairy, M. (2024). Factors impacting the adoption and acceptance of ChatGPT in educational settings: A narrative review of empirical studies. *Applied Systems Innovation*. 7:110.

Bennett, L. and Abusalem, A. (2024). Artificial Intelligence (AI) and its potential impact on the future of higher education'. *Athens Journal of Education,* 11 (3):195–212.

Chan, C.K.Y. (2023). A comprehensive AI policy education framework for university teaching and learning. *International Journal of Educational Technology in Higher Education.* 20 (1).

Chan, C.K.Y., and Hu, W. (2023). Students' voices on generative AI: Perceptions, benefits, and challenges in higher education. *arXiv preprint arXiv*: 2305.00290.

Chan, C.K.Y., and Tsi, L.H.Y. (2024). Will generative AI replace teachers in higher education? A study of teacher and student perceptions. *Studies in Educational Evaluation*. 83:101395.

Chatterjee, S. and Bhattacharjee, K.K. (2020). Adoption of artificial intelligence in higher education: a quantitative analysis using structural equation modelling. *Education and Information Technologies*. 25, 3443–3463.

Cohen, J. (2013). *Statistical power analysis for the behavioural sciences*. 2nd edition. Routledge.

Cotton, D.R.E., Cotton, P.A., and Shipway, J.R. (2023). Chatting and cheating: Ensuring academic integrity in the era of ChatGPT'. *Innovations in Education and Teaching International.* 61 (2):228–39.

Duah, J.E., and McGivern, P. (2024). How Generative Artificial Intelligence has blurred notions of authorial identity and academic norms in higher education, necessitating clear university usage policies. *International Journal of Information and Learning Technology*, February.

Eke, D.O. (2023). ChatGPT and the rise of Generative AI: threat to academic integrity? *Journal of Responsible Technology.* 13:100060.

Fu, C.J., Silalahi, A.D.K., Huang, S.C., et al. (2024). The (un)knowledgeable, the (un)skilled? Undertaking ChatGPT users' benefit-risk-coping paradox in higher education focusing on an integrated UTAUT and PMT. *International Journal of Human-Computer Interaction*.

Gulati, A., Saini, H., Singh, S., and Kumar, V. (2024). Enhancing learning potential: Investigating marketing students' behavioral intentions to adopt ChatGPT. *Marketing Education Review*. 34 (3).

Gundu, T. (2023). ChatGPT-proofing: Redesigning assessment practices for e-learning'. *Proceedings of the ... European Conference on e-Learning*, October, 121–30.

Habib, S., Vogel, T., Anli, X., and Thorne, E. (2024). How does generative artificial intelligence impact student creativity? *Journal of Creativity*. 34 (1):100072.

Hadi Mogavi, R., Deng, C., Kim, J.J., et al. (2024). ChatGPT in education: A blessing or a curse? A qualitative study exploring early adopters' utilization and perceptions. *Computers in Human Behavior: Artificial Humans.* 2 (1):100027.

Harry, A. and Sayudin, S. (2023). Role of AI in education. *Interdiciplinary Journal and Hummanity (INJURITY).* 2 (3):260–68.

Holmes, W., Porayska-Pomsta, K., Holstein, K., et al. (2022). Ethics of AI in education: Towards a community-wide framework. *International Journal of Artificial Intelligence in Education*. 1–23.

Hsu, W.L. and Silalahi, A.D.K. (2024). Exploring the paradoxical use of ChatGPT in education: Analyzing benefits, risks, and coping strategies through integrated UTAUT and PMT theories using a hybrid approach of SEM and fsQCA. *Computers and Education: Artificial Intelligence*. 7:100329.

Hu, L., Wang, H., and Xin, Y. (2025). Factors influencing Chinese pre-service teachers' adoption of generative AI in teaching: an empirical study based on UTAUT2 and PLS-SEM. *Education and Information Technologies*. Jan.

Irfan, M., Aldulaylan, F., and Alqahtani, Y. (2023). Ethics and privacy in Irish higher education: A comprehensive study of Artificial Intelligence (AI) tools implementation at University of Limerick. *Global Social Sciences Review*. 8 (2), 201–210.

Kasneci, E., Seßler, K., Küchemann, S., et al. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*. 103: 102274.

Le, A.V. and Metzger, W. (2024). Assessing the impact and challenges of AI-based language models on the education sector: A proposal for new assessment strategies and design. *Journal of Teaching in Travel & Tourism*. February, 1–12.

Mao, J., Chen, B., and Liu, J.C. (2023). Generative Artificial Intelligence in education and its implications for assessment'. *TechTrends: For Leaders in Education & Training*, November.

Menon, D. and Shilpa, K. (2023). Chatting with ChatGPT: Analyzing the factors influencing users' intention to use the Open AI's ChatGPT using the UTAUT model. Heliyon. 9:e20962.

Moorhouse, B.L., Yeo, M.A., and Wan, Y. (2023). Generative AI tools and assessment: Guidelines of the world's top-ranking universities'. *Computers and Education Open.* 5:100151.

Oc, T., Gonsalves, C., and Quamina, L.T. (2024). Generative AI in higher education assessments: Examining risk and tech-savviness on student's adoption. *Journal of Marketing Education*. 1-18.

Okoli, C. (2015). A guide to conducting a standalone systematic literature review. *Communications of the Association for Information Systems*. 37 (43).

Omughelli, D., Gordon, N., and Al Jaber, T. (2024). Fairness, bias, and ethics in AI: Exploring the factors affecting student performance. *Journal of Intelligent Communication.* 4 (1):100–110.

Pallant, J. (2020). SPSS survival manual. 7th edition. New York, NY: McGraw Hill.

Salloum, S.A. (2024). AI perils in education: Exploring ethical concerns. *Artificial Intelligence in Education: The Power and Dangers of ChatGPT in the Classroom*. 669–675.

Schön, E.M., Neumann, M., Hofmann-Stölting, C., Baeza-Yates, R. and Rauschenberger, M. (2023). How are AI assistants changing higher education? *Frontiers in Computer Science.* 5 (July).

Sharma, S. and Singh, G. (2024). Adoption of artificial intelligence in higher education: an empirical study of the UTAUT model in Indian universities. *Int Journal of System Assurance Engineering and Management*. Dec 2024.

Silverman, D. (2021). *Doing qualitative research*. 6th edition. Sage Publications, London.

Venkatesh, V., Morris, M.G., Davis, G.B., and Davis, F.D. (2003). User acceptance of information technology: toward a unified view. *MIS Quarterly*. 27, 425–478.

Wang, X., Wrede, S.E., van Rijn, L., and Wöhrle, J. (2023). AI-based quiz system for personalised learning'. In *ICERI Proceedings*, 1:5025–34.

Williams, R.T. (2024). The ethical implications of using Generative chatbots in higher education. *Frontiers in Education.* 8 (January).

Zhao, L., Rahman, H., Yeoh, W., Wang, S., and Ooi, K.B. (2024). Examining factors influencing university students' adoption of generative artificial intelligence: a cross-country study. *Studies in Higher Education*. Nov.

Zhu, R., Wang, X., Yu, X., and Chan, P. (2024). "AI matters, but my STEM sucks": Determinants of Chinese journalism students' views on greater AI training in journalism courses. *Education and Information Technologies*. Dec 2024.

Algorithmic Teaching, Fading Thought? Rethinking Engagement in the AI Era

Melisa M. Chawaremera
The Independent Institute of Education's IIEMSA, Johannesburg, South Africa

mchawaremera@iiemsa.co.za

Abstract: As artificial intelligence becomes increasingly embedded in educational environments, the promise of enhanced efficiency, personalised instruction and expanded access to knowledge is celebrated globally. However, the pedagogical implications of algorithmic instruction remain under theorised, particularly with regard to critical thinking and epistemic engagement. This paper interrogates how algorithmic-driven content delivery and automated assessment systems may inadvertently narrow intellectual curiosity and encourage conformity while reducing learners to be passive recipients of information. Through a doctrinal study into interdisciplinary literature in education, philosophy and AI ethics, this paper critically analyses how AI tools that are used in instructional design may entrench a form of educational minimalism that prioritises standardisation over inquiry. While artificial intelligence can personalise learning pathways, it also risks eliminating opportunities for open-ended exploration and problem solving. Through comparative insights from South Africa and the UK, the study reveals how algorithmic learning environments can either support or suppress higher order thinking depending on contextual use and pedagogical design. This paper calls for a deliberate reconfiguration of AI-enabled education towards epistemically rich engagement. This is where learners are positioned as co-constructors of knowledge. It proposes a model of "algorithmic dialogism" that blends AI support with critical pedagogy. This will ensure that technology develops as a tool for liberation rather than control. This contribution aligns with ongoing global debates on the ethics of AI in education and seeks to influence curriculum design that furthers curiosity, dialogue and reflective thinking in the digital age. Ultimately, this paper calls for a shift from efficiency-driven instruction to education that values diversity of thought and the cultivation of critical consciousness.

Keywords: Artificial Intelligence in Education, Algorithmic Instruction, Critical Thinking, Student Engagements, Epistemic Justice.

1. Introduction

The Lecture room, once a crucible of unpredictable thought and spontaneous debate, is now increasingly co-inhabited by silent algorithms. These systems do not speak but they shape what is said, seen and explored. The embrace of artificial intelligence in education has been swift and expansive. It has moved from speculative novelty to functional necessity in a matter of years. Instructors across all learning levels now routinely rely on Generative Artificial Intelligence (from hereunder referred to as "GenAI") tools like ChatGPT, Claude and GitHub for lesson planning, assessment design and administrative relief (Ghimire, 2024). Meanwhile, students often outpace their educators in adapting to and deploying these tools (Ghimire, 2024). This makes AI a ubiquitous feature of contemporary learning ecosystems. Much like the conveyor belt in a factory optimised production but standardised output, algorithmic teaching promises streamlined efficiency. However, it risks flattening the intellectual texture of education. The machine moves smoothly, but does the mind? A tension arises between instructional convenience and epistemic richness. In this tension underlies the key concern of this paper.

While algorithmic tools enable unprecedented levels of personalisation and accessibility, they may also reduce the cognitive labour that underpins critical thinking (Bianchi, 2024). In their quest to eliminate friction in the learning process, these systems may also erase moments of uncertainty and exploration, which are in fact vital for deep learning (Shalaby, 2024). The fundamental question that arises would therefore be: Is the efficiency of algorithmic instruction coming at the cost of epistemic vitality? Once encouraged to wander and wonder, is the student's mind now becoming a site of managed inputs and unpredictable outputs? What is celebrated as "personalised learning" may, in fact, produce epistemic echo chambers. Learners are fed what they prefer and not what provokes. As a result, the cognitive horizons narrow (Shalaby, 2024). The learner is at risk of no longer being challenged to rearrange, reconstruct or reimagine knowledge (Shalaby, 2024). In this way, algorithmic instruction may privilege correctness over curiosity and compliance over critique. To describe this phenomenon, the author introduces the acronym T.H.I.N.K. which translates to "*Technologically Handled Ideas, No Knowledge*". This coinage captures the irony of students appearing engaged while their thinking remains outsourced. It names the condition whereby students rely on AI -generated output without deep processing or intellectual struggle. In this context, "Technologically Handled Ideas" refers to both human ideas processed and packaged by machines, as well as machine-generated ideas presented as ready-made knowledge. The phrase signals a shift from critical engagement to passive reception. It highlights the risk of learners consuming outputs without interrogating their origins or implications. This paper interrogates these emerging pedagogical tensions.

It does so with a view of reimagining AI, not as a conveyor belt, but as a dialogic partner. It argues for a shift in how we think about learning in the AI era. AI should cease to be the transmission of optimised content and rather, be a tool from the co-construction of meaning. To this end, the paper proposes a model of algorithmic dialogism, which is a mode of AI integration that preserves epistemic agency and furthers critical thinking.

2. Research Methodology

This study uses a doctrinal and interdisciplinary research approach. It is based on conceptual analysis. The focus is on understanding how algorithmic teaching affects education, especially in terms of critical thinking and knowledge production. The study draws from literature in education theory, philosophy of education, and AI ethics. Sources were chosen for their academic credibility and their relevance to current debates on AI in education. Special attention was given to work that discusses epistemic justice and critical pedagogy. Only sources that engaged meaningfully with the ethical and teaching implications of technology use were included. A comparative element is also included. The paper looks at both South Africa and the United Kingdom. These contexts help show how AI in education is being used in different systems. This comparison helps the study remain context aware. It shows where AI can help, and where it may harm learning.

3. Theoretical Underpinnings (Educational Theories, AI Ethics and the Philosophy of Education)

This paper is anchored in an interdisciplinary theoretical framework that draws from education theory, AI ethics and the philosophy of education. Together, these perspectives offer a nuanced lens through which to analyse the pedagogical implications of algorithmic instruction. They move the debate beyond technological enthusiasm and ground it in the deeper human and ethical questions that AI integration demands.

3.1 Education Theories

The works of Piaget and Vygotsky on constructivism posit that learners should construct knowledge through experience and interaction. Vygotsky's concept of the Zone of Proximal Development also adds an important social dimension. It shows how learning is scaffolded by a more knowledgeable other (the educator) (Xi and Lantolf, 2021). In the context of AI, this raises the question on whether algorithms can function as a meaningful scaffold. If designed intentionally, AI can support active learning. If not, it actually risks turning learners into passive consumers of static content. Laurillard's Conversational Framework sees learning as a dynamic exchange between teacher and learner (Yong et al., 2020). It values dialogue and iteration (Yong et al.,2020). AI, especially the large language model, can simulate this, however, to a limited extent. Most free AI tools to date, when asked for an answer, provide the answer, even if the question was unclear instead of seeking clarity from the prompter. Conversational AI ideally asks probing questions, it offers counterpoints, and it can challenge assumptions. These are all things that human educators are trained to do. This paper builds on this to propose "algorithmic dialogism". This is a pedagogical approach that positions AI not as a content provider, but as a dialogic partner in meaning making. Self-Regulated Learning theory highlights how learners monitor and direct their own learning (Pilling-Cormick and Garrison, 2007). AI has potential to support Self-Regulated Learning by acting as a metacognitive coach. It can prompt reflection and track progress. It can also suggest strategies. However, without deliberate design, it may do the opposite by outsourcing thinking and suppressing student agency. This tension sits at the core of this paper's concern as far as epistemic engagement is concerned.

3.2 AI Ethics

AI systems are only as fair as the data they are trained on (Scatiggio, 2020). If datasets are skewed, algorithms can reinforce harmful stereotypes or produce inequitable outcomes (Modi, 2023). This is especially concerning in assessment where algorithmic feedback may shape academic trajectories. Principles from UNESCO call for diverse and transparent datasets that can guide against these risks (Morandín-Ahuerma, 2023). AI's decision-making processes are also often opaque. This "black box" problem undermines trust. Educators and students need to understand how outputs are generated to engage with them meaningfully (Holland et al., 2012). Ethical integration demands explainable AI systems where logic can be challenged. Also, AI should never replace human judgement. It must support, not supplant the educator and student's relationship. Over-reliance leads to "cognitive offloading", whereby the thinking is delegated to the machine. This erodes intellectual independence. Ethical frameworks insist that AI must reinforce human agency and not automate it out of the learning process (Nguyen, 2025).

3.3 The Philosophy of Education

The philosophy of education invites a deeper inquiry. It challenges us to ask, not what AI can do in education but rather, interrogates what AI should do. Education is not merely a tool for economic productivity (Barrow and Woods, 2006). It is a means of cultivating ethical individuals (Barrow and Woods, 2006). These individuals also should develop intellectual curiosity and social consciousness (Mead et al., 2015). AI integration in education needs to be constantly judged against these values. Efficiency and personalisation, while valuable, cannot be the sole goals. This paper asks whether AI helps us produce better thinkers or just better performers. At the heart of the discussion is the nature of knowledge. The key question is, is it static content to be delivered efficiently or is it a dynamic process of inquiry and co-construction? The paper adopts the latter view. Epistemic justice demands that diverse ways of knowing are valued (Stroud and Kerfoot, 2021). However, many AI systems are built on Western-centric data, marginalising non-Western epistemologies (Zia, 2025). This raises the spectre of digital colonialism (Zia, 2025). Calls for Afrocentric AI models aim to counter this bias and reclaim local epistemic agency. Transhumanist thought invites us to reflect on what it means to learn, to create and to think in partnership with machines (Frodeman, 2019). In education, this means interrogating how AI affects our sense of self and agency. If we are to embrace AI, we must do so without abandoning human values.

4. A Double-Edged Pedagogy

The integration of artificial intelligence into education presents a paradox. On the one hand, it offers efficiency while on the other hand, it risks diminishing critical thought.

4.1 The Promise of Efficiency

AI driven tools have transformed the administrative and instructional responsibilities of educators (Pedro et al., 2019). Systems such as Canva, Curipod, Eduaide and Quizzizz assist with lesson planning, assessment design, grading and content creation (Nehe and Rahman, 2024). For many educators, especially those in resource - constrained environments, these tools offer vital relief which can save them significant hours per week. This is particularly relevant to overburdened educational systems, including those in the underdeveloped and developing countries. In those jurisdictions, educators face structural and logistical constraints. Beyond the administrative efficiencies, generative AI enables dynamic personalisation. Adaptive learning platforms adjust instructional content in real-time based on student performance. Feedback is immediate and tailored which supports differentiated learning paths that cater to individual needs and abilities. This flexibility can undoubtedly enhance a student's engagement and motivation. Studies have evidenced that gamified learning, immersive story-telling and interactive assessments indeed further augment emotional as well as cognitive involvement. AI can also serve as a catalyst for creativity. It offers novel perspectives, and it provides scaffolding for complex problem-solving. Evidence suggests that AI -facilitated learning may enhance traits associated with innovation and attentiveness (Bianchi, 2024).

That being said, the very features that make AI efficient also carry the risk of merchandising the learning experience. If it is left unchecked, the educational benefits of personalisation may give way to cognitive predictability.

4.2 The Peril of Passivity

The darker side of AI-enabled education lies in its capacity to dull intellectual engagement. Over-reliance on algorithmic support may erode a student's ability to think critically and solve problems independently. Research highlights a negative correlation between frequent AI use and critical thinking performance, particularly when it comes to the young learners (Szmyd and Mitera, 2024). This phenomenon which is often referred to as "cognitive offloading", suggests that students may be intellectually passive when mental effort is continually outsourced to machines (Risko and Gilbert, 2016). This is not a superficial behavioural trend. It signals a deeper pedagogical concern which is the restructuring of cognition itself. Students begin to prefer the fast and automated solutions over the discomfort of grappling with ambiguity. In this instance this paper submits that, sadly, most learners have already come to value completion over comprehension. The celebrated personalisation that is offered by AI can also produce epistemic fragmentation. When algorithms tailor content based on prior interests, they risk creating "educational filter bubbles" (Herm-Morris, 2023). This actually mirrors what is observed in social media environments, whereby content reinforcement limits the exposure to dissenting ideas. In the lecture room, this can inevitably suppress curiosity, and it can inhibit the formation of interdisciplinary connections that are essential for critical and even creative thinking.

More importantly, concerns around academic integrity are intensifying. Students have already been found to use AI to complete tasks without genuine engagement, which reduces assignments to mechanical exercises. Algorithmic bias is another pressing issue. If AI systems are trained on data that reflects social prejudice or exclusion, they can actually reinforce rather than rectify these inequalities. This holds the potential to affect assessment outcomes and feedback rendered. This further holds the undeniable potential to disadvantage the already marginalised students. In such contents, it goes without saying, educator oversight is not optional. It is essential. The human educator's role must shift from content delivery to epistemic stewardship. This includes interpreting AI outputs critically and contextualising information. Finally, AI is not infallible. Hallucinations, which are defined as plausible but fabricated responses, are a known feature of generative models. This is a well-known characteristic of large language models (Chang et al,. 2024). This demands continuous vigilance from both educators and their students. Trust in AI must definitely be tempered by the cultivation of epistemic responsibility.

A recent incident in South Africa, where a junior advocate faced serious repercussions for submitting AI generated legal arguments containing hallucinated case law, starkly illustrates the peril of passivity associated with generative AI (Vermeulen, 2025). This case highlights how an over-reliance on AI tools without verification can lead to professional misconduct and reputational damage. While this specific instance impacted the legal profession, the inherent danger of uncritically accepting AI outputs extends to all other professions and specialisations. This emphasises on the universal need for human oversight and accountability to prevent dissemination of inaccurate or fabricated information.

5. Epistemic Engagement and Justice in the AI Era

Epistemic engagement refers to the active, critical and reflective participation in constructing and applying knowledge. It moves beyond passive information consumption. It includes the questioning, analysing, synthesising and creation of new understanding. This kind of engagement is essential for cultivating independent thinking and complex problem solving. AI's integration into education creates a double bind as it can advance inclusion and yet it can also deepen exclusion. Many AI tools are built on Western-centric data. They reflect and reproduce the already dominant epistemologies. It can be argued that it poses the risk to undermine decolonisation efforts, and it can entrench biases. In South Africa, the #FeesMustFall Movement revealed that access to education is not just about Infrastructure. In such a context, AI is not a neutral intervention. It can be argued to also be a cultural force. The growing call for Afrocentric AI models is a demand for context and representation. Without deliberate localisation, AI has the potential to deepen epistemic injustice. It may actually reinforce global knowledge hierarchies instead of dismantling them, which would not be ideal. Unfortunately, the access to AI technologies remains uneven. Disparities in internet connectivity, digital skills and device availability limit meaningful participation for many (Mwansa et al., 2025). In low-resourced communities, this does widen the digital divide (Mwansa et al., 2025). It therefore makes equitable AI integration socio-political issue and not just a technical one. That being said, AI still also holds promise, as previously established. It can support learners with diverse needs through content delivery in multiple languages. When and if it designed with intention, AI could act as a leveller. It can help to overcome barriers and to extend quality education to the underserved groups of people.

6. Algorithmic Dialogism as a Model Co-Constructed Learning

To counter AI's potential to promote passivity, this paper proposes a pedagogical model of algorithmic dialogism. This model reframes AI and not as an all-knowing oracle but as a dialogue partner. Dialogism is a theory that suggests the presence of more than one voice (Skidmore, 2019). It encourages conversation over command. Essentially, collaboration over automation. Algorithmic dialogism is designed to preserve cognitive effort. It resists the tendency to outsource thinking. Instead, it makes thinking central. It positions AI as a co-learner, one that prompts, challenges and scaffolds, rather than solves (Jacobs et al., 2025). This approach transforms AI from a shortcut to a stimulus for deeper engagements. It will be especially useful for young learners as they are still impressionable and need to be given an opportunity to develop their critical thinking. The model draws on key pedagogical foundations in order to promote reflective learning and epistemic growth.

Algorithmic dialogism shifts AI's role from content delivery to content co-creation. It encourages learners to build knowledge with, and not from, the machine. Tools like Curriculum Genie illustrate this shift. Students contribute to brainstorming and curriculum design. Their voices shape lesson plans. This approach addresses

concerns about algorithmic filter bubbles. It hands control back to the learner. AI therefore becomes a facilitator of exploration, not a limiter to it. Students are thus encouraged to pose questions and also interrogate outputs.

The Human-Centric AI First approach aligns with this vision. Students must explicitly attribute their use of GenAI and reflect on its impact. Journaling and self-assessment become integral to the process. This builds AI literacy and ethical awareness. It also cultivates critical thinking, which is essential.

7. Comparative Overview of AI in Education Policies and Pedagogical Implications (South Africa vs. UK)

To provide grounded and comparative perspective on the pedagogical integration of AI in education, the table below contrasts the key developments in South Africa and the United Kingdom. The comparison between South Africa and the United Kingdom is particularly intrusive, as it juxtaposes responses from a historically under-resourced context and a historically industrialised and globally dominant one. These are two socio-political and economic contexts with markedly different historical, infrastructural and epistemic realities. While both countries demonstrate agility in responding too AI's educational impact, their respective emphases reveal distinct priorities. South Africa seems to primarily foreground equity and access (primarily within the public institutions), while the United Kingdom centres academic integrity and structured AI literacy.

Table 1:

Aspect	South Africa	United Kingdom	Similarities/ Differences
Approach	Agile integration into existing policies (University of Johannesburg) (Khoza, 2025); ethical/responsible guidelines (NorthWest University and University of Western Cape) (Luo et al., 2024).	Multiple tertiary Institutional guidelines on responsible use (Roberts et al., 2023); Russell Group principles on academic integrity/AI literacy (Corcoran and Russell, 2021).	Both show agile policy responses.
Key Pedagogical Focus	AI literacy, multi-draft assignments for independent thought, innovation funds.	AI-proof assessments, Socratic learning enhancement, critical evaluation of AI outputs (Chukhlomin, 2024).	Both aim to foster higher-order thinking; SA emphasizes equity and access; UK emphasizes academic integrity.
Primary Challenges	Digital divide, decolonisation (Mwansa et al., 2025), Western-centric bias (Olufemi et al., 2023), teacher readiness (Tarisayi, 2024).	Lack of long-term evidence, over-reliance, misinformation, plagiarism (Orogun et al., 2024).	Common concerns: critical thinking, bias, ethics, training.
Key Initiatives	Student Short Learning Programmes, AI literacy in core courses (Patel and Ragolane, 2024), resource hubs, peer showcases.	Designing AI-resilient assessments, Socratic learning enhancement through AI-generated examples (Chukhlomin, 2024).	Both invest in teacher training and curriculum adaptation.
Epistemic Justice/Equity Lens	Strong focus on equitable access (Mwansa et al., 2025), Afrocentric models to counter digital colonialism (Olufemi et al., 2023).	Emphasis on academic rigour, human judgment, preventing misuse, user responsibility for accuracy (Orugun et al., 2024).	SA addresses systemic inequalities as well as challenges with regards to academic integrity; UK focuses on individual academic integrity.

Table summarised and drawn up using GeminiAI.

8. Recommendations

Both South Africa and the United Kingdom have shown commendable initiative in responding to the rise of AI in education. Their respective approaches reflect a growing awareness of AI's potential to reshape teaching and learning. The integration of AI into education necessitates a proactive and thoughtful approach to ensure it serves to enhance rather than to diminish human intellectual capacities. The future of education with AI is not predetermined by the technology itself, but by the deliberate choices made in its integration. This requires a conscious shift from merely managing risks to strategically leveraging opportunities for deeper learning.

Adopting "algorithmic dialogism" as a core pedagogical approach is vital. This involves using AI as a conversational partner for inquiry, scaffolding, and reflection, rather than merely a source of ready-made answers. The intentional design of AI to prompt critical thinking and metacognition actively promotes intellectual engagement. The designing of "AI Resilient" assessments is another critical strategy. These assessments should focus on the learning process, on critical evaluation, and on originality. Additionally, they should require that students interpret AI outputs, justify their reasoning and that they engage in complex problem solving. This approach transforms assessment into a pedagogical tool for cultivating higher order thinking and originality.

AI literacy must be integrated across curriculums. This means teaching students not only how to use AI tools, but also how they work, their limitations, potential biases, and especially their ethical implications. Human-led workshops remain vital to complement AI-assisted activities, as do collaborative learning environments. Curriculum designers must revise learning outcomes to include AI-literacy competencies and skills for effective human-AI collaboration. Encouraging interdisciplinary approaches that embed AI discussions across subjects will cultivate a more holistic understanding of AI's societal role. A culture of attribution and reflection should be nurtured, so students assess AI usage in their academic work. Lastly, the comprehensive and ongoing professional development for educators is indispensable. Training programmes must focus on AI competencies, ethical use and very importantly, pedagogical adaptation. It is important to acknowledge the fact that initial training alone is insufficient given AI's rapid evolution. "Tick box" training will not be sufficient under any means. This continuous professional development for educators is a foundational requirement, as educator competency directly mediates the ethical and effective integration of AI in the classroom. Without ongoing support and a commitment to lifelong learning, educators cannot effectively navigate the complexities of AI which can potentially lead to suboptimal or even harmful pedagogical outcomes. Therefore, in a move from being knowledge dispensers, educators need to be supported in transitioning their roles to become facilitators (coaches, if you will) and critical interpreters of AI generated content.

9. Conclusion

Artificial Intelligence tools continue to present a transformative yet challenging landscape for education. While offering unprecedented efficiencies, it simultaneously poses risks to critical thinking and epistemic justice. The proposed "algorithmic dialogism" offers a human centric model for integrating AI. It allows for active engagement and knowledge co-construction by leveraging AI as a dialogic partner rather than a mere information source. Comparative insights from South Africa and the United Kingdom underscore the universal challenges alongside context specific priorities. These distinctions highlight the need for agile, ethically grounded and equitable pedagogical responses. Without such intentional design, we risk falling into what the author has termed T.H.I.N.K., Technologically Handled Ideas, No Knowledge, as a state of algorithmic convenience eclipses intellectual depth. Ultimately, the true measure of AI's success in education will not be found in computational prowess. Rather, it will be found in its capacity to cultivate minds that are not merely informed by algorithms but profoundly enriched by the enduring human spirit of inquiry and connection.

Ethics Declaration

The author declares that ethical clearance was not required for this conceptual paper, as it relies solely on the analysis of existing, publicly available academic literature and does not involve primary data collection from human or animal subjects.

AI Declaration

The author declares that the table presented in this document was drafted with the assistance of GeminiAI. The author's use of GeminiAI involved providing two paragraphs that offered a comparative analysis of the current

use of Artificial Intelligence in education within the United Kingdom and South Africa, followed by a request for this information to be presented in a tabular format.

References

Barrow, R. and Woods, R., 2006. *An introduction to philosophy of education*. Routledge.

Bianchi, I., 2024. Enhancing Critical Thinking in Education: Leveraging AI Tools and Technologies in Pedagogical Practice.

Chang, Y., Wang, X., Wang, J., Wu, Y., Yang, L., Zhu, K., Chen, H., Yi, X., Wang, C., Wang, Y. and Ye, W., 2024. A survey on evaluation of large language models. *ACM transactions on intelligent systems and technology*, *15*(3), (pp.1-45).

Chukhlomin, V., 2024. Socratic Prompts: Engineered Dialogue as a Tool for AI-Enhanced Educational Inquiry. *Latin American Business and Sustainability Review*, *1*(1), pp.1-13.

Corcoran, J.N. and Russell, B., 2021. Teaching academic integrity: Lessons learned from a Canadian EAP program. In *BALEAP Conference Proceedings* (pp. 31-43).

Frodeman, R., 2019. *Transhumanism: An Ontology of the World's Most Dangerous Idea* (Doctoral dissertation, University of North Texas).

Ghimire, A., 2024. Generative AI in education from the perspective of students, educators, and administrators.

Herm-Morris, B., 2023. Education and the dislike society: The impossibility of learning in filter bubbles. In *Bernard Stiegler and the Philosophy of Education II* (pp. 44-53). Routledge.

Holland, C., Mulcahy, C., Besong, F. and Judge, M., 2012. Ethical-values pedagogical model. *Journal of Teacher Education for Sustainability*, *14*(2), pp.41-53.

Jacobs, J., Suresh, A., Booth, B.M., Sumner, T., Bush, J., Brown, C. and D'Mello, S.K., 2025. Automating feedback from recorded instructional observations: using AI to detect and support dialogic teaching. In *Research Handbook on Classroom Observation* (pp. 341-365). Edward Elgar Publishing.

Khoza, R.T., 2025. Integrating Artificial Intelligence, Blockchain, and Business Data Analytics into the University of Johannesburg Commercial Accounting Diploma Curriculum. In *International Conference of Accounting & Business* (pp. 973-992). Springer, Cham.

Luo, Y., Mao, C., Sanchez-Pinto, L.N., Ahmad, F.S., Naidech, A., Rasmussen, L., Pacheco, J.A., Schneider, D., Mithal, L.B., Dresden, S. and Holmes, K., 2024. Northwestern University resource and education development initiatives to advance collaborative artificial intelligence across the learning health system. *Learning Health Systems*, *8*(3), p.e10417.

Mead, G.H., Biesta, G.J. and Trohler, D., 2015. *Philosophy of education*. Routledge.

Modi, T.B., 2023. Artificial Intelligence Ethics and Fairness: A study to address bias and fairness issues in AI systems, and the ethical implications of AI applications. *Revista Review Index Journal of Multidisciplinary*, *3*(2), pp.24-35.

Morandín-Ahuerma, F., 2023. Ten UNESCO recommendations on the ethics of artificial intelligence.

Mwansa, G., Ngandu, M.R. and Mkwambi, Z., 2025. Bridging the digital divide: exploring the challenges and solutions for digital exclusion in rural South Africa. *Discover Global Society*, *3*(1), pp.1-24.

Nehe, B.M. and Rahman, Z.S.A., 2024. An Analysis of Technology Usage in Formative Assessment in English Language Classroom: Teachers' Experience. *PROCEEDING AISELT*, *9*(1).

Nguyen, K.V., 2025. The Use of Generative AI Tools in Higher Education: Ethical and Pedagogical Principles. *Journal of Academic Ethics*, pp.1-21.

Olufemi, I.O., Olukemi, O.M. and Danjuma, O., 2023. Afrocentirism and Eurocentrism: The Case of Artificial Intelligence. *ASRIC Journal on Social Sciences and Humanities*, *290*.

Orogun, O., Ogungbe, L., Ajani, A., Adegboye, N. and Ogunsola, O., 2024. Advancing Educational Equity through Sustainable AI Deployment: Strategies and Innovations for the United Kingdom. *European Journal of Contemporary Education and E-Learning*, *2*(5), pp.36-62.

Patel, S. and Ragolane, M., 2024. The implementation of artificial intelligence in South African higher education institutions: Opportunities and challenges. *Technium Education and Humanities*, *9*, pp.51-65.

Pedro, F., Subosa, M., Rivas, A. and Valverde, P., 2019. Artificial intelligence in education: Challenges and opportunities for sustainable development.

Pilling-Cormick, J. and Garrison, D.R., 2007. Self-directed and self-regulated learning: Conceptual links. *Canadian Journal of University Continuing Education*, *33*(2).

Risko, E.F. and Gilbert, S.J., 2016. Cognitive offloading. *Trends in cognitive sciences*, *20*(9), pp.676-688.

Roberts, H., Babuta, A., Morley, J., Thomas, C., Taddeo, M. and Floridi, L., 2023. Artificial intelligence regulation in the United Kingdom: a path to good governance and global leadership? *Internet Policy Review*, *12*(2), pp.1-31.

Scatiggio, V., 2020. Tackling the issue of bias in artificial intelligence to design ai-driven fair and inclusive service systems. How human biases are breaching into ai algorithms, with severe impacts on individuals and societies, and what designers can do to face this phenomenon and change for the better.

Shalaby, A., 2024. Classification for the digital and cognitive AI hazards: urgent call to establish automated safe standard for protecting young human minds. *Digital Economy and Sustainable Development*, *2*(1), p.17.

Skidmore, D., 2019. Dialogism and education. *The Routledge international handbook of research on dialogic education*, pp.27-37.

Szmyd, K. and Mitera, E., 2024. The Impact of Artificial Intelligence on the Development of Critical Thinking Skills in Students. *European Research Studies Journal*, *27*(2), pp.1022-1039.

Stroud, C. and Kerfoot, C., 2021. Decolonizing higher education: Multilingualism, linguistic citizenship and epistemic justice. *Language and decoloniality in higher education: Reclaiming voices from the South*, pp.19-46.

Tarisayi, K., 2024. Preparing for AI's transformational potential: rethinking teacher education in South Africa. *International Education Trend Issues*, *2*(1), pp.31-40.

Vermeulen, J., 2025. *Another South African lawyer caught using AI has landed in big trouble*. MyBroadband. [online] Available at: https://mybroadband.co.za/news/trending/601133-another-south-african-lawyer-caught-using-ai-has-landed-in-big-trouble.html.

Xi, J. and Lantolf, J.P., 2021. Scaffolding and the zone of proximal development: A problematic relationship. *Journal for the Theory of Social Behaviour*, *51*(1), pp.25-48.

Yong, F.Y., Neo, M. and Hew, S.H., 2020. Enhancing Students' Collaborative Learning Experiences with Laurillard's Conversational Framework. *International Journal of Creative Multimedia*, *1*(SI 1), pp.151-166.

Zia, S., 2025. Digital Colonialism: Reimagining Power, Identity, and Resistance by Decolonizing AI. *Yayasan Drestanta Pelita Indonesia*, pp.129-147.

Efficacy of Detecting AI Plagiarism in Higher Education

Henry Collier
Marshall University,Trenton, NJ USA

hcollier@tesu.edu

Abstract: Whether the text has been directly copied from a source and presented as the author's work, or if the author poorly paraphrased their source, the result is plagiarism. Plagiarism stems from a desire to get a good grade. It is the result of being sloppy, not having confidence in one's ability to paraphrase correctly, a lack of understanding of what needs to be cited, thinking they are supposed to reproduce what the experts have said rather than synthesize the expert's opinions, they panic as the deadline approaches and of course they are lazy. Plagiarism is not new to academia and detecting it has been made easier with plagiarism-detecting tools and simply conducting effective searches on the Internet. However, new plagiarism methods are being developed as technology grows, which are significantly harder to detect. Students now use artificial intelligence to write their academic papers. Detecting if AI was used in producing an academic paper is difficult because the paper has been properly paraphrased and/or cited. New tools like GPTZero and ZeroGPT have been developed to address this issue, but these tools are untested, and academic faculty don't want to pin a plagiarism charge on a student based on an untested tool. This study looks to address this issue and determine if either or both tools effectively determine whether AI has written something.

Keywords: Plagiarism, Artificial Intelligence, ZeroGPT, GPTZero

1. Introduction

Plagiarism within higher education is something that educators have struggled with for decades. Historically, in order to detect plagiarism, the teacher needed to have first-hand knowledge of the sources or go through each source painstakingly to see if plagiarism existed or not. This was a time-consuming endeavor, one that most educators felt was necessary to ensure student success. The Internet brought speed and efficiency to this process by allowing teachers to input suspected plagiarism examples into a search engine, and then within moments, sources that were potentially used will be returned, and suspected text will be highlighted. Using the Internet increases the efficiency of detecting plagiarism by reducing the time a teacher needs to commit to plagiarism detection.

Along with solving problems, technology can also create new ones. As Artificial Intelligence (AI) continues to advance, educators are starting to see more and more papers being produced that are highly likely to be written by AI and not by the student (King, 2023) (Francke & Alexander, 2019) (Hutson, 2024). Based on the simplest definition of plagiarism, having AI write a student's paper qualifies as plagiarism because the work is not the student's original work (Khalil & Er. 2023). When checked, through either traditional methods or an Internet search engine, papers that AI has written rarely return results demonstrating plagiarism (Dien, 2023). This is because AI does a great job of paraphrasing the data it is using to write the paper and, therefore, does not provide direct results (Mahajan, et al., 2023)(Kleebayoon & Wiwanitkit, 2023). With the increased availability of AI tools like ChatGPT, Microsoft Copilot, CopyAI, Jasper AI, and even Grammarly, more and more student papers appear to be heavily influenced by AI (Mahajan, et al., 2023).

Traditionally, one of the ways that a professor would suspect plagiarism is because the suspect paper would not be reflective of the author's previously submitted writing samples (Alzahrani, et al., 2012). The suspect paper will frequently appear to have been written by someone with significantly more education than the author (Alzahrani, et al., 2012). It further must be noted, that as classroom sizes grow, it will become more difficulte for faculty members truly get to know their student's writing style and detecting suspected plagiarism will become more difficult. Example 1 below is an AI-written sentence based on the human-written sentence in example 2(Leki & Carson, 2012).

- Example 1

A person's social media habits and online presence are critical factors that significantly enhance the success of social engineers.

- Example 2

A person's social media habits and their web presence is a significant factor in social engineers being successful.

Example 1 is clear and precise while avoiding redundancy and uses terms like 'critical factors' and 'enhance', which are direct and effective when conveying the topic. While example 2 is slightly less clear, the term 'social

engineers being successful' is vague. Example 1 is stronger and better written, and if the writer submitted this as their assignment after submitting samples more in line with example 2, it would be evident that there is a high likelihood of plagiarism.

AI has created a situation where educators need to work harder to determine whether a student's submission is their own work (Dien, 2023) (Hutson, 2024). From an educational perspective, ensuring students are doing the work themselves is important, as it is the best way for them to learn and become effective in their chosen industry. Certainly, educators need to teach them how to use AI as a tool, but they also need to ensure they teach the students how to use it ethically. In order to ensure we are holding students to the standards, there needs to be AI detection tools that provide results with a high efficacy rate. The two most common tools are ZeroGPT and GPTZero. This study aims to determine if either or both of the tools are effective at determining if a writing sample has been written by AI or by a student. The hope is that this tool will give educators an additional resource that can be used to support student success and maintain academic integrity.

2. Methodology

This study is a comparative analysis comparing documents that are proven to have been written by humans and AI. The human component is broken into two sections: Native English speakers and English as a second language (ESL). Within higher education, there is concern that students whose first language is not English will have a higher false positive rate when their work is submitted to the two detection tools. This concern is because individuals who have learned English as a second language tend to write more formally, using less slang, and contractions. Resulting in writing that is less casual and more formal.

Furthermore, ESL speaker's use of articles and literal translations differs from that of native English speakers (Leki & Carson, 2012). For example, an ESL speaker might say, "I went to hospital," while a native English speaker would say, "I went to a hospital" or "I went to the hospital." Additionally, someone who is an ESL might say "I am making a photo" while someone who is a native speaker would say "I am taking a photo." These are just a couple of examples of how someone who is a native English speaker will write differently than an ESL speaker. These differences in sentence structure and word choice could lead the AI detection tool to determine that an ESL speaker's work has been written by AI.

This study consists of 150 papers, 50 from each category. The papers associated with a human were selected based on their publication date to ensure they could not have been influenced by AI. All human-written papers were published or written before November 2022, when ChatGPT was first released to the public. This does not count for Apple's Siri, Google Now, and Microsoft Cortana, which were introduced on smartphones between 2011 and 2014. It further does not account for early forms of AI that were not available to the general public but could have been available to researchers. Although there is the possibility that these tools may have influenced writing, at the time they were introduced, they could not write full papers but rather provide a response to a specific question.

Portions of each paper were submitted to the two tools, and the results were recorded and analyzed. ZeroGPT returns a response of how much of the writing was likely written by AI while GPTZero broke the results into three categories—AI written, mixed and human. For this study, only the percentage of AI was considered to ensure the two tools could be compared equitably.

3. Results

The results were statistically analyzed using an unpaired two-tailed T-test and a standard deviation assessment. Furthermore, a comparative analysis was completed using whether or not something was 100% AI-written or 100% human-written. Although the goal would be for the tool to 100% of the time identify the source of a writing sample correctly, it must be noted that this is a game of probability, and therefore, other values must be considered. For example, is there a return rate that is not 100% that demonstrates an extremely high probability of being written by AI or not? One of the goals of this study is to identify what the lowest probability value asserts whether or not AI likely wrote something.

Table 1: Standard deviation-human, English as first language.

		ZeroGPT	GPT Zero
Standard	**s =**	**0.269034**	**0.0587367**
Variance	s^2 =	0.072379	0.00345
Count	n =	50	50
Mean	$\bar{x}$ =	0.1696	0.041
Sum of Squares	SS =	3.546592	0.16905

Table 2: Standard deviation-human, English as second language.

		ZeroGPT	GPTZero
Standard Deviation	**s =**	**0.10683288**	**0.19667688**
Variance	s^2 =	0.011413265	0.038681796
Count	n =	50	50
Mean	$\bar{x}$ =	0.031	0.0628
Sum of Squares	SS =	0.55925	1.895408

Table 3: Standard deviation-AI written.

		ZeroGPT	GPTZero
Standard Deviation	**s =**	**0.26140086**	**0.2037454**
Variance	s^2 =	0.06833041	0.0415122
Count	n =	50	50
Mean	$\bar{x}$ =	0.895542	0.9002
Sum of Squares	SS =	3.3481901	2.034098

The standard deviation between ZeroGPT and GPTZero demonstrates the significance of the results of this experiment. All the standard deviation rates are less than 1%, which means the results demonstrate that the tools assess the paper with a certain level of preciseness and equity across the spectrum of papers. However, it is important to note that preciseness and equity do not equate to accuracy but rather consistency. It can be said that these tools evaluate writing samples in a consistent manner.

When the data sets are processed through a two-tailed P-test with a pre-determined significance (alpha) level of .05, some of the results are statistically significant, while others are less significant. Tables 4-6 show the results of the two-tailed P-test conducted on the results of this experiment.

Table 4: Two-Tailed P-Test, English as a first language.

T-value	3.30
P-value	0.001300
df	98.00
Standard Error of Difference	0.04

By conventional criteria, the results for the English as a first language category are very statistically significant. The extremely low p-value suggests that the results are unlikely to have occurred by chance. When the results for the English as a second language and AI written categories p-values are evaluated against the pre-determined alpha value, they are considered not statistically significant.

Table 5: Two-Tailed P-Test, English as a second language.

T-value	1.00
P-value	0.32
df	98.00
Standard Error of Difference	0.032

Table 6: Standard deviation-AI written.

T-value	0.09940
P-value	0.92100
df	98.00000
Standard Error of Difference	0.047

When the results are evaluated from a structural perspective, it is clear that neither tool is 100% effective. GPTZero identified 21 papers that were written by a human whose first language was English as having been fully or partially written by AI. This results in a 42% misidentification rate. On the other hand, ZeroGPT demonstrated that AI had fully or partially written 49 papers resulting in a 98% misidentification rate. When a human wrote the papers, and English was their second language, the results showed that GPTZero identified four papers as having been partially or fully written by AI, which is a less than 8% misidentification rate. While ZeroGPT identified 42 papers as having been partially or fully written by AI, which equates to an 85% misidentification rate.

Regarding the AI-written papers, ZeroGPT flagged 18 papers as having been partially or entirely written by a human, and GPTZero flagged 14 papers. Since the AI-written papers were created by this author using ChatGPT, they are known to be 100% AI-written papers with no human intervention. This means that ZeroGPT had a 36% misidentification rate, while ZeroGPT had a 28% misidentification rate. Table 7 shows the misidentification rates side by side.

Table 7: Misidentification Rates

	Zero GTP	**GPTZero**
Human English First Language	98%	42%
Human English Second Language	85%	8%
AI Generated	36%	28%

Since the AI-written papers are confirmed to have been written by AI, it was expected that the tools would have identified 100% of the papers as having been written by AI, with no human intervention. However, it is feasible that the tools might have misidentified a small number as having had human influence. If the results were 1% or less, it could be determined as accurate and reliable. Since the results are both above 25%, this significantly reduces the reliability rate of these tools.

If the percentage of misidentification is similar across all three groups, with a degree of separation that is less than 5%, an educator could possibly use the tool to successfully determine the probability that AI wrote the submitted work. However, even in this case, the professor should not rely solely on the tools to determine whether plagiarism has occurred. It is better to err on the side of caution than to improperly accuse a student of cheating.

4. Future Work

This study shows that there is a need for more work on this subject. A future study is being designed that will incorporate a larger pool of papers that were all written by humans before 2000, which should further guarantee that no AI influence could be possible. There might be some difficulty in this next study when it comes to determining if English is a first or second language. Since the results of this study did not show a significant disadvantage to individuals where English is a second language, the next study may not split the categories apart. The hypothesis would be that English as a second language is not a factor in determining whether or not AI has been used in writing the paper. This would result in a more holistic approach to the study. Furthermore, it would be prudent to rerun this test every six months as the two tools continue to be refined.

5. Conclusion

This study shows that more work needs to be done so that educators can rely on the results of these tests when determining plagiarism. The fact that the AI detection tools failed to identify 100% of the AI-written papers as having been written by AI shows that the metrics used by the tools need to be adjusted. It is not unreasonable for the tools to misidentify some of the papers written by both categories of human submissions, but it should have been able to determine the AI papers were 100% AI-written. It is clear that educators cannot use these tools to effectively determine if a paper has or has not been written or is heavily influenced by AI tools like ChatGPT. Educators should continue using other sources to determine if a paper has a high probability of being written by AI or not.

Ethics Declaration

This paper used secondary data which did not require ethics clearance.

AI Declaration

This paper did not make use of AI to write content; Covidence was used as a tool to extract and organize data for thematic analysis.

References

Alzahrani, S. M., Salim, N. & Abraham, A., 2012. Understanding Plagiarism Linguistic Patterns, Textual Features, and Detection Methods. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 42(2).

Khalil, M & Er, E. 2023. Will ChatGPT get you caught? Rethinking of Plagiarism Detection. Copenhagen, HCI International 2023.

Dien, J., 2023. Editorial: Generative artificial intelligence as a plagiarism problem. Biological Psychology, Volume 181.

Francke, E. & Alexander, B., 2019. The Potential Influence of Artificial Intelligence on Plagiarism: A Higher Education Perspective. Oxford, Academic Conferences, and Publishing-International.

Hutson, J., 2024. Rethinking Plagiarism in the Era of Generative AI. Digital Commons @Lindenwood University.

King, M. R., 2023. A Conversation on Artificial Intelligence, Chatbots, and Plagiarism in Higher Education. Volume 16, pp. 1-2.

Kleebayoon, A. & Wiwanitkit, V., 2023. Artificial Intelligence, Chatbots, Plagiarism and Basic Honesty: Comment. Cellular and Molecular Bioengineering, Volume 16, pp. 173-174.

Leki, I. & Carson, J., 2012. “Completely Different Worlds”: EAP and the Writing Experiences of ESL Students in University Courses. Tesol Quarterly.

Mahajan, A., Anshika, Sharma, A., Sharma, N., Kaur, A., 2023. Challenges to Plagiarism Detection and the Usof Voice Assistants in Everday Life and Education. s.l., Congress on Smart Computer Technologies: Proceedings of CSCT.

Play, Learn, Empower: A Design Model of Student Engagement in Environmental Education

Julia DeVoy, Qingwan Cheng, Natalie Pedley, Carter Frato-Sweeney, Sophia Ferrone, Mary O'Brien, Mia Cresti
Boston College, Chestnut Hill, United States

whitcavi@bc.edu
cecelia@aftermathlearninglab.com
pedleyn@bc.edu
fratoswe@bc.edu
ferronso@bc.edu
obriemar@bc.edu
cresti@bc.edu

Abstract: Amid the largely underrecognized and escalating textile waste crisis, this study explores student engagement in active, experiential learning for sustainability and personal responsibility. We developed *Aftermath*, an educational board game co-designed with students to raise awareness via accessible, design- and play-based learning. In Phase One, eight students contributed to 14 participatory design workshops guided by the Stanford Design Thinking framework (*Empathy, Define, Ideate, Prototype, Test*). Iterative cycles began with empathy, focusing on everyday players navigating sustainability challenges and communities experiencing environmental injustice. In the define phase, we identified the core problem, its consequences, and the target audience. During ideation, participants reviewed existing board games and generated novel concepts for theme, mechanics, and content. Prototypes were refined through sketching, digital tools, and multiple rounds of testing to enhance clarity, inclusivity, and engagement. The process culminated in a renewed focus on empathy and defining, establishing the game's name, *Aftermath*, and articulating its educational, pro-environmental aims. Each workshop concluded with qualitative group reflections, in which participants shared insights gained, changes in perspective, and recommendations for the ongoing development of the game's design and pedagogical value. As the game design evolved from competitive to cooperative, so did the participants: shifting from passive learners to active co-creators throughout cycles of play, learning, and empowerment. Data from group discussions and reflective narratives demonstrated that collaborative design fostered critical reflection on individual roles within larger systems, increasing awareness and encouraging more mindful consumption practices in daily life. Phase Two later expanded participation, engaging 13 high school students in an exploration of textile waste, gameplay, and the design process. Working in teams, students created their original board games addressing the issue of textile waste, reinforcing knowledge through creative, hands-on learning. The educational game design process became a catalyst for behavioural change and environmental responsibility. This work indicates that design thinking in education not only solves problems but also fosters imagination, agency, and collective action. Through play, participants gained not only sustainability knowledge, but the ability to rethink and reshape their communities for a more sustainable future.

Keywords: Design Thinking, Play-Based Learning, Environmental Education, Gamification, Textile Waste, Pro-environmental Behaviour

1. Introduction

Despite its scale, textile waste remains insufficiently understood by the public. Many do not grasp the environmental or health impacts of textile waste or correct disposal practices (Paul et al., 2023). As a global crisis, textile waste contributes to nearly 10% of carbon emissions - a figure projected to rise by 50% by 2030 (Igini, 2023). This disconnect between the scope of the problem and public awareness presents an opportunity: How might communities be actively engaged in learning to recognize and help address textile waste?

Our work addresses student engagement via design futuring (Cooper, 2022), using design as a medium for problem-solving and rethinking relationships with waste, systems, and future possibilities. Rooted in participatory play - a vital aspect of human development - we employ game design as a pedagogical strategy to make environmental issues tangible and relatable (Dancis et al., 2023). In this framework, participants are not only learners but also co-creators of knowledge and futures.

Employing design thinking workshops, we encourage exploration of new perspectives and empower participants as active change agents. Through shared play, participants cultivate imagination, reflection, and collective responsibility - essential components for more just, inclusive, and sustainable futures.

2. Literature Review and Contextual Background

2.1 Textile Waste

The global textile waste crisis is a significant yet overlooked environmental issue. In the United States, post-consumer textile waste has increased tenfold since 1960, surpassing 34 billion pounds by 2018 (U.S. EPA, 2017). This injustice reflects structural inequities: communities with higher income and education produce disproportionate textile waste, yet the resulting health burdens fall on more vulnerable populations. Most remain unaware of fast fashion's consequences and improper textile disposal, which, alongside air and noise pollution, disproportionately affect poor regions (Tonne et al., 2018).

2.2 Participatory Design

Participatory design embodies equal power dynamics, context-based behaviours, bidirectional learning, and democratic practices (Luck, 2018). Literature affirms its role across contexts and adaptability for contributors as design partners or advisors (Literat et al, 2020). Participatory design empowers participants as stakeholders, fostering critical reflection on environmental impacts of everyday choices (Bell & Davis, 2016; Kafai & Burke, 2015).

2.3 Games for Good

While the *Aftermath* sculpture was impactful, large infrastructure limits its reach (Aftermath Sculpture, n.d.). "Games for good" leverage the motivational structures of play to address societal challenges, raising awareness and improving critical thinking (Gugerell, 2023). Examples include Fakeopoly, adapted from Monopoly to teach fake news literacy (Literat et al., 2020).

2.4 Game-based Learning

Game-based learning harnesses interactive, relational instruction technologies (simulation, role-play, cases) to unite pedagogy with play (Hromek et al, 2009). When games connect process and outcome, motivation and retention improve (Jabbar et al., 2015). Existing environmental games often present sustainability *too* broadly or are disconnected from participants' lived experiences. Our project seeks to close this gap through participatory play linked to concrete pro-environmental action.

3. Methodology and Materials

3.1 Phase One: Consciousness-Oriented Participatory Design

Eight college students (N=8) served as co-designers across 14 workshops, engaging in "future-state consciousness development" (Atance & Meltzoff, 2005). This approach fosters deep engagement, enabling rich qualitative data collection to map initial consciousness shifts. We focused on reshaping mindsets toward regenerative, collective practices.

The Stanford Design Thinking framework (*Empathy, Define, Ideate, Prototype, Test*) structured the 14 sessions (Figure 1). The initial Empathy phase centered on understanding the experiences of everyday individuals navigating sustainability challenges, as well as the systemic injustices faced by communities disproportionately impacted by environmental degradation (Workshop 1). In the Define phase, participants collaboratively identified the core problem, examined its social and environmental consequences, and determined the target audience (Workshop 2-3). During Ideation (Workshop 4-7), participants analysed existing board games and generated original concepts for game themes, mechanics, and narrative content. These ideas were developed into prototypes using both analogue sketching and digital tools. Multiple rounds of user testing and refinement were conducted to improve clarity, inclusivity, and user engagement (Workshop 8-12). The final iteration returned to the Empathy and Define phases to ensure alignment with the project's values and intentions, resulting in the naming of the game - Aftermath - and a clearly articulated set of educational and pro-environmental objectives (Workshop 13-14).

No.	Stage & Details	No.	Stage & Details
1	**Empathy** - Empathize with environmental injustice and potential game users	8	**Prototype** - Draw our ideas on paper
2	**Define** - Define who, what, where of environmental injustice and board game	9	**Test & Ideate & Prototype** - Play the prototype, discuss positive and negative feedback, ideate solutions, prototype the next version
3	**Define** - Define the age range of target user	10	**Test & Ideate & Prototype** - Play the prototype, discuss the game them, ideate solutions, prototype the next version
4	**Ideate** - Learn from other board games and apply to ours	11	**Test & Ideate & Prototype** - Play the prototype, discuss the game mechanics, ideate solutions, prototype the next version
5	**Ideate** - Ideate our board game theme	12	**Test & Ideate & Prototype** - Play the prototype, discuss the game contents, ideate solutions, prototype the next version
6	**Ideate** - Ideate our board game mechanics	13	**Empathy & Define** - Discuss Inclusion and Accessibility of our game
7	**Ideate** - Ideate our board game contents	14	**Define & Ideate** - Generate Statement of Intent and our game name: Fast Fashion Fixer

Figure 1: Participatory Design Workshop Plan

Each one-hour workshop followed a structured format. Sessions began with a brief presentation introducing the Design Thinking phase under focus, followed by a short lecture on game design principles, emphasizing the characteristics of effective educational games. This was followed by hands-on Design Thinking activities such as crafting Point of View (POV) statements, generating How Might We questions, and visual ideation exercises. Each workshop concluded with a group reflection, during which participants discussed key insights, shifts in understanding, and offered recommendations for the ongoing development of the game's design and its educational impact (Figure 1) .

Three prototypes emerged during the design process:

- Version 1: Competitive, role-based gameplay (Consumers, Advocates, Landfill Manager) emphasizing extractive mindsets
- Version 2: Additional roles (Teachers, Lawyers, Fast Fashion Company Leaders, Policy Makers), systemic elements; increased inclusivity but retained competition
- Version 3: Fully cooperative model; shared destiny, mutual support, real-world solution networks

Themes from workshop reflections guided iterative redesign to ensure alignment with consciousness transformation and social action. Data arose from interactive activities, reflection, note-taking, ethnographic observation, and self-reported behavioural changes.

3.2 Phase Two: Consciousness Scaling and Impact Amplification

Phase Two engaged thirteen secondary-level students (N = 13) in a two-hour participatory design workshop. The session began with a pre-survey designed to assess participants' baseline knowledge, attitudes, familiarity, and ethical concerns related to textile waste. Following a structure similar to Phase One, students were introduced to the Design Thinking framework through a brief presentation, along with an overview of foundational principles in game development. Participants were then divided into three groups and guided through a rapid design sprint incorporating the five phases of Design Thinking (Empathize, Define, Ideate, Prototype, Test). Each group developed a playable game concept addressing textile waste and presented their prototypes to the larger cohort. The workshop concluded with a post-survey aimed at evaluating knowledge acquisition, shifts in mindset, and changes in ethical reasoning (Figure 2).

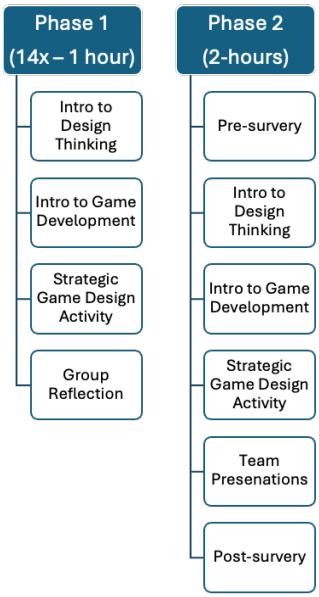


Figure 2: Phase One and Phase Two Workshop Structure

4. Results and Key Findings

4.1 From Awareness Gaps to Engagement

In Phase One, participants entered the workshop series with a limited understanding of textile waste and its environmental consequences. The game served as an informal and accessible entry point into this complex issue, introducing players to the broader global implications of individual consumption habits. The interactive and experiential nature of the game facilitated a smoother transition into the topic, creating space for genuine curiosity, engagement, and reflection. As participants became more comfortable exploring the subject, their initial curiosity evolved into deeper, more critical thinking.

Early reflections revealed low baseline awareness:

> *"I didn't know much about textile waste before starting on the project, but I definitely found the game to be an approachable way to learn about the topic.*" (Participant A, Phase One)

> "*I don't think I knew much about textile waste prior to becoming very involved in game design. It was wholly unfamiliar to me."* (Participant B, Phase One)

By the end of the workshop series, participants demonstrated a more interconnected and systems-level understanding:

> *"The game led us to think about how all the elements of this global issue are interconnected and contribute to the problem."* (Participant A, Phase One)

> *"Being involved in game designing pushed me to understand what textile waste is about, and furthermore it helped to think about how textile waste impacts daily life."* (Participant B, Phase One)

These qualitative insights point to a clear trajectory from unfamiliarity to meaningful engagement and critical reflection, facilitated through iterative, game-based learning.

Findings from Phase Two further corroborated the qualitative results from Phase One. Pre-survey data revealed that a majority of participants had limited prior awareness of the textile waste crisis. Specifically, 15.4% of respondents reported a "limited" understanding, 23.1% "basic," 38.5% "moderate," and 23.1% "good." No participant self-identified as having expert-level knowledge (Figure 3).

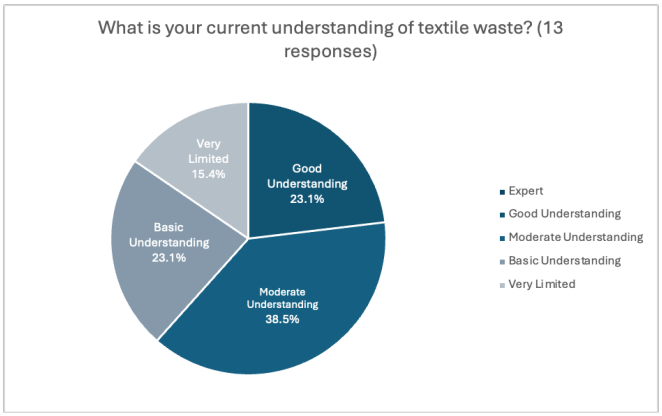


Figure 3: Pre-survey results on current understanding of textile waste

Post-survey results demonstrated significant improvements in comprehension:

- 75% of participants reported a “good” understanding.
- 25% reported a “moderate” understanding.
- No participants reported “limited” or “basic” levels of understanding.

This shift represents a twofold (200%) increase in those reporting "good" understanding, and complete elimination of the lowest two categories, indicating not only improved awareness but a clear movement toward higher levels of conceptual grasp (Figure 4).

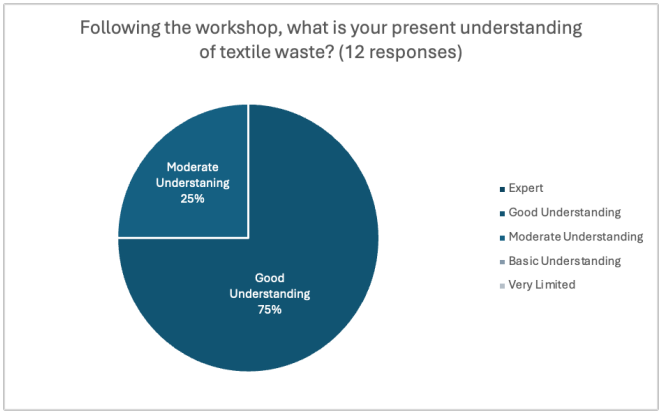


Figure 4: Post-survey results on present understanding of textile waste

In addition to increased understanding, participants reported heightened concern about textile waste. While pre-survey concern levels varied widely (ranging from 4 to 10 on a 10-point scale), post-survey responses skewed significantly higher, with no participant rating their concern below 5 and most selecting 8 or above (Figures 5 and 6). This suggests a measurable shift not just in awareness, but in emotional and ethical engagement with the issue.

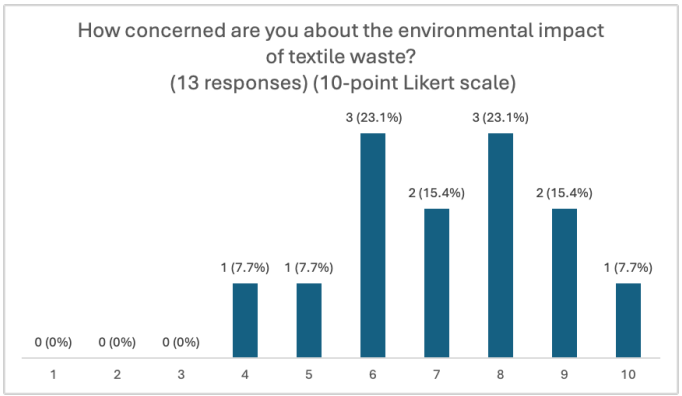


Figure 5: Pre-survey results on levels of concern regarding the environmental impact of textile waste

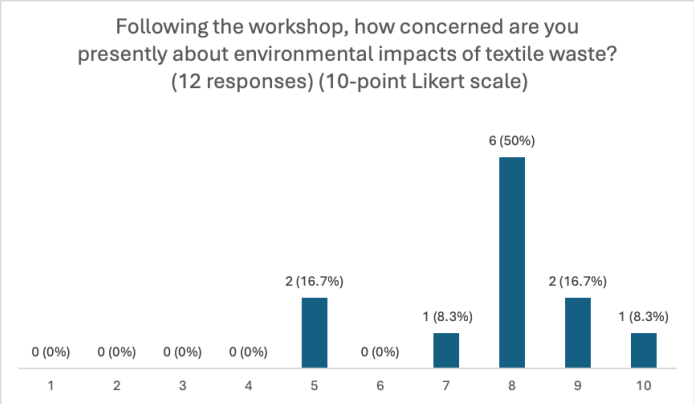


Figure 6: Post-survey results on levels of concern regarding the environmental impact of textile waste

Across both phases, participants consistently found the game's interactive and creative elements essential for engaging with the topic. The hands-on, collaborative design process deepened their involvement, transforming initial curiosity into sustained, meaningful engagement.

4.2 From Gameworld Choices to Real-World Habits

Participants noted connections between game scenarios and daily choices. Through play, personal consumption habits were reassessed shifts included interest in clothing swaps and mindful purchasing.

As Phase One participants noted:

> *"Textile waste gradually became part of my everyday thoughts."* (Participant C, Phase One)

> *"I think this was valuable practice for talking about it with others and helping them see how their habits can contribute to the problem and what changes could help."* (Participant D, Phase One)

In Phase Two, post-survey responses further emphasized the game's potential to spark both personal and collective action. Participants expressed a growing awareness of the systemic nature of textile waste and a desire to address it through advocacy and social innovation. Suggestions included:

> *"Campaigns that collaborate with fast fashion companies, so that they can work around their marketing style to also incorporate textile waste awareness."* (Participant A, Phase Two)

> *"Have social media movements and businesses which reuse clothes to manufacture pieces of clothing"* (Participant B, Phase Two)

Through the elements of play and collaboration, participants can see the in-game cards are a number of everyday choices that actually connect to each other. Before playing the game, what seemed like separate decisions - buying clothes, throwing things away, choosing where to shop - were later seen as part of a larger web of impact.

4.3 When Designers Become Learners

The design process *itself* proved highly educational. Participants, initially unfamiliar with the textile crisis, deepened understanding while determining how to communicate issues through the game. As game creators, they also became educators, spreading awareness among peers.

In Phase One, one participant reflected that

> *"After working on the game design, I felt like I had a better understanding of the different layers of the problem... we spent time thinking about how to talk about this issue and present it to young students."* (Participant F, Phase One)

In Phase Two, participants had not only internalized the issue but also began envisioning broader educational interventions. In post-survey responses, students suggested organizing "courses and student workshops" to further raise awareness. Others proposed creating a documentary, a museum exhibit, or an online course to "teach people about the issue" and "provoke more emotion from the audience."

Rather than being instructed on what to learn, participants - who also served as game designers - shaped the learning experience from the inside out, making meaning through iteration and collaboration.

4.4 The Power of Small Actions ("Mattering")

Students came to recognize that individual, everyday actions collectively drive broader environmental change and that small, intentional actions - such as reducing, reusing, and only then recycling - lead to measurable sustainability gains while reinforcing individuals' sense of mattering and community leadership (O'Halloran, 2024). Adopting cumulative, sustainable, micro-actions can foster significant, lasting behavioral change at scale (Eilam, 2025). Reflection data echoed this insight that small, repeated actions are pivotal for challenging textile waste fast fashion at the grassroots level and leading to feelings of individual and collective positive impact and mattering (Flett, 2021).

"It was valuable practice for helping others see how their habits contribute to the problem, and what changes could help." (Participant E, Phase One)

"Spread the word on how much it is actually affecting the world and what the world could be if we cut down massively" (Participant C, Phase Two)

Mattering emerged through curiosity - spotting patterns, building habits, and recognizing influence. As participants saw their actions as meaningful, they shared ideas and inspired others, creating a cycle where belief in impact led to real change.

5. Implications

Aftermath operationalizes the idea that incremental choices - reinforced via gameplay - drive meaningful outcomes. The game's structure parallels child development theories (Vygotsky, Bronfenbrenner): cycles of play, learning, and empowerment facilitate both knowledge and systems-level transformation.

Participants gained an awareness by taking notice of how the small, repeated actions could lead to wider change. This reflects findings from Hvass (2015), who showed that second-hand business models both reduce textile waste and help shift consumer culture toward more mindful, sustainable habits. In these models, smaller actions and everyday habits like swapping clothes add up to challenge the fast fashion mindset starting at the grassroots level.

Aftermath builds on this idea by showing players how minor in-game decisions, made repeatedly over time, can have meaningful outcomes. The game helps people see that their actions matter, not just in theory, but in practice. We accomplish this by putting into practice current, real-world issues into its deck of cards. As the player progresses through the game, they are able to build agency and a sustainable mindset shift. A mindset that fosters long-term routine practices that are achievable versus an unreachable ideal of immediate change. Consequently, Aftermath helps reframe individual impact from an insufficient lens to one that is viewed as integral to systems-level change, echoing Hvass's conclusion that meaningful transformation often begins at the micro level.

After identifying recurring patterns in participant reflections, we developed the Aftermath Cycle (Figure 7): a model that maps out the game's prosocial and educational impact. The Aftermath Cycle shows how participants manoeuvre through a repeating loop of play, learn, and empower, with each round strengthening their awareness and expanding their range of impact. This cycle can be profoundly understood when applying the lenses of crucial child development theories such as, Vygotsky's Zone of Proximal Development (ZPD) and Bronfenbrenner's Ecological Systems Theory.

Vygotsky's ZPD suggests that learners grow most when they are supported in taking on challenges just beyond what they could manage alone. Specifically, when the support is accomplished through social interaction and guided experiences (1978). In Aftermath, each card drawn invites players into conversations and choices about sustainability that might be new or unfamiliar. Through reflection and collaborative problem-solving, players get the social support they need to begin to become literate of relevant concepts like closed-loop supply chains, the social cost of cheap labour, and collective action vs. individual responsibility.

Bronfenbrenner's ecological theory enhances this by emphasizing that learning is always shaped by context (1979). Aftermath places participants inside intersecting systems: their immediate social group (microsystem), the community setting where the game is played (mesosystem), and broader societal patterns around

overconsumption and sustainability (macrosystem). As participants learn and impart their knowledge on others, they start to play a part not only in their own choices, but also the practices of the systems they are associated with.

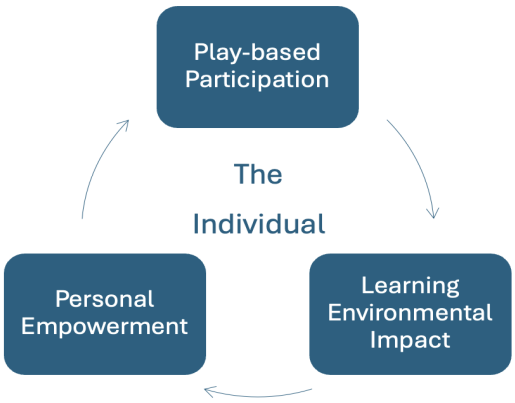


Figure 7: The *Aftermath* Cycle: A continuous loop of play, learn, and empower

6. Discussion

The evolution of *Aftermath* from a competitive to cooperative game mirrors a fundamental shift in how participants conceptualized environmental challenges - moving from individual competition to collective responsibility where learners become co-investigators of reality rather than passive recipients of knowledge. Our findings demonstrate that when students engage as co-designers rather than mere consumers of educational content, they develop deeper ownership of both the learning process and the environmental issues at hand.

The design thinking framework proved particularly effective in scaffolding this transformation. The iterative cycles of empathy, definition, ideation, prototyping, and testing created multiple opportunities for reflection and refinement of understanding. Notably, the empathy phase - often overlooked in traditional environmental education - emerged as crucial for connecting abstract global issues to lived experiences and local communities.

6.1 The Pedagogical Power of Play

Our results validate the theoretical foundations of play-based learning while extending them into environmental education. The dramatic improvement in textile waste understanding - from 23% “good” understanding to 75% achieving the level of knowledge - suggests that game-based approaches can effectively bridge complex environmental concepts with accessible learning experiences.

However, our findings reveal something more profound than knowledge transfer. The shift from "Gameworld choices to Real-world habits" indicates that play can serve as a rehearsal space for environmental citizenship. When participants made decisions within the game's safe space, they developed decision-making frameworks that extended beyond gameplay. This suggests that environmental games function not merely as information delivery systems but as laboratories for practicing sustainable behaviours and exploring their consequences without real-world risks.

6.2 Consciousness Development and Systems Thinking

The "consciousness-oriented participatory design" approach yielded insights into how environmental awareness develops. Participants progressed from viewing textile waste as an individual problem requiring individual solutions to understanding it as a systemic issue requiring collective action - and the ability to understand interconnections between personal actions and larger systems.

The concept of "*mattering*" that emerged from participant reflections is particularly significant. Students' recognition that small actions contribute to broader change addresses a critical challenge in environmental education: overcoming feelings of powerlessness in the face of global crises. By experiencing how individual choices aggregate into collective impact through gameplay, participants developed the belief that groups can create pro-environmental actions required to produce positive change.

6.3 Design Thinking as Environmental Pedagogy

Our study extends the application of design thinking beyond product and service development into environmental education. The framework's emphasis on human-centered problem-solving proved particularly valuable for addressing the disconnect between global environmental issues and personal relevance. The iterative nature of design thinking allowed participants to continuously refine their understanding of both the problem (textile waste) and potential solutions (behavioural change strategies).

The emergence of three distinct prototypes reflects participants' evolving understanding of environmental challenges. The progression from competitive to cooperative models parallels broader shifts in environmental discourse from market-based competition to collaborative sustainability. This evolution was not predetermined but emerged organically from participants' deepening engagement with the issues, suggesting that design thinking processes can reveal insights that traditional instructional approaches might miss.

6.4 Scalability and Systemic Impact

Phase Two's expansion to high school students demonstrated the approach’s scalability and highlighted key implementation considerations. The maintained effectiveness across different age groups suggests that the fundamental principles - participatory design, play-based learning, and consciousness development - transcend specific demographic boundaries. However, the need for sustained engagement and iterative refinement indicates that this approach requires more intensive facilitation than traditional educational interventions.

The finding that participants became ‘educators’ themselves - spreading awareness among peers - suggests a multiplier effect, extending impact beyond direct participants. This peer-to-peer transmission of environmental consciousness represents a form of learning that could foster broader cultural shifts toward sustainability.

6.5 Limitations and Future Directions

While our findings are promising, several limitations warrant consideration. The relatively small sample sizes (N=8 in Phase One, N=13 in Phase Two) limit generalizability, though the depth of qualitative engagement provides rich insights into the mechanisms of change. Future studies should explore larger-scale implementations while maintaining the intensive engagement essential to the approach's effectiveness.

The study's focus on textile waste, while addressing an important but underrecognized issue, raises questions about transferability to other environmental topic challenges. Research examining applications to climate change, biodiversity loss, or pollution could illuminate the broader applicability of this approach.

Additionally, the study period was insufficient to assess long-term behavioural persistence. Longitudinal follow-up studies tracking participants' sustained engagement with environmental issues would provide crucial insights into the durability of consciousness shifts achieved through this method.

6.6 Implications for Environmental Education

This research has significant implications for environmental education practice and policy. Our findings suggest that participatory, play-based approaches that position learners as co-creators of knowledge and solutions may be more effective for developing environmental consciousness and agency.

Educational institutions seeking to enhance environmental programming should consider incorporating design thinking frameworks and game-based learning. However, implementation requires significant shifts in pedagogical approach - from instructor-centered to learner-centered, from knowledge transmission to knowledge co-creation, and from individual learning to collective engagement.

Policymakers supporting environmental education should recognize that effective programs require sustained engagement, iterative refinement, and facilitation resources. The participatory nature of this approach also suggests the importance of community partnerships and local relevance in environmental programming.

7. Conclusion

The *Aftermath* project demonstrates that environmental education can be transformed through participatory design thinking and play-based learning. By positioning students as co-designers rather than passive recipients of environmental information, this approach fostered deep engagement, systems thinking, and sustained

behavioural change. The evolution from competitive to cooperative gameplay reflected participants' growing understanding of environmental challenges as collective rather than individual problems.

The dramatic improvements in environmental knowledge, coupled with reported behavioural changes and peer education activities, suggest that this approach addresses critical gaps in traditional environmental education. Emphasizing "mattering" - the recognition that individual actions contribute meaningfully to larger systems - can help counter the paralysis that often accompanies awareness of global environmental crises.

Perhaps most significantly, this work demonstrates that design thinking in environmental education serves not merely as a problem-solving tool but as a *consciousness-development process*. Through cycles of empathy, definition, ideation, prototyping, and testing, participants developed not only deeper environmental knowledge but also enhanced agency, imagination, and commitment to collective action.

As we face escalating environmental challenges, educational approaches that develop both knowledge and agency become increasingly critical. The *Aftermath* project suggests that when learners become co-creators of environmental solutions, they develop the consciousness, skills, and motivation necessary for sustained environmental engagement. Through play, participants gained not only sustainability knowledge but the ability to rethink and reshape their communities for a more sustainable future.

This research contributes to growing evidence that environmental education must evolve beyond information transmission toward approaches that develop environmental consciousness, systems thinking, and collective efficacy. The integration of design thinking, participatory learning, and play-based engagement offers a promising framework for this evolution, one that honours both the complexity of environmental challenges and the creative capacity of learners to address them.

Ethics Declaration

This manuscript presents original research with accurate reporting and sufficient methodological detail for replication. All sources are properly cited, permissions obtained. All authors jointly responsible for the work.

AI Declaration

ChatGPT assisted with rewording and rephrasing sections. All content was subsequently reviewed and edited by the authors, who accept full responsibility for the final version.

Acknowledgements

We are grateful to both Boston College and the Design for Impact SDF Gift. The authors also thank the participants for their support to this research.

References

Aftermath sculpture. Aftermath Learning Lab. (n.d.). https://aftermathlearninglab.com/sculpture

Atance, C. M., & Meltzoff, A. N. (2005). My future self: Young children's ability to anticipate and explain future states. *Cognitive Development*, *20*(3), 341-361

Bell, A., & Davis, K. (2016). Learning through participatory design. *Proceedings of The 15th International Conference on Interaction Design and Children*, 218–229. https://doi.org/10.1145/2930674.2930705

Bronfenbrenner, U. (1979). The ecology of human development: Experiments by nature and design. Harvard university press.

Cooper, C. M. (2022). Design timescapes: futuring through visual thinking. *Visual Communication,* 23(1), 172-188. https://doi.org/10.1177/14703572211065116

Dancis, J.S., Coleman, B.R. and Ellison, E.R. (2023) 'Participatory Action Research as Pedagogy: Stay Messy', Journal of Participatory Research Methods, 4(2). Available at: https://doi.org/10.35844/001c.75174

Eilam, E. (2025). Considering the role of behaviors in sustainability and climate change education. *Frontiers in Psychology, 15,* Article 1394326. https://doi.org/10.3389/fpsyg.2024.1394326

Flett, G. L. (2021). An Introduction, Review, and Conceptual Analysis of Mattering as an Essential Construct and an Essential Way of Life. *Journal of Psychoeducational Assessment*, *40*(1), 3-36. https://doi.org/10.1177/07342829211057640

Gugerell, K. (2023). Serious games for sustainability transformations: Participatory research methods for sustainability - toolkit #7. *GAIA - Ecological Perspectives for Science and Society*, *32*(3), 292+. http://dx.doi.org/10.14512/gaia.32.3.5=

Hromek, R., & Roffey, S. (2009). Promoting Social and Emotional Learning with Games: It's Fun and We Learn Things. *Simulation & Gaming,* 40(5), 626–644. https://doi.org/10.1177/1046878109333793

Hvass, K. K. (2015). Business Model Innovation through Second Hand Retailing: A Fashion Industry Case. The Journal of Corporate Citizenship, 57, 11–32. http://www.jstor.org/stable/jcorpciti.57.11

Igini, M. (2023, August 21). 10 concerning fast fashion waste statistics. Earth.Org. https://earth.org/statistics-about-fast-fashion-waste/

Jabbar, A. I. A., & Felicia, P. (2015). Gameplay Engagement and Learning in Game-Based Learning: A Systematic Review. *Review of Educational Research*, *85*(4), 740–779. http://www.jstor.org/stable/24753028

Literat, I., Chang, Y. K., & Hsu, S.-Y. (2020). Gamifying fake news: Engaging youth in the participatory design of news literacy games. *Convergence*, *26*(3), 503-516. https://doi.org/10.1177/1354856520925732 (Original work published 2020)

Luck, R. (2018). What is it that makes participation in design participatory design? *Design Studies*, *59*, 1–8. https://doi.org/10.1016/j.destud.2018.10.002

O'Halloran, C. (2024). Small actions to promote conservation and sustainability. *Conservation Science and Practice*, 6(12), e13272

Paul, S., Pegu, R., Das, S., Kim, K.-H. and Bhattacharya, S.S. (2023). Eco-geological consequences of textile processing wastes: Risk assessment, elemental dissolution kinetics, and health hazard potential. *Environmental Research*, 216, p.114693. doi:https://doi.org/10.1016/j.envres.2022.114693.

Tonne, C., Mil`a, C., Fecht, D., Alvarez, M., Gulliver, J., Smith, J., Beevers, S., Ross Anderson, H., Kelly, F., (2018). Socioeconomic and ethnic inequalities in exposure to air and noise pollution in London. *Environment International* 115, 170–179. https://doi.org/10.1016/j.envint.2018.03.023.

U.S. EPA, 2017. Textiles: Material-Specific Data [WWW Document]. URL https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/textiles-material- specific-data.

Vygotsky, L. S. (1978). Mind in Society: Development of Higher Psychological Processes (M. Cole, V. Jolm-Steiner, S. Scribner, & E. Souberman, Eds.). Harvard University Press. https://doi.org/10.2307/j.ctvjf9vz4

Modeling the Role of Graphical and Textual Complexity in Geometry Problem-Solving Using SEM

Farshid Farzan[1],Canwen Wang[2], Rachel L Ankney[3] and Paulo Carvalho[4]

[1]Cognitive Group, Psychology Department, University of Memphis, USA

[2]Human Computer Interaction Institute, Carnegie Mellon University, USA

[3]Psychology Department, University of Memphis, USA

[4]Human Computer Interaction Institute, Carnegie Mellon University, USA

ffarzan@memphis.edu
canwenw@andrew.cmu.edu
rlankney@memphis.edu
pcarvalh@cs.cmu.edu

Abstract: Learning geometry is vital for K–12 students, fostering spatial reasoning and problem-solving skills crucial in STEM fields. However, its abstract nature, reliance on visualization, deductive reasoning, and specific vocabulary make it challenging. Cognitive Load Theory explains how excessive graphical and textual complexity can overwhelm working memory, impeding learning. The revised Cognitive Load Theory framework highlights the importance of directing cognitive effort toward meaningful schema construction (germane processing) rather than being hindered by extraneous load. This study uses Structural Equation Modeling (SEM) to examine how structural complexity (graphical and textual complexity) affects student performance in geometry learning, modeled as a latent variable measured by accuracy, latency, and first correct attempt. Forty geometry questions exam answered by 59 students from the 1996–97 Cognitive Tutor dataset (DataShop) were analyzed to examine how graphical and textual complexity influenced student performance. Each question systematically varied in complexity, and student performance was measured using accuracy rate, latency, and first correct attempt, well-established metrics in educational research. Student Performance is conceptualized as a latent variable measured by Accuracy Rate, Latency, and First Correct Attempt. Graphical Complexity and Textual Complexity serve as observed variables. Employing a two-phase SEM approach, the study evaluates both measurement and structural models. The findings reveal that Graphical Complexity and Textual Complexity significantly and negatively influence student performance overall, with unstandardized regression coefficients of -.132 and -.142, respectively, and explain 40.9% of the variance in SP. However, contrary to the initial understanding that it seems the higher complexity may lead to initial wrong answers, higher levels of Graphical Complexity and Textual Complexity were associated with increased First Correct Attempt, suggesting that complexity may promote deeper cognitive engagement in some contexts aligned with Cognitive Load Theory, highlighting both the detrimental effects of complexity on efficiency and the potential benefits for accuracy in problem-solving.

Keywords: Geometry Problem-Solving, Structural Complexity, Student Performance, Cognitive Load Theory, Structural Equation Modeling

1. Introduction

Learning geometry is useful for K-12 students, as it develops critical spatial reasoning, problem-solving, and foundational mathematical skills that apply across disciplines and real-world contexts (Mix & Battista, 2018) and enhance their spatial visualization and logical thinking, key components in STEM fields (Sinclair & Bruce, 2014). Learning geometry presents unique challenges for K-12 students, largely due to its abstract nature and the need for strong spatial reasoning skills (Dhlamini et al, 2019). Many students struggle with visualizing and mentally manipulating shapes in two- and three-dimensional spaces, which is essential for understanding concepts like symmetry, transformations, and spatial relationships (Clements & Battista, 1992). Additionally, geometry often requires a level of deductive reasoning and logical proof construction that can be challenging for younger learners, as these skills are not as heavily emphasized in other areas of math (Hiele, 1986). Language also plays a role (Darke, 1982); geometry introduces specific terms and definitions that may confuse students, especially if they lack prior exposure to geometric vocabulary. Moreover, the interplay of graphical and textual complexity (TC) in problem-solving environments adds further cognitive load (Lin & Lin, 2014), potentially impairing student performance (SP). Cognitive Load Theory (CLT) (Sweller, 1988) provides a theoretical framework for this study, positing that excessive visual or textual demands can overwhelm working memory and hinder learning outcomes.

CLT (Sweller, 1988) emphasizes that excessive visual or textual demands can overwhelm working memory and hinder learning. Initially, CLT categorized cognitive load into intrinsic, extraneous, and germane load, with the latter referring to cognitive effort for schema formation (Sweller, 1988). However, the 2019 revision (Sweller et

al, 2019) removed germane load as a distinct category, redefining it as germane processing, a qualitative aspect of learning rather than a separate cognitive load component. Empirical studies (Husni et al, 2022) suggest that learning efficiency depends on learners' engagement in meaningful schema construction. In geometry problem-solving, complexity arises from various components (Bobis et al, 1993), which can either impose extraneous load or contribute to germane processing depending on how students interact with the problem. High graphical complexity (GC) may increase cognitive burden but can also enhance engagement by encouraging integration of visual and conceptual understanding (Bobis et al, 1993; Lin & Lin, 2014). Similarly, textual complexity, which involves the structure, length, and syntactic complexity of problem statements, can be assumed informational elements (Lin & Lin, 2014), may require additional working memory resources, but can also encourage students to engage in more deliberate cognitive processing (Seufert, 2018). According to the revised CLT framework, learning occurs most effectively when cognitive resources are directed toward germane processing rather than being overwhelmed by excessive extraneous load (Sweller et al, 2019). This perspective underscores the importance of understanding how problem complexity influences cognitive engagement, particularly in geometry (Clements & Battista, 1992; Dhlamini et al, 2019), where effective problem-solving relies on the interplay between visual representation, conceptual reasoning, and textual interpretation.

This study models SP as a latent construct measured by Accuracy Rate (AR), Latency (LT), and First Correct Attempt (FCA), with GC and TC as key predictors. Following CLT, structural Equation modeling (SEM) analysis evaluates how problem complexity is associated with SP.

2. Method

2.1 Participants and Test Items

The study utilized 40 geometry questions derived from the Geometry Area (1996-97) dataset, accessed via DataShop (Koedinger et al, 2010). This database is widely utilized in educational research and is recognized for its robust design within the Cognitive Tutor framework, ensuring the quality and relevance of the questions for analyzing SP in geometry. The data for this study were collected from the area unit of a Geometry course conducted during the 1996–1997 school year. Specifically, the dataset was derived from activities completed on February 1, 1996, using the Cognitive Tutor 1996 system, which was designed to support student learning in mathematics. The subset used in this study includes interaction data from 59 students, encompassing a total of 3591 problem-solving steps recorded during their engagement with the geometry problems. This dataset focuses on the area subject within Geometry and captures SP metrics from that period. Unfortunately, additional contextual information, such as the names of participating schools or specific student demographics, is not available in the dataset. The absence of such data limits the ability to generalize findings to specific educational settings but does not impact the core analysis of SP and its relationship to problem complexity. These questions, designed within the framework of the Cognitive Tutor system, are commonly used in educational research to measure SP in geometry (Stamper & Koedinger, 2011). Each question varies systematically in GC and TC, allowing for an analysis of their associations with three key SP metrics: AR (proportion of incorrect responses), LT (time to complete each question), and FCA (success on the first attempt). These metrics are well-established in educational research as indicators of SP, particularly in studies examining cognitive and problem-solving processes in mathematics (Clements & Battista, 1992; Jones & Tzekaki, 2016).

In this study, TC refers to the complexity of the textual content in geometry problems, evaluated using a range between 1 to 3 based on question text length (Table 1).

Table 1: Rubric for geometry problem TC

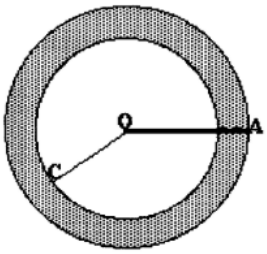
Level (Value)	Criteria
Low (1)	Question with fewer than 30 words
Medium (2)	Question with 30 to 60 words
High (3)	Question with more than 60 words

GC represents the complexity of visual elements, also evaluated using a range between 1 to 3 based on the number and arrangement of shapes, required spatial reasoning, and graphical detail (Table 2).

Table 2: Rubric for geometry problem GC

Level (Value)	Criteria
Low	One plane shape
Medium	Plane shape with one additional component
High	Plane shape with more than one additional component

These categorizations were designed to align with CLT (Sweller, 1988), which suggests that increases in TC or GC impose greater cognitive demands on learners. A sample of these questions has been shown in Figure 1. The rubric criteria for GC and TC were developed through a combination of theory-driven reasoning and practical analysis of item features, consistent with CLT's focus on surface- and structure-level complexity (Sweller, 1988; Sweller et al, 2019). For TC, word count was used as a proxy for syntactic and semantic load, which aligns with approaches in prior educational psychology and text complexity research (Lin & Lin, 2014). GC levels were informed by visual inspection of problem diagrams, focusing on the number and configuration of visual components and the spatial reasoning required elements previously shown to affect cognitive demand in geometry problem-solving tasks (Bobis et al, 1993; Dhlamini et al, 2019). While simplified, these rubrics offer a structured and replicable way to classify complexity across a standardized item set and serve as a basis for exploratory modeling.



Problem Statement

In the figure, the shaded area is 60.75π square inches. If OC = 4.5 inches, find OA.

$\pi = 3.1416$.

Figure 1: Sample problem with TC = 1 and GC = 2

This study examines SP as a latent variable measured by three key indicators: AR, representing the proportion of correct responses (1 – Error Rate); LT, the time taken to complete problems; and FCA, the number of correct answers on the first attempt. GC and TC are the observed variables representing problem complexity, defined by visual elements (e.g., shape arrangement) and textual characteristics (e.g., sentence structure and length). The conceptual framework integrates measurement and structural models, hypothesizing that SP is associated with GC and TC, with a correlation between the two complexities to account for shared variance. In the structural equation model (SEM), GC and TC serve as exogenous predictors, while AR, LT, and FCA function as endogenous effect indicators of SP. These indicators capture distinct yet interrelated dimensions of SP: accuracy (AR), efficiency (LT), and mastery (FCA), ensuring the construct's validity. SP is standardized through Unit Loading Identification (ULI), fixing one path variance to unity for consistent interpretation of relationships. Residual variance accounts for unexplained variability, preventing measurement error and external influences from inflating relationships. For latent variables like SP, it captures unmeasured influences, while for observed variables like GC and TC, it accounts for noise, enhancing model validity and reflecting real-world complexity.

No control variables were included, as GC and TC are assumed to capture the primary cognitive demands affecting SP. Furthermore, the dataset does not include comprehensive information on participant demographics or prior knowledge, making it challenging to incorporate such variables reliably without introducing additional assumptions. While the absence of control variables may limit the ability to explore moderating influences, this choice ensures a clear and unbiased evaluation of the hypothesized relationships.

2.2 Two-Phase SEM Approach

To evaluate relationships in this study, the SEM model was analysed in two phases: the measurement phase, defining SP, and the structural phase, assessing the direct predictive effects of complexity factors (Brown, 2015).

In the measurement phase, SP is defined as a latent variable measured by its three indicators (AR, LT, and FCA). The observed variables GC and TC are included in the model with a bidirectional arrow between them, representing their correlation. In this phase, no causal or predictive relationships are assumed; instead, the focus is on confirming the validity and reliability of SP as a latent construct and assessing the covariation between GC and TC (Figure 1). In the structural phase, an improved model introduced to treat GC and TC as predictors, directly modeling their relationships with SP. This allows the model to test the direct effects of GC and TC on SP and assess how each complexity factor independently impacts SP.

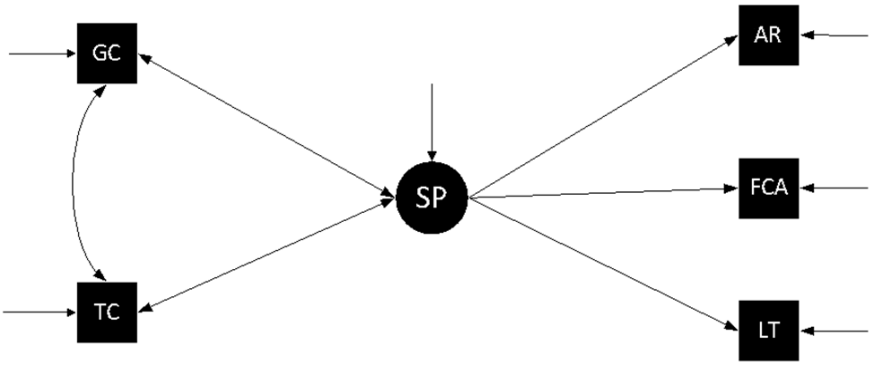


Figure 2: Measurement Phase Model Result

The dataset met all SEM assumptions with no violations in normality, linearity, or multicollinearity. Skewness, kurtosis, and VIF values were within acceptable limits, and no missing data or outliers were found, ensuring suitability for analysis. The measurement model, estimated using Maximum Likelihood (ML) in Mplus Version 8, converged successfully without issues, meeting the convergence criterion (.00005). The information matrix was positive definite, with no warnings regarding parameter identification, non-positive-definite covariance matrices, or linear dependencies among parameters. Furthermore, no offending estimates, such as negative error variances or Heywood cases, were identified.

3. Result

Descriptive statistics for the measured variables provide an overview of their distribution and characteristics. GC *(M = 2.20, SD =.71)*, and TC *(M = 1.93, SD = .85).* The indicators of the latent variable SP demonstrated the following properties: AR *(M = 2.05, SD = .65)*, LT *(M = .50, SD = .69)*, and FCA *(M = .73, SD = .76)*. (All indicators have been normalized to a range of 0 to 3.)

3.1 Model Fitting Analysis

In assessing model fit for this study, multiple indices were used to evaluate the adequacy of both the measurement and structural components. The chi-square (χ^2) test was included as an overall measure of global fit, with *p>.05* indicating acceptable model fit (Kline, 2023). Additional global fit indices included the Root Mean Square Error of Approximation (RMSEA), with values ≤ .05 indicating a good fit (Hu & Bentler, 1999), and the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI), where values ≥ .95 represent a good fit. The Standardized Root Mean Square Residual (SRMR), with values ≤ .08, was also used to evaluate fit (Hu & Bentler, 1999). To assess local fit, the analysis will focus on inspecting residuals to ensure the model accurately represents the data. Residuals will be evaluated by interpreting standardized residuals as z-scores, with values exceeding |1.96| (correlation residuals, .1) indicating potential misfit. For the two-step SEM process, model comparisons will be conducted using the chi-square difference test for nested models, allowing for a rigorous evaluation of model fit and theoretical refinement (Hancock & Mueller, 2019). Both the measurement and structural models were estimated using the Maximum Likelihood (ML) method in Mplus Version 8.

3.2 Measurement Model

The measurement model demonstrated an acceptable global fit to the data. The chi-square test yielded a value of $\chi^2(5) = 8.208$, $p = .145$, indicating no significant misfit. The RMSEA was .127, with a 90% confidence interval of .000 – .276, suggesting that the model is plausible, particularly given that the lower bound includes zero. The Comparative Fit Index (CFI) was .956, exceeding the threshold of .90, reflecting good comparative fit. Additionally, the Standardized Root Mean Square Residual (SRMR) value was .049, indicating minimal

discrepancies between observed and predicted values. The local fit assessment for the measurement model was satisfactory. Standardized residuals for the covariances were within acceptable limits, with none exceeding |1.96| and residuals for correlation with none exceeding |.1|, indicating that the covariances were adequately represented. The residual variances for the observed variables AR, LT, and FCA were statistically significant, confirming that the indicators contributed meaningfully to the measurement of the latent variable SP.

3.3 Structural Model

The structural model, which includes regression paths from GC and TC to SP, also exhibited good global fit. The chi-square test resulted in a value of $\chi^2(5) = 8.208$, $p = .145$, indicating no significant misfit. The RMSEA was .127, with a 90% confidence interval of .000 – .276, suggesting that the model is plausible, particularly given that the lower bound includes zero. The Comparative Fit Index (CFI) was .957, exceeding the threshold of .90, reflecting good comparative fit. Additionally, the Standardized Root Mean Square Residual (SRMR) value was .049, indicating minimal discrepancies between observed and predicted values. The local fit assessment for the measurement model was satisfactory. Standardized residuals for the covariances were within acceptable limits, with none exceeding |1.96| and residuals for correlation with none exceeding |.1|, indicating that the covariances were adequately represented. Residual variances for all observed variables were significant, supporting the proper specification of regression paths and the overall structural relationships. These results confirm that the structural model captures the hypothesized associations between GC and TC on SP effectively and is well-suited for testing the research hypotheses.

3.4 Model Comparisons

The measurement model yielded mixed fit indicators: $\chi^2(5) = 8.208$, $p = .145$, CFI = .956, and SRMR = .049, all of which suggest acceptable to good fit. However, the RMSEA of .127 (90% CI: .000–.276) exceeds commonly accepted thresholds, indicating potential local misfit. Given the non-significant chi-square and favourable CFI and SRMR values, the overall model fit is considered adequate, though interpretation should be made with caution due to the elevated RMSEA. The structural model, which added regression paths from GC and TC to SP, yielded identical fit indices: a chi-square value of 8.208 with 5 degrees of freedom, an RMSEA of .127 *(90% CI: .000–.276)*, a CFI of .957, and an SRMR of .049. Given the identical chi-square values and degrees of freedom, the measurement and structural models are statistically equivalent. This lack of change in fit reflects the fact that the two models cannot be statistically distinguished based on the current data. Despite this equivalence, the inclusion of the structural relationships is theoretically justified, as it allows for the examination of the direct relationships between GC and TC on SP. While the results should be interpreted cautiously, the structural model aligns with the theoretical framework being investigated. Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) were also consistent across models, further supporting the appropriateness of the structural model without suggesting overfitting. Overall, the structural model was retained due to its theoretical relevance, despite no significant statistical difference with the measurement model in terms of fit indices.

3.5 Latent Factor Validity and Reliability

Validity and reliability analyses confirmed the appropriateness of SP as a latent construct. *Average Variance Extracted (AVE) = .610*, exceeding the .50 threshold, supports construct validity by explaining most indicator variance. *Composite Reliability (CR) = .650,* though below the ideal .70, indicates moderate reliability, suggesting room for measurement refinement. Overall, these results validate SP for further analysis.

3.6 Parameter Estimates and Variance

The structural model was evaluated using unstandardized parameter estimates to assess the relationships between latent and observed variables (Figure 2). The latent variable SP was measured by three observed indicators. For AR, the unstandardized parameter was fixed at 1.000 to scale the latent construct (ULI constraint). For LT, the unstandardized parameter was −2.453 *(SE = 1.034, p = .018)*, indicating that a one-unit increase in SP corresponds to a 2.453 decrease in LT. For FCA, the unstandardized parameter was −3.213 *(SE = 1.313, p = .014)*, suggesting that a one-unit increase in SP corresponds to a 3.213 decrease in FCA.

The structural regression paths indicated significant relationships between the predictors and SP. GC was a significant predictor with an unstandardized parameter of −.132 *(SE=.067, p = .050)*. This suggests that a one-unit increase in GC is associated with a .132 decrease in SP. Similarly, TC significantly predicted SP with an

unstandardized parameter of −.142 *(SE=.067, p = .035),* indicating that a one-unit increase in TC corresponds to a .142 decrease in SP. The covariance between GC and TC was not statistically significant *(p = .917).*

The variance explained (R2) for each endogenous variable demonstrated the contribution of the predictors to the latent construct. For SP, *R2=.409 (SE=.120, p = .001)*, indicating that GC and TC collectively explain 40.9% of the variance in SP. The variance explained for each indicator of SP reflects how well the latent construct predicts the observed variables. LT *(R2=0.702, SE=0.079, p<0.001)* demonstrates a strong relationship with SP, indicating that 70.2% of its variance is explained by the latent construct. Similarly, FCA *(R2=0.998, SE=0.000, p<0.001)* shows an almost perfect alignment with SP, as 99.8% of its variance is accounted for. In contrast, AR *(R2=0.130, SE=0.099, p=0.189)* contributes less significantly, with only 13.0% of its variance explained by SP. These findings suggest that LT and FCA are more strongly tied to the latent construct than AR.

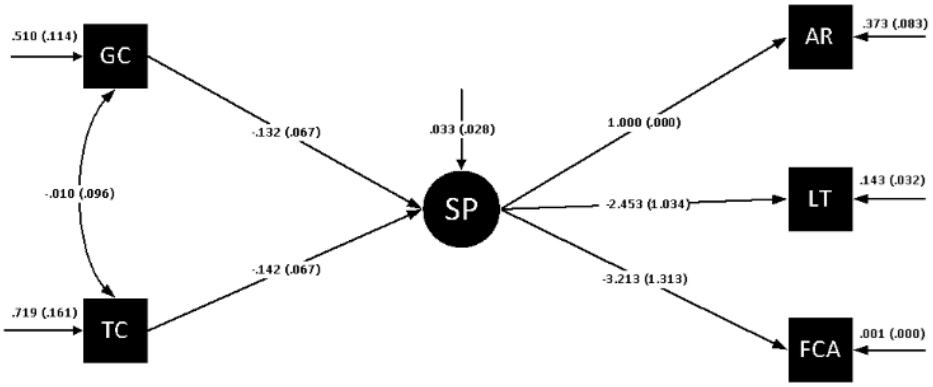


Figure 3: Full SEM for SP in geometry learning

4. Discussion

This study employed a two-phase SEM approach to investigate the relationships between GC, TC, and SP. The latent construct SP, measured through Accuracy Rate (AR), Latency (LT), and First Correct Attempt (FCA), demonstrated adequate validity and moderate reliability. The structural model revealed statistically significant negative associations between both GC and TC with SP, aligning with the hypothesis that increased complexity may correspond to decreased SP.

While the measurement and structural models showed statistically equivalent fit, the structural model remains theoretically informative. Its inclusion supports the exploration of how complexity metrics relate to SP outcomes in geometry problem-solving. However, this equivalence also highlights the importance of future methodological refinements, including the integration of additional variables, more recent datasets, or longitudinal and experimental designs that can support stronger causal inferences.

These findings are interpreted through the lens of Cognitive Load Theory (CLT). The negative associations observed between both TC and GC with SP are consistent with the notion that increased complexity imposes extraneous cognitive load, potentially overwhelming working memory and interfering with task SP. Specifically, TC likely contributes to extraneous load through longer problem statements, syntactic density, or unnecessary wording that may divert cognitive resources away from schema acquisition or conceptual reasoning. Higher visual complexity may also impose extraneous load, particularly when diagrams are cluttered or irrelevant to the learning objective.

However, according to the results of this study, it seems that when the geometry evaluation materials are designed effectively, structural complexity may contribute to germane processing, supporting schema construction by engaging students in spatial reasoning and conceptual integration (Sweller et al, 2019). This theoretical interpretation aligns with the observed positive relationship between complexity and First Correct Attempt (FCA), suggesting that higher complexity may prompt learners to allocate greater cognitive effort and engage more deeply with problem-solving processes. Another possible explanation for the positive link between complexity and FCA is that students may have responded to more complex problems with increased attentional effort, especially when the problem format encouraged active engagement.

However, it is important to consider that certain problem types or student characteristics (e.g., prior knowledge, motivation) may moderate this relationship. Future research should test this possibility by examining whether the effect of complexity on FCA varies by problem type or levels of learner involvement, using larger and more

diverse datasets. Additionally, some high-complexity problems may have incidentally included features, such as clearer spatial cues or better-organized information, that offset their cognitive demands. It is also possible that individual differences in prior knowledge, spatial ability, or mathematical experience moderated how students interacted with complex problems. Learners with stronger background skills may have been better able to manage cognitive demands and capitalize on opportunities for successful problem-solving on the first attempt.

5. Conclusion

By modeling SP as a latent construct composed of accuracy, efficiency, and mastery, this study offers a nuanced understanding of how different forms of problem complexity relate to geometry problem-solving behaviours. The use of a two-phase SEM approach allows for the exploration of these relationships in a theoretically grounded yet data-driven manner.

These findings have important implications for the application of Cognitive Load Theory (CLT) in educational design. The results suggest that increased graphical and textual complexity is not uniformly associated with decreased SP. While higher complexity levels may impose additional cognitive demands, they can also be linked to deeper cognitive engagement and more deliberate problem-solving strategies, particularly in cases where students succeed on their first attempt. This highlights the dual nature of complexity: it can either overload working memory (extraneous load) or support meaningful schema construction (germane processing), depending on the design of instructional materials and learners' cognitive readiness. Rather than minimizing difficulty outright, educators and curriculum designers should aim to optimize complexity levels to promote germane processing while minimizing unnecessary cognitive burden. In doing so, they can create learning environments that balance challenge and clarity, enhancing both engagement and SP.

Future research should expand on these findings by incorporating learner-level characteristics such as prior knowledge, cognitive ability, and motivational factors. Identifying which students benefit most from high-complexity tasks could inform the development of adaptive learning systems that personalize complexity based on learner profiles. Additionally, extending this research with more recent datasets and experimental designs will further strengthen the generalizability and practical applicability of these findings in contemporary educational settings.

6. Limitations

While the dataset originates from 1996–1997, its use is still valuable because it was collected within a well-established intelligent tutoring system (Cognitive Tutor) whose structure and instructional design principles continue to inform modern adaptive learning systems. Moreover, the underlying cognitive principles of geometry problem-solving and cognitive load remain highly relevant across decades. However, we recognize that technological tools and curricula have evolved, and we strongly encourage future research to replicate and extend these findings using more recent datasets to validate the robustness of the observed relationships.

It is important to recognize that these results are based on cross-sectional data, which limits the ability to establish definitive causal relationships. While Structural Equation Modeling (SEM) is a powerful tool for testing theoretically informed models, acceptable fit indices only suggest that the model is one plausible explanation for the observed data. Alternative explanations, such as unmeasured confounding variables or bidirectional influences, could also account for the observed associations. Future research should address these limitations by employing longitudinal or experimental designs that allow for robust testing of temporal and causal mechanisms. Also, future work may refine these categories using more granular linguistic and visual analysis tools or machine-coded complexity metrics. Such approaches could enhance objectivity and replicability in complexity coding, reducing potential bias introduced by manual rubric-based classification.

Additionally, the dataset does not include detailed participant information such as demographics or prior knowledge measures. While this focused sample enables close examination of problem-solving behaviour in a real-world educational setting, the absence of prior knowledge indicators limits our ability to assess how individual differences in mathematical background may have influenced SP or moderated the effects of complexity. Future research should consider incorporating background measures or pre-assessments to better capture learner variability and cognitive preparedness.

Ethics Declaration

This study involved secondary analysis of de-identified log data from student interactions with the Cognitive Tutor system, originally collected in an educational setting during the 1996–1997 school year. No personal, demographic, or sensitive information was included in the dataset, and no direct contact with participants occurred. As the dataset is fully anonymized and publicly accessible via DataShop, formal ethical clearance was not required. All procedures complied with institutional and field-specific guidelines for ethical use of archival educational data involving minors.

AI Declaration

During the preparation of this manuscript, the authors used GPT-4 for grammar and clarity checks. No content was generated by the AI tool beyond surface-level editorial suggestions. All substantive content, analysis, and interpretations were developed by the authors, who take full responsibility for the final work.

References

Bobis, J., Sweller, J., and Cooper, M. (1993). Cognitive load effects in a primary-school geometry task. Learning and Instruction, 3(1), pp 1–21. https://doi.org/10.1016/S0959-4752(09)80002-9

Brown, T. A. (2015). Confirmatory factor analysis for applied research. Guilford Publications.

Clements, D. H., and Battista, M. T. (1992). Geometry and spatial reasoning. Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics, pp 420-464.

Darke, I. (1982). A review of research related to the topological primacy thesis. Educational Studies in Mathematics, 13, pp 119–142. https://doi.org/10.1007/BF00460707

Dhlamini, Z. B., Chuene, K., Masha, K., and Kibirige, I. (2019). Exploring grade nine geometry spatial mathematical reasoning in the South African Annual National Assessment. Eurasia Journal of Mathematics, Science and Technology Education, 15(11). https://doi.org/10.29333/ejmste/105481

Hancock, G. R., and Mueller, R. O. (Eds.). (2019). The reviewer's guide to quantitative methods in the social sciences (2nd ed.). Routledge. https://doi.org/10.4324/9780203861554

Hu, L. T., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling, 6(1), pp 1–55. https://doi.org/10.1080/10705519909540118

Husni, N. A., Jumaat, N., and Tasir, Z. (2022). Investigating student's cognitive engagement, motivation, and cognitive retention in learning management system. International Journal of Emerging Technologies in Learning, 17(9), pp 184–200. https://doi.org/10.3991/ijet.v17i09.29727

Jones, K., and Tzekaki, M. (2016). Research on the teaching and learning of geometry. The second handbook of research on the psychology of mathematics education: The journey continues, pp 109-149. https://doi.org/10.1007/978-94-6300-561-6_4

Kline, R. B. (2023). Principles and practice of structural equation modeling (5th ed.). Guilford Publications.

Koedinger, K. R., Baker, R. S., Cunningham, K., Skogsholm, A., Leber, B., and Stamper, J. (2010). A data repository for the EDM community: The PSLC DataShop. Handbook of educational data mining, 43, pp 43-56.

Lin, J. J. H., and Lin, S. S. (2014). Cognitive load for configuration comprehension in computer-supported geometry problem solving: An eye movement perspective. International Journal of Science and Mathematics Education, 12, pp 605–627. https://doi.org/10.1007/s10763-013-9479-8

Mix, K. S., and Battista, M. T. (2018). Visualizing Mathematics: The Role of Spatial Reasoning in Mathematical Thought. Research in Mathematics Education. Research in Mathematics Education. https://doi.org/10.1007/978-3-319-98767-5

Seufert, T. (2018). The interplay between self-regulation in learning and cognitive load. Educational Research Review, 24, pp 116–129. https://doi.org/10.1016/j.edurev.2018.03.004

Sinclair, N., Bruce, C., Caswell, B., Lissa, D., Amour, B., Davis, M., Drefs, I., Elia, T., Flynn, K., Francis, D., Hallowell, Z., Hawes, H., Kaur, A., Mamolo, L., McGarvey, J., Moss, S., Naqvi, O.-L., Ng, Y., Okamoto, A., and Hawes, Z. (2014). Spatial reasoning for young learners. https://doi.org/10.13140/2.1.2543.5521

Stamper, J. C., and Koedinger, K. R. (2011). Human-machine student model discovery and improvement using DataShop. In G. Biswas, S. Bull, J. Kay, & A. Mitrovic (Eds.), Proceedings of the 15th International Conference on Artificial Intelligence in Education (AIED 2011), pp 353–360. Springer. https://doi.org/10.1007/978-3-642-21869-9_46

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. Cognitive Science, 12(2), pp 257–285. https://doi.org/10.1207/s15516709cog1202_4

Sweller, J., Van Merriënboer, J. J. G., and Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. Educational Psychology Review, 31, pp 261–292.

Van Hiele, P. M. (1986). Structure and insight: A theory of mathematics education. Academic Press.

Rethinking Generative AI in Human-Computer Interaction: Review of Affordances, Constraints, and Implications

Niklas Humble and Åsa Cajander
Department of Information Technology, Uppsala University, Uppsala, Sweden

niklas.humble@it.uu.se
asa.cajander@it.uu.se

Abstract: Generative Artificial Intelligence (GAI) transforms our technological interactions, including new capabilities and concerns about biases and misuse. In the field of human-computer interaction (HCI), previous research has investigated generative AI in relation to human-centred AI, user trust, user experience, design work, co-creativity, and user personas. This study applies the theoretical lens of affordances and constraints to ask the question: Which affordances and constraints of generative AI can be identified in human-computer interaction research? The study employs a scoping literature review approach to collect data from the Web of Science Core Collection databases. The query string combined keywords, such as "generative", "artificial intelligence", and "human computer interaction", with Boolean operators AND and OR. Inclusion and exclusion criteria were used in the screening of 156 identified articles, from which a total of 37 were selected for inclusion in the study. An initial categorization matrix, based on the theory of affordances, was used to conduct a deductive thematic analysis. The analysis followed the guidelines for thematic analysis suggested by Braun and Clarke. The investigation identified seven key themes, with included sub-themes, illustrating the varied applications and potential effects of generative AI. The seven key themes are: 1) improving algorithms, 2) collaborative work, 3) education support, 4) truth issues, 5) biases, 6) ethical considerations, and 7) consequences for job market. The study further highlights the importance of considering contextual differences and short-term and long-term consequences when applying GAI technologies, as well as ethical considerations, such as ethical and legal accountability. The paper concludes with a novel conceptual model for affordances and constraints of generative AI, informing future research, guiding stakeholders' use and implementation, and providing design recommendations for generative AI systems across various sectors.

Keywords: Generative Artificial Intelligence, Human-Computer Interaction, Affordances, Literature Review

1. Introduction

In Human-Computer Interaction (HCI) research, the birth of Generative Artificial Intelligence (GAI) marks a transformative phase, broadening the horizon of possibilities for how humans to engage with digital systems. GAI, which includes several models for generating images, videos, text and so on, could be divided into Natural Language Processing (NLP) and Image Processing (Kim et al., 2024). Viewed from the perspective of NLP, Deep Neural Networks mark an important milestone (Kim et al., 2024). For example, deep learning architectures such as the transformer in ChatGPT includes attention mechanisms which allows for focus on the most important parts in the inputs, necessary for processing and comprehending large amount of data (Hashana, Brundha & Ayoobkhan, 2023). In relation to Image Processing, Generative Adversarial Network (GAN) could be mentioned as an important technology (Kim et al., 2024). Another technology related to Image Processing is Variational Auto-Encoder (VAE), which is often compared to, and combined with, GAN (Li et al., 2025; Akkem et al., 2024). Studies have shown that combining VAE and GAN allows for drawing on the strengths from both technologies, such as easier training with VAE and higher quality output with GAN (Akkem et al., 2024; Qiang et al., 2023).

As a technology, GAI has begun reshaping the industry and work landscapes (Chui et al., 2023), such as user experience (UX) design processes (Stige et al., 2024) and effectiveness in sales performances (Liao et al., 2024). Artificial Intelligence (AI) also offers opportunities for education, such as personalized and AI driven tutoring (Zhang et al., 2024), novel approaches for prototyping (Rapp, 2019), and enhanced teaching and learning practices (Giannakos et al., 2024). Additionally, GAI integration has consequences. It presents challenges such as ethical considerations (Farina, Yu & Lavazza, 2025; Cong-Lem et al., 2024; Hagendorff, 2024; Sison et al., 2023), data biases (Ali & Aysan, 2025; Hagendorff, 2024; Oppenlaender, 2023; Yu, Ma & Zhu, 2023), sustainability impact (Hosseini, Gao & Vivas-Valencia, 2025; Humble & Mozelius, 2024), and the potential for misuse (Ali & Aysan, 2025; Duong et al., 2024; Triantafyllopoulos et al., 2023), raising essential questions about the future of work, the nature of creativity, and the role of humans in a machine-driven landscape.

Focusing on theoretical concepts, the concepts of affordances and constraints provide a nuanced lens to explore the research on GAI in HCI. Affordances, initially coined by psychologist James J. Gibson, refers to the possibilities for actions offered by objects and environments to an organism (Gibson, 2014). As later stated by Donald A. Norman (2008), affordances according to Gibson's definition do not need to be perceivable or even knowable by the organism, "they simply existed". Norman's (1999) own definition, which is commonly applied in HCI,

encompasses affordances that are perceivable by a user, therefore 'perceived affordances'. For example, users perceives that they can interact with a computer system. Similarly, constraints are about what users cannot do or perceive that they cannot do. For example, clicking outside the computer screen or navigating a computer system in a way that seems illogical or breaks conventions (Norman, 1999). In the context of the literature review, affordances denote the actionable capabilities of GAI systems found in the HCI literature, and constraints refer to the limitations or boundaries within which these systems operate, encompassing technical, ethical, and practical barriers that may hinder their effective use.

Moreover, recent literature reviews in the field of HCI have investigated GAI concerning, for example, human-centred AI (Schmager, Pappas & Vassilakopoulou, 2025), user trust (Bach et al., 2024), user experience (UX) design (Stige et al., 2024), design work (Shi et al., 2023), and quantitative user personas (Salminen et al., 2023). Complementing these, Liu et al. (2023) provide a systematic overview of how AI and machine learning foster human-computer co-creativity, underscoring a gap in design-oriented research within HCI. However, no prior literature review has, to the authors' knowledge, explored GAI in HCI through the theoretical lens of affordances and constraints. This study aims to address that specific research gap. Since affordances is an influential and widely applied theoretical lens in HCI, adding this perspective to the body of knowledge would constitute a contribution to the field. Further, compared with previous research that has explored GAI in technical implementation, this study can more comprehensively reveal GAI mechanism in HCI through the use of affordances theory, and thus provide new directions for future research.

This study aims to identify the affordances and constraints of generative AI in human-computer interaction research. The following research question has guided the study: *Which affordances and constraints of generative AI can be identified in human-computer interaction research?*

2. Materials and Methods

This literature study was conducted with a scoping review approach. Further details on the conducted steps for collecting and analysing data are described below.

2.1 Data Collection

Data were collected by two searches in the Web of Science (WoS) Core Collection databases, which include six online indexing databases. The searches were conducted in early 2024, to collect data on research of generative AI in HCI conducted up to that date, and in late 2024, to complement the previous search with more recently published research. The query string used in both searches:

> *((ALL=("generative")) AND ALL=("artificial intelligence")) AND ALL=("human computer interaction" OR "human-computer interaction" OR "HCI")*

The first search was set with no time frame and identified 84 potentially relevant papers. As a basis for deciding whether papers would be included or excluded in the study, inclusion and exclusion criteria were applied (Table 1).

Table 1: Inclusion and exclusion criteria

Inclusion	Exclusion
Is a proceedings paper or a journal article	Is NOT a proceedings paper or a journal article
Is written in English	Is NOT written in English
Is published as Open Access	Is NOT published as Open Access

After the initial search, filters were applied in WoS, based on the inclusion and exclusion criteria (Table 1). This reduced the number to 21 potentially relevant papers published between 2008 and 2024 (excluding 63). The 21 selected papers underwent manual screening of the title, abstract and keywords based on the inclusion and exclusion criteria presented in Table 1 to detect papers that were not excluded through the filters applied in Web of Science. To the previous inclusion and exclusion criteria additional criteria were added for the manual screening: address a topic related to GAI in the HCI field. After the manual screening process, all 21 papers were deemed relevant for addressing the aim and research question of the study and included in the study.

To extend the list of included papers and capture more recent research, a second search was conducted in WoS for research published in 2024. The search used the same query string, which resulted in identifying 72

potentially relevant papers published in 2024. Filters, based on Table 1, were then applied in WoS. This reduced the number to 16 potentially relevant papers published in 2024 (excluding 56). The 16 selected papers underwent manual screening of the title, abstract and keywords based on the updated inclusion and exclusion criteria, for detecting papers that were not excluded through the filters applied in WoS. After the manual screening process, all 16 papers were deemed relevant for addressing the aim and research question of the study and included in the study. This increased the total of included papers in the study to 37.

2.2 Data Analysis

The data analysis utilized a deductive theoretical thematic analysis approach to investigate GAI in HCI research, following Braun and Clarke's thematic analysis guidelines (Braun & Clarke, 2006). Initially a categorization matrix was created in a spreadsheet document, containing the categories “affordances”, “constraints” and “unclear”. After that, the analysis applied the six phases of Braun and Clarke's thematic analysis (Braun & Clarke, 2006): Data familiarizing, Code generating, Searching for themes, Reviewing themes, Defining and naming themes, and Producing the report. Identified themes (n=25) where combined to create super-themes (n=7), which are presented in Table 2.

Table 2: Identified super-themes

Affordances	Constraints
Improving algorithms	Truth issues
Collaborative work	Biases
Education support	Ethical considerations
	Consequences for job market

3. Results

The analysis of the included papers identified seven super-themes relating to affordances or constraints (Table 2). These are presented in subheadings below according to which central concept in the theory of affordances they address, affordances or constraints.

3.1 Affordances

The analysis of included papers identified eleven themes and three super-themes related to affordances. The theme of improving algorithms is supported in 12 of the 37 included papers (Dembinsky et al., 2024; Kucukler et al., 2024; Kurtoğlu et al., 2024; Acien et al., 2021; Burrows et al., 2021; Liu et al., 2021; Numan et al., 2021; van Rijn et al., 2021; Bergmanis et al., 2020; Forbes, 2020; Yin et al., 2019 Ma et al., 2018). These highlight, for example, the possibilities of GAI technologies to improve bot detection (Acien et al., 2021), image colour and depth accuracy (Numan et al., 2021). Papers compare generated synthetic data to ‘real’ data for training (Kurtoğlu et al., 2024) and in some studies note that generated data could be used in training to improve algorithms, for example in object recognition (Ma et al., 2018) and machine translation (Bergmanis et al., 2020).

Collaborative work is supported in 15 of the 37 included papers (Elagroudy et al., 2024; Ford et al., 2024; Geyer et al., 2024; Ibarrola, Lawton & Grace, 2024; Muller et al., 2024; Nacke, 2024; Newman, 2024; Sivertsen et al., 2024; Maican et al., 2023; Oppenlaender, 2023; Sarkar, 2023; Sison et al., 2023; Forbes, 2020; Liikkanen, 2019; Romero et al., 2008). These highlight that GAI systems can be used in collaboration with human intelligence as a companion to work on design and creativity (Sivertsen et al., 2024; Forbes, 2020; Liikkanen, 2019), improve and assist mundane writing tasks (Sison et al., 2023), and analyse and visualize large amount of data to inform quick and efficient decision making (Maican et al., 2023). Collaborative work could be essential for understanding complex risks and threats, such as environmental challenges and criminal activities, where GAI could support in identifying patterns and forecast trends in the future (Maican et al., 2023). It is further highlighted that the integration of GAI in human work to complement or support human decision-making rather than replace it (Maican et al., 2023), as well as in creative work, could be labelled as critical integration (Sarkar, 2023).

GAI as education support is supported by 5 of the 37 papers selected for inclusion in this study (Li et al., 2024; Newman et al., 2024; Zheng et al., 2024; Maican et al., 2023; Sison et al., 2023). These highlight that GAI technologies can be used both as a teaching tool and a learning tool, for example, by assisting assessments (Zheng et al., 2024), by supporting teachers in preparing engaging lessons (Li et al., 2024; Sison et al., 2023) and

by providing students visual explanations that can support the understanding of complex theoretical concepts (Maican et al., 2023). It is further noted that GAI systems are often trained on English texts and could, therefore, serve as English tutors for improving students' grammar and spelling, but that this should be done under supervision to limit the risks of both cheating and bad accuracy in the responses (Sison et al., 2023). Lastly, it is highlighted that proficiency in utilizing GAI will be a competitive advantage for students and that efforts should be made to upgrade GAI skills in the existing workforce and support them in staying relevant, for example, through lifelong learning programs (Maican et al., 2023).

3.2 Constraints

The analysis of included papers identified fourteen themes and four super-themes related to constraints. The theme of 'Truth issues' is supported in 10 of the 37 included papers (Mim et al., 2024; Muller et al., 2024; Bryan-Kinns et al., 2024; Plohl et al., 2024; Bryan-Kinns et al., 2023; Maican et al., 2023; Sarkar, 2023; Sison et al., 2023; Triantafyllopoulos et al., 2023; Zhu et al., 2021). It is highlighted that GAI problematizes our old beliefs regarding ownership, plagiarism, copyright, originality, and creativity when anyone can use and transform their work with generative tools (Sarkar, 2023). On the other hand, many of these tools require a specific skill set and personality to fully utilize them, such as the English language and creativity, which could make them more accessible to some people (Maican et al., 2023). Many of the tools provide little to no information about how to fully utilize them or how they affect, for example, the environment (Bryan-Kinns et al., 2024). It is noted that there is still limited research on how GAI can be more explainable and user centred (Bryan-Kinns et al., 2023). Research further notes the problem of hallucinations when interacting with GAI, false information that sounds confident, and that outputs need to be validated and verified (Sison et al., 2023). False outputs can also be produced with ill intent by users. Papers note the potential use of GAI to spread disinformation and defame individuals through deepfakes (Plohl et al., 2024; Triantafyllopoulos et al., 2023), which could threaten politics and economics (Zhu et al., 2021). GAI tools, such as ChatGPT, have therefore been labelled as a potential "weapon of mass deception" because of the dangers of massive deceit and criminal activities through their use (Sison et al., 2023).

Potential biases associated with GAI are supported in 8 of the 37 included papers (Bryan-Kinns et al., 2024; Mim et al., 2024; Muller et al., 2024; Liikkanen, 2019; Oppenlaender, 2023; Ragot et al., 2020; Sison et al., 2023; Triantafyllopoulos et al., 2023). It is highlighted that biases in training data for GAI models can have a cultural effect on the outputs, for example affect the skin-color of people in AI-generated images (Oppenlaender, 2023). However, this could also be a result from data availability, which makes some cultures more dominant in the training data, which could still be problematic (Triantafyllopoulos et al., 2023). The black box nature of GAI is related to potential biases. The models are often uninterpretable and unexplainable to those who use them (Bryan-Kinns et al., 2024; Muller et al., 2024), which must be addressed if improving fairness and reducing biases in GAI is a goal (Sison et al., 2023). One paper also notes the potential negative biases of humans towards AI-created content, such as paintings, if they know that AI has produced it (Ragot et al., 2020).

Ethical concerns related to GAI are supported in 8 of the 37 included papers (Constantinides et al., 2024; Zheng et al., 2024; Maican et al., 2023; Sison et al., 2023; Triantafyllopoulos et al., 2023; Alfrink et al., 2022; Forbes, 2020; Liikkanen, 2019). Papers highlight that GAI does not sufficiently respect personal rights (Sison et al., 2023), for example with the possibility of creating deepfakes (Forbes, 2020) and limitations of cultural representation (Triantafyllopoulos et al., 2023), which can cause concerns for discrimination, biases, and privacy (Maican et al., 2023). A potential problem is that machines are not typically accountable for their actions or outputs (Constantinides et al., 2024). Therefore, humans should be kept in the loop (Sison et al., 2023) for the possibility of human intervention and protection against unjust, illegitimate and fallible automated decisions (Alfrink et al., 2022). Papers highlight that more attention should be placed on the users of GAI to preserve their dignity and agency while still enhancing the experience of using these models (Zheng et al., 2024; Sison et al., 2023). It is further noted that a potential problem with technology development, as it is driven, is that users, like designers, can typically only adjust their choices and actions in accordance with new technology but not affect them on a fundamental level (Liikkanen, 2019).

The theme of potential consequences for the job market with GAI is supported in 5 of the 37 included papers (Mim et al., 2024; Maican et al., 2023; Oppenlaender, 2023; Sison et al., 2023; Liikkanen, 2019). Papers highlight that human jobs can be lost or changed due to the introduction of GAI (Mim et al., 2024; Maican et al., 2023; Sison et al., 2023). For example, it is noted that GAI will transform both the content and agency in human work and how we work and interact with computers (Oppenlaender, 2023). Skills and knowledge related to GAI are also expected to increase as demands on the future job market, which would pressure universities to provide what future specialists need to remain relevant in the job market (Maican et al., 2023). Lastly, it is highlighted

that GAI can potentially transform society on a larger scale by, for example, disrupting the economy and creating whole new worlds, such as games, through prompt engineering (Oppenlaender, 2023).

4. Discussion

In light of this literature review, a proposed conceptual model encapsulates the interplay of affordances and constraints of GAI in HCI research (Figure 1). This model serves as a visual representation, illustrating how various factors interact. The model highlights the role of contextual differences for affordances and constraints and the potential short-term and long-term consequences that these might have. Further, the model visually represents how affordances and constraints of GAI can overlap and be interchangeable in a dynamic relationship between the two, depending on the contextual circumstances.

For instance, the ability of GAI to support education (Li et al., 2024; Sison et al., 2023) showcases an affordance that can also pose constraints if not carefully managing concerns about privacy, biases, and potential discrimination (Maican et al., 2023). Similarly, the ability of GAI to support work through human-AI collaboration (Maican et al., 2023; Oppenlaender, 2023) showcases affordances that can also pose constraints if concerns regarding future jobs and job market (Maican et al., 2023; Oppenlaender, 2023) are not considered. The identified themes cover both short-term and long-term aspects of GAI, for example that it can support in preparing lessons (Li et al., 2024; Sison et al., 2023) but also potentially become an essential skill for staying relevant (Maican et al., 2023), that depend on contextual circumstances, likelihood, and if they are to be perceived as affordances or constraints. Putting all this together forms a potential conceptual model of GAI in HCI research based on the theory of affordances (Figure 1).

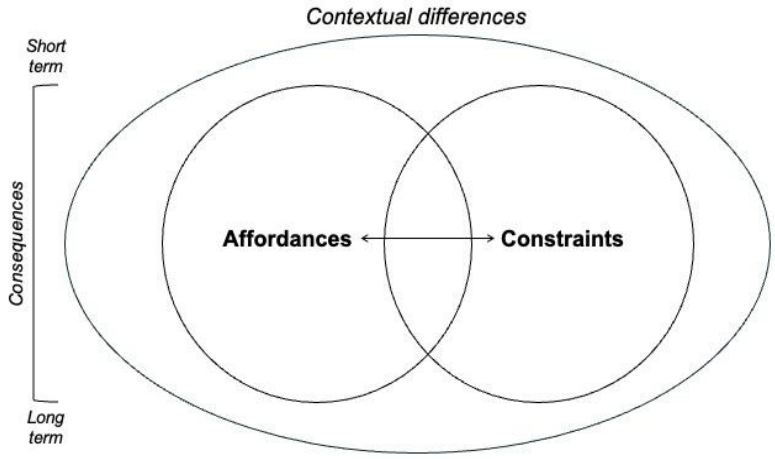


Figure 1: Conceptual Model of GAI affordances and constraints in HCI

5. Concluding Remarks

This study has charted the affordances and constraints of generative AI (GAI) within human-computer interaction research, highlighting a complex interplay influenced by various contextual factors and the potential short-term and long-term consequences that GAI might have. Results have highlighted GAI's future potential of forecasting trends and identifying patterns that can support in addressing societal challenges, such as climate change and criminal activities, which should be a prioritized area for future research. GAI marks a disruptive shift in human-computer interaction, by enabling natural and conversational interfaces that adopt to users rather than the other way around. Unlike traditional HCI technologies, GAI offers dynamic, context-aware, and creative collaborations, which position it not only as a tool, but also as a potential partner in digital work.

The study's proposed conceptual model provides a framework for understanding the dynamics between affordances and constraints, contextual factors, and short-term and long-term consequences when applying GAI. Which should be used to guide the design and development of adaptable and ethical GAI systems. Moving forward, the aim is to leverage the possibilities of GAI by ensuring that technological progress aligns with human values and societal benefits. For example, through research that develops and tests new ethical frameworks for GAI, ensuring alignment with societal values amidst rapid technological progression.

Acknowledgements

The authors thank AI4Research at Uppsala University and Afa Försäkringar (Sweden) for supporting this project.

Ethics and AI Declarations

Ethical clearance was not required for this research. AI tools have been used in this paper for proofreading and suggestions for improved language and clarity. The authors have conducted the research and written the paper and take full responsible for its content.

References

Acien, A., Morales, A., Fierrez, J., Vera-Rodriguez, R., & Delgado-Mohatar, O. (2021). BeCAPTCHA: Behavioral bot detection using touchscreen and mobile sensors benchmarked on HuMIdb. *Engineering Applications of Artificial Intelligence*, *98*, 104058. https://doi.org/10.1016/j.engappai.2020.104058

Akkem, Y., Biswas, S. K., & Varanasi, A. (2024). A comprehensive review of synthetic data generation in smart farming by using variational autoencoder and generative adversarial network. *Engineering Applications of Artificial Intelligence*, *131*, 107881. https://doi.org/10.1016/j.engappai.2024.107881

Alfrink, K., Keller, I., Kortuem, G., & Doorn, N. (2022). Contestable AI by Design: Towards a Framework. *Minds and Machines*, *33*(4), 613–639. https://doi.org/10.1007/s11023-022-09611-z

Ali, H., & Aysan, A. F. (2025). Ethical dimensions of generative AI: a cross-domain analysis using machine learning structural topic modeling. *International Journal of Ethics and Systems*, *41*(1), 3-34. https://doi.org/10.1108/IJOES-04-2024-0112

Bach, T. A., Khan, A., Hallock, H., Beltrão, G., & Sousa, S. (2024). A systematic literature review of user trust in AI-enabled systems: An HCI perspective. *International Journal of Human–Computer Interaction*, *40*(5), 1251-1266. https://doi.org/10.1080/10447318.2022.2138826

Bergmanis, T., Stafanovičs, A., & Pinnis, M. (2020). Robust Neural Machine Translation: Modeling Orthographic and Interpunctual Variation. In A. Utka, J. Vaičenonienė, J. Kovalevskaitė, & D. Kalinauskaitė (Eds.), *Frontiers in Artificial Intelligence and Applications*. IOS Press. https://doi.org/10.3233/FAIA200606

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bryan-Kinns, N., Ford, C., Chamberlain, A., Benford, S. D., Kennedy, H., Li, Z., Qiong, W., Xia, G. G., & Rezwana, J. (2023). Explainable AI for the Arts: XAIxArts. *Creativity and Cognition*, 1–7. https://doi.org/10.1145/3591196.3593517

Bryan-Kinns, N., Ford, C., Zheng, S., Kennedy, H., Chamberlain, A., Lewis, M., Hemment, D., Li, Z., Wu, Q., Xiao, L., Xia, G., Rezwana, J., Clemens, M., & Vigliensoni, G. (2024). Explainable AI for the Arts 2 (XAIxArts2). In *Proceedings of the 16th Conference on Creativity & Cognition (C&C '24)* (86–92). https://doi.org/10.1145/3635636.3660763

Burrows, H., Zarrin, J., Babu-Saheer, L., & Maktab-Dar-Oghaz, M. (2021). Realtime Emotional Reflective User Interface Based on Deep Convolutional Neural Networks and Generative Adversarial Networks. *Electronics*, *11*(1), 118. https://doi.org/10.3390/electronics11010118

Chui, M., Hazan, E., Roberts, R., Singla, A., Smaje, K., Sukharevsky, Al., Yee, L., & Zemmel, R. (2023). *The economic potential of generative AI: The next productivity frontier.* McKinsey & Company. https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-economic-potential-of-generative-AI-the-next-productivity-frontier

Cong-Lem, N., Soyoof, A., & Tsering, D. (2024). A systematic review of the limitations and associated opportunities of ChatGPT. *International Journal of Human–Computer Interaction*, 1-16. https://doi.org/10.1080/10447318.2024.2344142

Constantinides, M., Tahaei, M., Quercia, D., Stumpf, S., Madaio, M., Kennedy, S., ... & Pistilli, G. (2024, May). Implications of Regulations on the Use of AI and Generative AI for Human-Centered Responsible Artificial Intelligence. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems* (pp. 1-4). https://doi.org/10.1145/3613905.3643979

Dembinsky, D., Watanabe, K., Dengel, A., & Ishimaru, S. (2024). Gaze generation for avatars using gans. *IEEE Access*. https://doi.org/10.1109/ACCESS.2024.3430835

Duong, C. D., Ngo, T. V. N., Khuc, T. A., Tran, N. M., & Nguyen, T. P. T. (2024). Unraveling the dark side of ChatGPT: a moderated mediation model of technology anxiety and technostress. *Information Technology & People*. https://doi.org/10.1108/ITP-11-2023-1151

Elagroudy, P., Li, J., Väänänen, K., Lukowicz, P., Ishii, H., Mackay, W. E., ... & Schmidt, A. (2024, May). Transforming HCI Research Cycles using Generative AI and "Large Whatever Models"(LWMs). In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems* (pp. 1-5). https://doi.org/10.1145/3613905.3643977

Farina, M., Yu, X., & Lavazza, A. (2025). Ethical considerations and policy interventions concerning the impact of generative AI tools in the economy and in society. *AI and Ethics*, *5*(1), 737-745. https://doi.org/10.1007/s43681-023-00405-2

Forbes, A. (2020). Creative AI: From Expressive Mimicry to Critical Inquiry. *Artnodes*, *26*. https://doi.org/10.7238/a.v0i26.3370

Ford, C., Noel-Hirst, A., Cardinale, S., Loth, J., Sarmento, P., Wilson, E., ... & Bryan-Kinns, N. (2024, June). Reflection Across AI-based Music Composition. In *Proceedings of the 16th Conference on Creativity & Cognition* (pp. 398-412). https://doi.org/10.1145/3635636.3656185

Geyer, W., Maher, M. L., Weisz, J. D., Buschek, D., & Chilton, L. B. (2024, March). HAI-GEN 2024: 5th Workshop on Human-AI Co-Creation with Generative Models. In *Companion Proceedings of the 29th International Conference on Intelligent User Interfaces* (pp. 122-124). https://doi.org/10.1145/3640544.3645254

Giannakos, M., Azevedo, R., Brusilovsky, P., Cukurova, M., Dimitriadis, Y., Hernandez-Leo, D., ... & Rienties, B. (2024). The promise and challenges of generative AI in education. *Behaviour & Information Technology*, 1-27. https://doi.org/10.1080/0144929X.2024.2394886

Gibson, J. J. (2014). *The ecological approach to visual perception: Classic edition*. Psychology press. https://www.taylorfrancis.com/books/mono/10.4324/9781315740218/ecological-approach-visual-perception-james-gibson

Hagendorff, T. (2024). Mapping the ethics of generative ai: A comprehensive scoping review. *Minds and Machines*, *34*(4), 39. https://doi.org/10.1007/s11023-024-09694-w

Hashana, A. J., Brundha, P., & Ayoobkhan, M. U. A. (2023, April). Deep learning in ChatGPT-A survey. In *2023 7th international conference on trends in electronics and informatics (ICOEI)* (pp. 1001-1005). IEEE. https://doi.org/10.1109/ICOEI56765.2023.10125852

Hosseini, M., Gao, P., & Vivas-Valencia, C. (2025). A social-environmental impact perspective of generative artificial intelligence. *Environmental Science and Ecotechnology*, *23*, 100520. https://doi.org/10.1016/j.ese.2024.100520

Humble, N., & Mozelius, P. (2024, December). Generative Artificial Intelligence and the Impact on Sustainability. In *Proceedings of the 4th International Conference on AI Research (ICAIR 2024)* (Vol. 4, No. 1, pp. 175-182). ACI. https://doi.org/10.34190/icair.4.1.3024

Ibarrola, F., Lawton, T., & Grace, K. (2024). A collaborative, interactive and context-aware drawing agent for co-creative design. *IEEE Transactions on Visualization and Computer Graphics, 30*(8). https://doi.org/10.1109/TVCG.2023.3293853

Kim, T. S., Ignacio, M. J., Yu, S., Jin, H., & Kim, Y. G. (2024). UI/UX for Generative AI: Taxonomy, Trend, and Challenge. *IEEE Access*. https://doi.org/10.1109/ACCESS.2024.3502628

Kucukler, O. F., Amira, A., & Malekmohamadi, H. (2024). EEG dataset for energy data visualizations. *Data in Brief*, *52*, 109933. https://doi.org/10.1016/j.dib.2023.109933

Kurtoğlu, E., DeHaan, K., Pezzarossi, C. K., Griffin, D. J., Crawford, C., & Gurbuz, S. Z. (2024). Interactive learning of natural sign language with radar. *IET Radar, Sonar & Navigation*. https://doi.org/10.1049/rsn2.12565

Li, W., Liu, D., Li, Y., Hou, M., Liu, J., Zhao, Z., Guo, A., Zhao, H., & Deng, W. (2025). Fault diagnosis using variational autoencoder GAN and focal loss CNN under unbalanced data. *Structural Health Monitoring*, *24*(3), 1859-1872. https://doi.org/10.1177/14759217241254121

Li, W., Zhang, X., Li, J., Yang, X., Li, D., & Liu, Y. (2024). An explanatory study of factors influencing engagement in AI education at the K-12 Level: an extension of the classic TAM model. *Scientific Reports*, *14*(1), 13922. https://doi.org/10.1038/s41598-024-64363-3

Liao, C., Wen, X., Li, S., & Du, P. (2024). How effective is AI augmentation in human–AI collaboration? Evidence from a field experiment. *Information Technology & People*, *37*(7), 2357-2389. https://doi.org/10.1108/ITP-11-2022-0859

Liikkanen, L. A. (2019). It AIn't Nuttin' New – Interaction Design Practice After the AI Hype. In D. Lamas, F. Loizides, L. Nacke, H. Petrie, M. Winckler, & P. Zaphiris (Eds.), *Human-Computer Interaction – INTERACT 2019* (Vol. 11749, pp. 600–604). Springer International Publishing. https://doi.org/10.1007/978-3-030-29390-1_45

Liu, H. X., Huang, Y., & Holopainen, J. (2023). How to use Generative AI as a design material for future human-computer (co-) creation?. *The CHI 2023 Workshop on Generative AI and HCI*. https://github.com/GenerativeAIandHCI/GenerativeAIandHCI.github.io/blob/main/papers/LIU-HowToUseGenerativeAIasaDesignMaterial.pdf

Liu, W., Zhang, Y., Deng, Z., Zhao, J., & Tong, L. (2021). A hybrid quantum-classical conditional generative adversarial network algorithm for human-centered paradigm in cloud. *EURASIP Journal on Wireless Communications and Networking*, *2021*(1), 37. https://doi.org/10.1186/s13638-021-01898-3

Ma, Y., Liu, K., Guan, Z., Xu, X., Qian, X., & Bao, H. (2018). Background Augmentation Generative Adversarial Networks (BAGANs): Effective Data Generation Based on GAN-Augmented 3D Synthesizing. *Symmetry*, *10*(12), 734. https://doi.org/10.3390/sym10120734

Maican, C. I., Sumedrea, S., Tecau, A., Nichifor, E., Chitu, I. B., Lixandroiu, R., & Bratucu, G. (2023). Factors Influencing the Behavioural Intention to Use AI-Generated Images in Business: A UTAUT2 Perspective With Moderators. *Journal of Organizational and End User Computing*, *35*(1), 1–32. https://doi.org/10.4018/JOEUC.330019

Mim, N. J., Nandi, D., Khan, S. S., Dey, A., & Ahmed, S. I. (2024, May). In-Between Visuals and Visible: The Impacts of Text-to-Image Generative AI Tools on Digital Image-making Practices in the Global South. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (pp. 1-18). https://doi.org/10.1145/3613904.3641951

Muller, M., Kantosalo, A., Maher, M. L., Martin, C. P., & Walsh, G. (2024, May). GenAICHI 2024: Generative AI and HCI at CHI 2024. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems* (pp. 1-7). https://doi.org/10.1145/3613905.3636294

Nacke, L. E. (2024, May). How to Write Better CHI Papers (with AI). In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems* (pp. 1-4). https://doi.org/10.1145/3613905.3636272

Newman, M., Sun, K., Dalla Gasperina, I. B., Shin, G. Y., Pedraja, M. K., Kanchi, R., ... & Yip, J. (2024, May). " I want it to talk like Darth Vader": Helping Children Construct Creative Self-Efficacy with Generative AI. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (pp. 1-18). https://doi.org/10.1145/3613904.3642492

Norman, D. A. (1999). Affordance, conventions, and design. *Interactions*, *6*(3), 38–43. https://doi.org/10.1145/301153.301168

Norman, D. A. (2008). The way I see IT signifiers, not affordances. *interactions*, *15*(6), 18-19. http://doi.acm.org/10.1145/1409040.1409044

Numan, N., Haar, F. T., & Cesar, P. (2021). Generative RGB-D Face Completion for Head-Mounted Display Removal. *2021 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, 109–116. https://doi.org/10.1109/VRW52623.2021.00028

Oppenlaender, J. (2023). A taxonomy of prompt modifiers for text-to-image generation. *Behaviour & Information Technology*, 1–14. https://doi.org/10.1080/0144929X.2023.2286532

Plohl, N., Mlakar, I., Aquilino, L., Bisconti, P., & Smrke, U. (2024). Development and Validation of the Perceived Deepfake Trustworthiness Questionnaire (PDTQ) in Three Languages. *International Journal of Human–Computer Interaction*, 1-18. https://doi.org/10.1080/10447318.2024.2384821

Qiang, N., Gao, J., Dong, Q., Yue, H., Liang, H., Liu, L., Yu, J., Hu, J., Zhang, S., Ge, B., Sun, Y., Liu, Z., Liu, T., Li, J., Song, H., & Zhao, S. (2023). Functional brain network identification and fMRI augmentation using a VAE-GAN framework. *Computers in Biology and Medicine*, *165*, 107395. https://doi.org/10.1016/j.compbiomed.2023.107395

Ragot, M., Martin, N., & Cojean, S. (2020). AI-generated vs. Human Artworks. A Perception Bias Towards Artificial Intelligence? *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–10. https://doi.org/10.1145/3334480.3382892

Rapp, A. (2019). Design fictions for behaviour change: exploring the long-term impacts of technology through the creation of fictional future prototypes. *Behaviour & Information Technology*, *38*(3), 244-272. https://doi.org/10.1080/0144929X.2018.1526970

Romero, M., Pousman, Z., & Mateas, M. (2008). Alien presence in the home: The design of Tableau Machine. *Personal and Ubiquitous Computing*, *12*(5), 373–382. https://doi.org/10.1007/s00779-007-0190-z

Salminen, J., Jung, S., Almerekhi, H., Cambria, E., & Jansen, B. (2023). How Can Natural Language Processing and Generative AI Address Grand Challenges of Quantitative User Personas? In H. Degen, S. Ntoa, & A. Moallem (Eds.), *HCI International 2023 – Late Breaking Papers* (Vol. 14059, pp. 211–231). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-48057-7_14

Sarkar, A. (2023). Exploring Perspectives on the Impact of Artificial Intelligence on the Creativity of Knowledge Work: Beyond Mechanised Plagiarism and Stochastic Parrots. *Proceedings of the 2nd Annual Meeting of the Symposium on Human-Computer Interaction for Work*, 1–17. https://doi.org/10.1145/3596671.3597650

Schmager, S., Pappas, I. O., & Vassilakopoulou, P. (2025). Understanding Human-Centred AI: a review of its defining elements and a research agenda. *Behaviour & Information Technology*, 1-40. https://doi.org/10.1080/0144929X.2024.2448719

Shi, Y., Gao, T., Jiao, X., & Cao, N. (2023). Understanding Design Collaboration Between Designers and Artificial Intelligence: A Systematic Literature Review. *Proceedings of the ACM on Human-Computer Interaction*, *7*(CSCW2), 1–35. https://doi.org/10.1145/3610217

Sison, A. J. G., Daza, M. T., Gozalo-Brizuela, R., & Garrido-Merchán, E. C. (2023). ChatGPT: More Than a "Weapon of Mass Deception" Ethical Challenges and Responses from the Human-Centered Artificial Intelligence (HCAI) Perspective. *International Journal of Human–Computer Interaction*, 1–20. https://doi.org/10.1080/10447318.2023.2225931

Sivertsen, C., Salimbeni, G., Løvlie, A. S., Benford, S. D., & Zhu, J. (2024, May). Machine Learning Processes as Sources of Ambiguity: Insights from AI Art. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (pp. 1-14). https://doi.org/10.1145/3613904.3642855

Stige, Å., Zamani, E. D., Mikalef, P., & Zhu, Y. (2024). Artificial intelligence (AI) for user experience (UX) design: A systematic literature review and future research agenda. *Information Technology & People, 37(6), 2324-2352*. https://doi.org/10.1108/ITP-07-2022-0519

Triantafyllopoulos, A., Schuller, B. W., İymen, G., Sezgin, M., He, X., Yang, Z., Tzirakis, P., Liu, S., Mertes, S., André, E., Fu, R., & Tao, J. (2023). An Overview of Affective Speech Synthesis and Conversion in the Deep Learning Era. *Proceedings of the IEEE*, *111*(10), 1355–1381. https://doi.org/10.1109/JPROC.2023.3250266

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., Levac, D., Ng, C., Sharpe, J. P., Wilson, K., Kenny, M., Warren, R., Wilson, C., Stelfox, H. T., & Straus, S. E. (2016). A scoping review on the conduct and reporting of scoping reviews. *BMC Medical Research Methodology*, *16*(1), 15. https://doi.org/10.1186/s12874-016-0116-4

van Rijn, P., Mertes, S., Schiller, D., Harrison, P. M. C., Larrouy-Maestri, P., André, E., & Jacoby, N. (2021). Exploring emotional prototypes in a high dimensional TTS latent space. *Interspeech 2021*, 3870–3874. https://doi.org/10.21437/Interspeech.2021-1538

Yin, Y., Xu, D., Wang, X., & Zhang, L. (2019). Adversarial feature sampling learning for efficient visual tracking. *IEEE Transactions on Automation Science and Engineering*, *17*(2), 847–857. https://doi.org/10.1109/TASE.2019.2948402

Yu, J., Ma, Z., & Zhu, L. (2023). The configurational effects of artificial intelligence-based hiring decisions on applicants' justice perception and organisational commitment. *Information Technology & People*. https://doi.org/10.1108/ITP-04-2022-0271

Zhang, J., Liu, Z., Lv, H., & Jiang, M. (2024). AI in e-learning: the affordance perspective. *Behaviour & Information Technology*, *43*(15), 3863-3892. https://doi.org/10.1080/0144929X.2023.2287660

Zheng, C., Yuan, K., Guo, B., Hadi Mogavi, R., Peng, Z., Ma, S., & Ma, X. (2024, May). Charting the Future of AI in Project-Based Learning: A Co-Design Exploration with Students. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (pp. 1-19). https://doi.org/10.1145/3613904.3642807

Zhu, Y., Li, Q., Wang, J., Xu, C., & Sun, Z. (2021). One Shot Face Swapping on Megapixels. *2021 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, 4832–4842. https://doi.org/10.1109/CVPR46437.2021.00480

A Study of Preservice Teachers Developing Teaching Competencies with VEX GO Robotics

Kamini Jaipal-Jamani
Brock University, St. Catharines, Canada

kjaipal@brocku.ca

Abstract: There is global impetus to include the learning of STEM skills across k-12 school curricula to keep abreast of changing occupational, economic and societal needs. The province of Ontario, Canada implemented a revised Grades 1-8: Science and Technology curriculum in 2022 that emphasises STEM learning across the elementary grades. However, majority of elementary teachers in Canada are generalists – they are expected to teach all subjects such as language, science, mathematics, and the arts. In this type of teacher education context, where majority of the elementary preservice teachers (PTs) do not have undergraduate degrees in the STEM disciplines, there is need to provide them with STEM experiences to develop their STEM knowledge and skills and their teaching competencies for elementary school STEM teaching. The literature shows that educational robotics (ER) can develop STEM skills in k-12 students. This paper reports on a study that examined how middle-school preservice teachers develop confidence and knowledge to teach about coding with VEX GO robotics. Data sources for n = 50 preservice teachers included a pre-questionnaire on prior knowledge, a pre- and post-questionnaire on confidence to teach with robotics, and a worksheet to guide activities and record coding solutions. Preservice teacher (PT) participants volunteered to participate and signed a consent form, approved by the university research ethics board. The quantitative data were analysed with SPSS version 29. The results were statistically significant for the effect of the robotics intervention on PTs' confidence about their competencies to use robotics in teaching and learning of middle school science and a large effect size was observed. The findings also revealed that PTs' participation in the robotics activity resulted in a gain in their reported knowledge about robotics to integrate in teaching and learning. The results inform the design of instructional experiences in Teacher Education courses to improve elementary preservice teachers' self-efficacy and competencies to teach with robotics in classrooms and also provide insights into the design of ER learning experiences for elementary school contexts.

Keywords: Preservice Teachers, Robotics, Self-efficacy, Teaching Competencies, STEM, Quantitative

1. Introduction

Over the past two decades, the implementation of educational robotics (ER) in educational settings has been widespread (Benitti, 2012; Darmawansah et al., 2023). Educational robotics (ER) involves the use of robotics kits, programming software, and computers as hands-on learning tools to foster problem-solving, critical thinking, collaboration and learning of STEM concepts and ideas (Eguchi, 2016, 2021). ER has been consistently implemented in informal learning settings such as in afterschool programs to develop k-12 students' STEM knowledge and skills (Benitti, 2012; Anwar, 2019). ER programs in formal school settings have been initiated as part of research projects (e.g., Papanikoloau, Frangou, & Alimisis, 2007), school board professional learning initiatives (e.g., Sinay et al, 2016) or introduced to enhance creativity and interest in STEM (e.g., Hendricks, Alemdar, & Ogletree, 2012; Master et al, 2017). The inconsistent implementation of ER to support STEM learning in schools is in part due to barriers such as typical school structures with discipline-based subjects and lack of funding and resources (Chiu, Price, & Ovrahim, 2015; Margot & Kettler, 2019). However, in the past decade, rapid scientific and technological advancements and the emergence of new interdisciplinary fields such as bioengineering and automation have spurred many countries to plan strategies for economic development that include integrating STEM and computing skills in formal school curricular (Vegas et al., 2021). Many countries have introduced STEM and computer science (CS) into school curricular over the past eight years. For example, South Africa introduced STEM, coding and robotics in their national curriculum in 2020 and implemented this curriculum incrementally in 2023, 2024 and 2025 (Department of Basic Education, 2024), and as a response to the European Commission's Digital Education Action Plan (European Commission, 2018), the Italian Ministry of Education in 2019 legislated that computer science and computational thinking (CT) be included in primary school curricula by 2022. Similarly, the Ministry of Education in the province of Ontario, Canada revised the science and technology grade 1-8 and grades 9 curricula in 2022 to include the development of STEM skills such as computational thinking, coding, and innovation as student learning expectations or outcomes. ER is recommended as a strategy for students to learn about science and technology concepts, do science, and develop solutions to technological problems in a hands-on, experiential way (Ontario Curriculum and Resources, 2022).

However, the inclusion of STEM and coding skills into the elementary science curriculum has exacerbated challenges already experienced by elementary PTs. In Ontario, elementary teachers are generalists; they are

required to teach all subjects such as math, science and technology, language, visual arts, music, and physical education even though they do not have undergraduate degrees in every curricular subject. In the science and technology subject, PTs are required to teach middle-school students, fundamental concepts of science and technology related to four strands: life systems, matter and energy, earth and space systems and structures and mechanisms (Ontario Curriculum and Resources, 2022). Since 2022, elementary teachers are also expected to provide students with coding and automation experiences. It has been found that elementary preservice teachers (PTs), with minimal formal education in the STEM and CS subjects, exhibit low levels of STEM knowledge and confidence to teach science (Kazemour, 2015).

This paper reports on a study that investigated how elementary PTs developed confidence to teach and knowledge of teaching competencies with respect to VEX GO robotics. The study builds on prior studies (e.g., Jaipal-Jamani & Angeli, 2017) that reported on PTs experiences learning with different robotics applications such as LEGO WeDo.

2. Literature Review

The literature provides an overview of the theoretical framework of teacher knowledge for teaching with technology and a brief review of studies on teacher and PT self-efficacy teaching with robotics.

2.1 Teacher Knowledge for Teaching With Technology

There is widespread consensus among teacher educators that learning to teach a subject involves teachers learning the disciplinary content (C), the pedagogy (P) involved in teaching, and the pedagogy unique or appropriate for teaching the content (the intersection of C and P) referred to as pedagogical content knowledge (PCK; Shulman, 1987). Likewise, learning to teach content with technology such as robotics involves teachers learning how to use the technology to teach content in ways that promote student learning of skills and content. With respect to teaching with technology, Koehler and Mishra's (2009) TPACK model provides a reliable framework for understanding teacher knowledge in this expanded context. In developing the TPACK model, Koehler and Mishra built upon the PCK model and included technology knowledge. The two technology knowledge (T) intersections with C and P, in this three-component, TPACK model give rise to two other knowledge components: Technological Content Knowledge (TCK) – knowledge about the ways in which technology can be used to represent and transform the content, and Technological Pedagogical Knowledge (TPK) – knowledge about the affordances and constraints of tools and how it affects pedagogical designs and strategies in relation to the disciplinary context (Koehler, Mishra, & Cain, 2013).

Besides TPACK being a theoretical model that elucidates teacher knowledge of content, pedagogy and technology and their knowledge intersections in the practice of teaching, the updated TPACK model explains the development of teaching with technology in practical educational contexts (Petco et al., 2025).

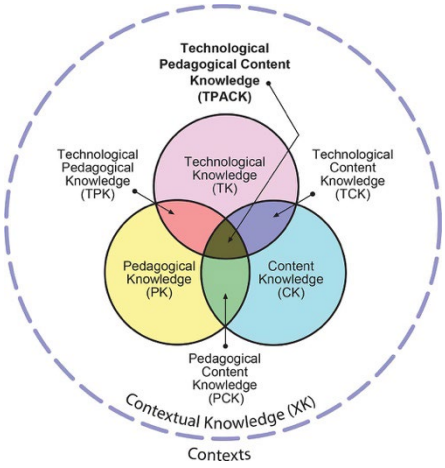


Figure 1: The updated TPACK model (Petco, Mishra & Koehler, 2025)

In figure 1, contexts or external influences is outside the dotted line and contextualised knowledge (XK) in on the inside of the dotted line. Contextual knowledge includes knowledge of the characteristics of the learner and classroom environment which promotes the transfer of teachers' technology teaching competencies from one context to another (Petko et al, 2025). TPACK and TPACK-related contextualized knowledge therefore develop

in “specific practical contexts” (Petco et al, 2025, p.4). The TPACK model, through the contextual knowledge component, reflects and reinforces the situated nature of how teachers learn teaching competencies. According to Roth and Jornet, (2013, p. 7), “learning is not viewed as the acquisition of knowledge contents but in terms of expanding the leaner’s action possibilities” in other contexts. The authors explain that “it is not an internal model that transfers to another setting but a set of subject-environment relations”. The situated theory of learning therefore explains that teaching competencies and skills are transferred when learned in situations that have similar situational aspects to those in which they are applied (Roth & Jornet, 2013). Competence is viewed as the latent cognitive abilities and affect-motivation that underlie performance in real world situations (Blömeke, Gustafsson, & Shavelson, 2015). In the real world of teaching, research has shown that transfer of knowledge by PTs is facilitated when learning with technology is situated in practical experiences that closely resemble conditions in real K-12 classrooms (Tondeur et al, 2012).

2.2 Teacher Self-efficacy Teaching With Robotics

Martin, Dennen and Bonk (2020) capture the current context for teaching by stating that “effective teaching has become more challenging with the introduction of digital and robotic technologies” (p. 221). Learning to teach with technology requires digital competencies that include being confident, critical, and responsible when using technologies for teaching and learning (European Union, 2018). Confidence or self-efficacy to teach is the belief or conviction that a teacher has in their ability and capability to execute a teaching task to achieve learning outcomes in a specific context (Bandura,1977; Tschannen-Moran & Woolfolk Hoy, 2001). Research shows that PTs with low self-efficacy beliefs to teach content will not readily integrate the content into their classroom teaching (Tschannen-Moran & Mcmaster, 2009). It can be argued that self-efficacy beliefs, like teaching competencies, are likely to transfer if the teacher encounters a teaching context that has similar situational aspects in terms of resources and constraints. However, in the current global context characterised by rapidly changing digital technologies, PTs may experience challenges because of a lack of knowledge and skills to use unfamiliar technologies, Hence, Tondeur et al (2025) argue that for PTs to develop strong digital competencies in ways that will help them gain confidence to teach with the technology, they need multiple exposure to strategies that foster technical, pedagogical, social and wellbeing or emotional competencies. In a recent meta-analysis, Tondeur et al updated the strategies in their Synthesis of Qualitative Data (SQD) model to prepare PTs for teaching with technology in changing digital classroom contexts. These strategies include: 1) familiarization through modelling pedagogical approaches and hands-on exploration, 2) reflective practice by critically reflecting on affordances and limitations of technology and doing research-based tasks, 3) collaborative instructional design activities to create rich digital learning experiences, 4) a cycle of scaffolded authentic teaching experiences and feedback support, and 5) supporting affective characteristics such as attitudes and beliefs, emotions and sensitivities to cultural and equitable views on the use of technology. Strategies such as modelling, scaffolding, curriculum alignment, hands-on coding experiences and reflective feedback with robotics can improve elementary PTs pedagogical content knowledge of coding and can result in gains in PT teaching efficacy beliefs to code with robotics (Kaya et al, 2020).

3. Methodology and Methods

The study design was a quasi-experimental, one-group pretest-posttest (Bernard, 2012). The research questions investigated were:

- What effect did the robotics activity have on PTs’ self-efficacy to teach with VEX GO robotics?
- How did the robotics activity affect PT’s knowledge about robotics for teaching and learning?

3.1 Study Context and Participants

This study occurred at a Canadian University in Ontario in the winter of 2023. Preservice teachers were in year 5 of a 6-year Concurrent Education, Junior Intermediate (JI) program which consisted of a 4-year honours undergraduate degree with mostly non-science majors and some education courses, followed by the 2-year Bachelor of Education (B.Ed.) teacher certification degree. During the 2022-2023 academic year, PTs completed language, math and some curriculum foundations courses in the fall semester of the B.Ed. program. This was followed by a 6-week school placement in a grade 4 - 8 classroom where PTs taught language and math and other subjects depending on what the host teacher at the school taught. All JI preservice teachers returned to the university for the winter semester and then completed the 12-week science and technology methods course. In this course, they were introduced to the Ontario science and technology curriculum for grades 4 – 10 through

theoretical and practical activities on topics such as unit planning, lesson planning, assessment, scientific inquiry, engineering design, scientific research, science micro-teaching, cross-curricular subject connections, environmental education, Indigenous perspectives, coding with microbits and automation with robotics. Due to the many curriculum topics covered in the course, one three-hour session was spent on automation and robotics.

The ER activity with VEX GO robotics was taught by the author to PTs in three class sections. Each section had enrolments that ranged from 20 to 30 students. The robotics class began with an interactive lecture that introduced the definition of automation and robotics, examples of applications of robots, explanation of coding concepts such as algorithms, program, debugging, coding languages, and science curriculum connections. The author then demonstrated how to use the VEX GO robotics coding platform and explained the worksheet activities. Preservice teachers worked in groups of 3 or 4 and followed the directions on the scaffolded worksheet on how to build the robot driving base, connect to the codegogo.vex.com coding platform website. The coding exercises guided PTs to code the base robot to make simple moves in a straight line followed by a simple challenge, to coding for turns, and then creating code for a complex, yet familiar, real world challenge: to autonomously park the driving base using parallel or perpendicular parking. A total of 50 PTs completed the pre- and post- data questionnaires.

3.2 Ethical Considerations

Permission to conduct the study was obtained from the university. Since the researcher/author was the instructor of the course, a graduate research assistant invited PTs to participate in the study. PTs were told that participation was voluntary and that they could withdraw at any time from the study without penalty; there would be no effect on their grades. There were a few students in each class section who did not provide consent; these PTs participated in the robotics activity but their data were not included in the study.

3.3 Data Sources and Data Analysis

Sources of data for this paper included a questionnaire that asked about prior experiences with robotics, a robotics questionnaire that included 4 items about PT confidence on their skills to use robotics in teaching, and two questions on knowledge of robotics for teaching. All data were analysed using IBM SPSS Statistics version 29.0.1.0.

The robotics self-efficacy questionnaire consisted of 4 items that rated confidence on a scale from 0 to 100 (from not confident to completely confident) and coded in SPSS from 0 to 10. Items were 1) I feel confident that I have the skills necessary to use robotics coding applications for simple classroom STEM activities such as robots moving forward, 2) I feel confident that I have the skills necessary to use robotics coding applications for more complex classroom STEM activities such as coding for parallel parking and motion sensors, 3) I feel confident that I can help students when they have difficulty coding robots to perform simple tasks (e.g., use of moving and turning motions), and 4) I feel confident that I can help students when they have difficulty with coding robots to perform more complex tasks (e.g., avoiding collisions using sensors, creating variables with if.. then conditions). The same questionnaire was administered prior to the robotics intervention, Cronbach's alpha = 0.930, and a week after the robotics intervention, Cronbach's alpha = 0.944, suggesting a good level of reliability.

The two knowledge items scored on a Likert scale of 1 (strongly disagree) to 5 (strongly agree) were, 1) I have sufficient knowledge of coding as it applies to robotics, and 2) I have sufficient knowledge about robotics to integrate in teaching and learning JI science. A test was not used to measure knowledge as tests are not used to assess PTs learning in this course. The same questionnaire was administered before and a week after the robotics intervention. The Spearman-Brown Coefficient (Eisinga et al., 2013) was used to test for reliability; pre-knowledge Spearman-Brown Coefficient = 0.741; post-knowledge Spearman-Brown Coefficient = 0.786 suggesting an acceptable level of reliability for the two items.

All pre- and post-data were tested for normality. The resulting Shapiro–Wilk significance values were less than 0.05 indicating the data did not follow normal distribution. Hence, the non-parametric Wilcoxon Signed test was used to compare all pre- to post-data scores and the effect size was calculated with the formular: $r = z/\sqrt{2n}$ with values for r = 0.10 (small effect), 0.30 (moderate effect) and 0.5 (large effect; Fritz et al, 2012).

4. Results

4.1 Demographics and Prior Experience With Robotics

Fourteen males and 36 females participated in the study as shown in Table 1.

Table 1: Number of male and female preservice teacher participants

Gender		
	N	%
male	14	28.0%
female	36	72.0%

Figure 2 illutrates PTs' prior experiences with coding and robotics. 46% of the PTs had few prior experiences with robotics (the one experience many had was coding a different robot application in their math methods class in the fall semester), 24% had some experiences (math methods class and some exposure teaching coding with mainly Scratch at schools), and 28% had used robotics many times (math methods, prior university courses, taught coding during practicum or used robotics to teach at STEM summer camps).

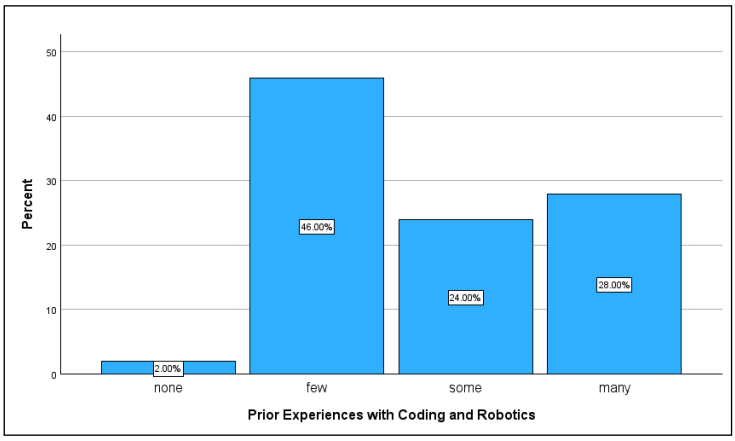


Figure 2: Preservice teachers prior experiences with coding and robotics

4.2 Preservice Teachers' Self-efficacy to Teach With Robotics

Null Hypothesis: Ho: There is no difference in preservice teachers' self-efficacy to teach with robotics before and after the robotics intervention.

Alternate Hypothesis: H1: There is a difference in preservice teachers' self-efficacy to teach with robotics before and after the robotics intervention.

The sum of 4 knowledge items (total score equal to 40) was compared pre and post intervention.
The Wilcoxon Signed Test revealed that PT post self-efficacy scores (*Mdn rank* = 26) were statistically significant compared to pre self-efficacy scores (*Mdn rank* = 12.5) with W= 1078.50, $z = -5.879$, $p < 0.001$ as shown in Tables 2, 3 and 4. The null hypothesis is rejected and the alternate hypothesis is accepted indicating that the robotics intervention did result in gains in PTs' self-efficacy. The findings show a large effect size of r = z/√2n = 5.879//√2*50 = 0.5879.

Table 2: Descriptive statistics for PT pre-post self-efficacy to teach with robotics

Descriptive Statistics for Four Items on Self-Efficacy								
	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
PREsum	50	13.3900	9.69446	.00	38.00	4.0000	12.5000	19.5000
POSTsum	50	25.2400	7.18718	4.00	38.00	22.7500	26.0000	30.1250

Table 3: Wilcoxon signed ranks test for PT pre-post self-efficacy to teach with robotics

Ranks				
		N	Mean Rank	Sum of Ranks
POSTsum – PREsum	Negative Ranks	1[a]	2.50	2.50
	Positive Ranks	45[b]	23.97	1078.50
	Ties	4[c]		
	Total	50		

a. POSTsum < PREsum

b. POSTsum > PREsum

c. POSTsum = PREsum

Table 4: Statistics for Wilcoxon signed ranks test for PT pre-post self-efficacy to teach with robotics

Test Statistics[a]	
	POSTsum - PREsum
Z	-5.879[b]
Asymp. Sig. (2-tailed)	<.001
Exact Sig. (2-tailed)	<.001
Exact Sig. (1-tailed)	<.001
Point Probability	.000

a Wilcoxon Signed Ranks Test

b Based on negative ranks.

4.3 Preservice Teachers Knowledge of Robotics for Teaching

With respect to knowledge item 2, *I have sufficient knowledge about robotics to integrate in teaching and learning of Junior-intermediate (JI) science*, only 4 % of PTs reported that they agreed with this statement prior to the intervention (see figure 3).

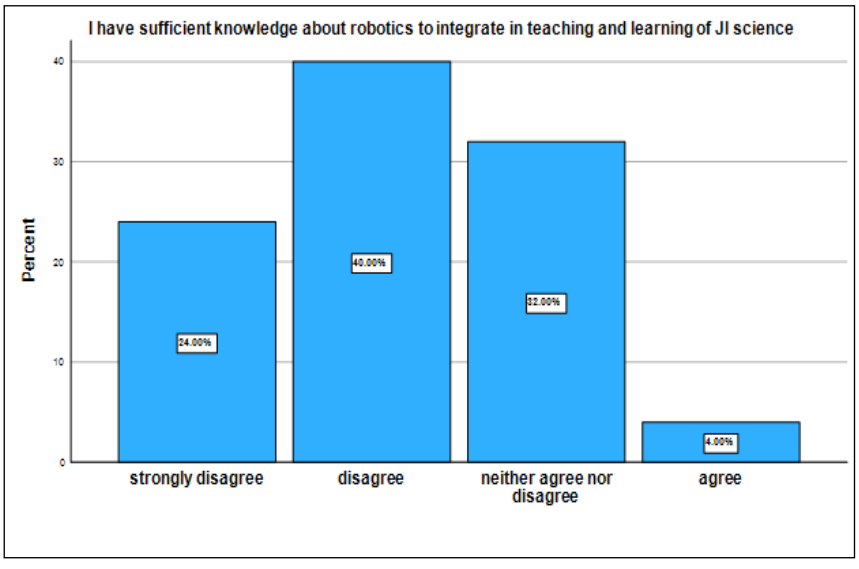


Figure 3: Pre-intervention knowledge about robotics to integrate in teaching and learning

After the robotics activity, 62 % PTs agreed and 10% strongly agreed that they had sufficient knowledge about robotics to integrate into teaching and learning (see figure 4)

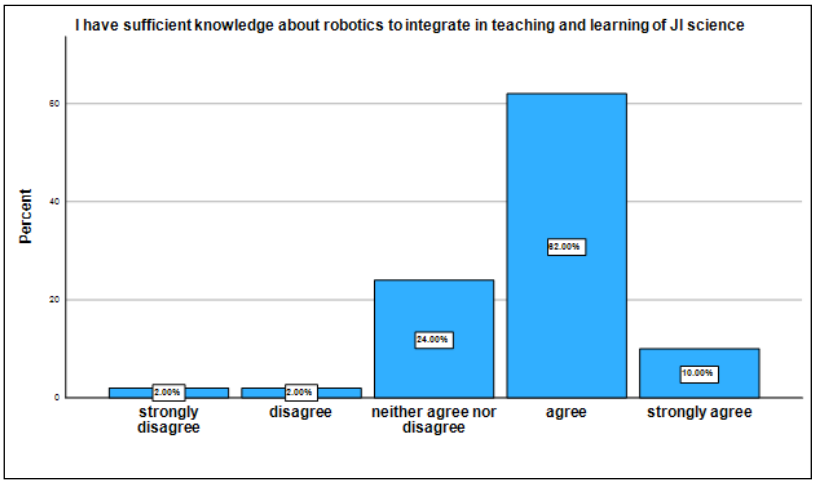


Figure 4: Post-intervention knowledge about robotics to integrate in teaching and learning

Preservice teachers' knowledge about robotics for teaching was compared statistically to find out the impact of the robotics intervention. The sum of the pre- and post-scores for both knowledge items did not follow normal distribution; Shapiro–Wilk significance values were less than 0.05. Hence, the non-parametric Wilcoxon Signed test was used to compare knowledge gains from pre- to post-data with statistical data shown in Tables 5, 6 and 7. The hypotheses were:

- H0: There is no difference in PT knowledge about robotics for teaching before and after the robotics intervention.
- H1 There is a difference in PT knowledge about robotics for teaching before and after the robotics intervention.

The Wilcoxon signed-rank test showed a statistically significant median rank difference between post-reported knowledge about robotics for teaching (*Mdn rank* = 8) when compared to pre-reported knowledge of robotics for teaching (*Mdn rank* = 4) with W = 1128, $z = -6.006$, $p < 0.001$. The results indicate that PTs gained knowledge about robotics for teaching as it applied to the VEX Go robotics after participating in the robotics intervention. The effect size was $r = z/\sqrt{2n}$; $r = 6.006/\sqrt{2}*50 = 0.6006$ which indicates a large effect size suggesting that the VEX GO robotics intervention did have practical significance for PTs to learn knowledge about robotics for teaching.

Table 5: Descriptive Statistics for PT knowledge about robotics for teaching

Descriptive Statistics								
	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
SUMPREknowledge	50	4.4200	1.62995	2.00	8.00	3.0000	4.0000	6.0000
SUMPOSTknowledge	50	7.3600	1.33646	2.00	10.00	6.0000	8.0000	8.0000

Table 6: Ranks for the Wilcoxon signed ranks test

Ranks				
		N	Mean Rank	Sum of Ranks
SUMPOSTknowledge - SUMPREknowledge	Negative Ranks	0[a]	.00	.00
	Positive Ranks	47[b]	24.00	1128.00
	Ties	3c		
	Total	50		
a SUMPOSTknowledge < SUMPREknowledge b SUMPOSTknowledge > SUMPREknowledge c SUMPOSTknowledge = SUMPREknowledge				

Table 7: Wilcoxon signed rank test statistics

Test Statistics[a]	
	SUMPOSTknowledge - SUMPREknowledge
Z	-6.006[b]
Asymp. Sig. (2-tailed)	<.001
Exact Sig. (2-tailed)	<.001
Exact Sig. (1-tailed)	<.001
Point Probability	.000
a Wilcoxon Signed Ranks Test b Based on negative ranks.	

5. Discussion and Implications

With the expectation that coding and automation concepts, be taught in elementary schools in Ontario, Canada since 2022, this study investigated the effect of a robotics intervention with VEX GO robotics on junior-intermediate (JI) preservice teachers' (PTs') self-efficacy and knowledge with respect to robotics for teaching. All findings were statistically significant. PTs self-efficacy to teach with robotics after the intervention increased from M= 13.39 to M= 25.24 with a large effect size observed (r = 0.5879). While the intervention did improve participants' self-efficacy, the means suggest that PTs are still not fully confident and will require more practice. PTs' knowledge about robotics for teaching showed strong gains from pre- to post-intervention with effect size (r) = 0.6006. These findings together suggest that the targeted, scaffolded intervention that guided PTs learning from simple to more complex coding tasks was effective at improving PTs' self-efficacy to teach with robotics and it improved their knowledge about robotics for teaching and learning in JI science. Other studies which have used scaffolded programming strategies specific to robotics applications have reported gains in PT self-efficacy to teach with robotics (Jaipal-Jamani & Angeli, 2017; Kaya et al, 2020; Schina et al, 2021). The use of a scaffolded programming strategy to teach PTs how to integrate specific robotics coding applications into teaching and learning also supports calls for the use of targeted strategies to develop PT digital competencies (Tondeur et al, 2025). Besides scaffolding, collaboration, authentic experiences, and critical reflection on pedagogy are strategies that can be used in Teacher Education programs to develop PT competencies. These strategies also add to contextual knowledge for developing TPACK (Petco, Mishra & Koehler, 2025). As illustrated in this study, PTs participated in robotics activities that were designed to model classroom pedagogy and were linked to middle school curricular learning outcomes. PTs collaborated in groups of 3 and 4 similar to how middle school students work in a classroom, the instructor modelled how robotics concepts were to be introduced by the teacher, and PTs participated in hands-on robotics activities to learn coding and problem-solve an authentic, real-world problem – parking a vehicle autonomously. PTs, in their role as middle school learners, experienced the activity as learners in a practical context similar to a classroom. As they experienced the affordances and constraints associated with the technology, they were developing TPK. The choice to use VEX GO robotics was made because the two local schoolboards provide these robotics resources to schools. Using the same robotics resources used in the local classroom context increases the similarity of situational aspects and improves transfer of teaching competencies into the classroom (Roth & Jornet, 2013).

6. Limitations of Study

The study results are based on self-report data and reflect PTs perceptions of their self-efficacy and knowledge at a particular point in time. Due to how the Teacher Education program is designed, PTs could not be observed in real classrooms teaching with robotics to find out if they did make the transfer of competencies learned into the classroom. The small sample size limits generalizations of results to JI PTs in other universities or to the secondary PT population due to different contextual factors. For example, secondary school PTs, with specialised science majors may have different prior knowledge with STEM skills and robotics. While the ratio of males to females in the study was not balanced, 28:72, it is consistent with trends in the population of elementary male and female teachers in schools in the region. The ratio reported for male: female teachers at the two schoolboards in the Niagara region in 2019-2020 was 21:79 (Government of Ontario. 2020). Similar to Piedade et al (2020) findings, a correlation test revealed that the gender of PTs did not have an effect on PT self-efficacy or knowledge of robotics. There was a correlation between prior knowledge and PT self-efficacy which is beyond the scope of this paper due to word limitations. The results are also limited to PTs' experiences learning how to

teach with VEX GO robotics and may not necessarily reflect how their teaching competencies and self-efficacy would be affected if using another robotics application.

7. Conclusion

The findings of this study indicate that the modelling of robotics teaching and learning in a similar school classroom context, and with an authentic robotics problem context, supports the transfer of technological pedagogical knowledge and teaching competencies into the real classroom reinforcing the current literature (Petco, Mishra, & Koehler, 2025; Tondeur et al, 2025). The use of these strategies in the science and technology methods course resulted in positive gains for PTs in terms of self-efficacy and knowledge to teach robotics. Since there is a significant correlation between PT self-confidence and knowledge of robotics (Piedade et al, 2020), the modelling of pedagogy in authentic contexts is recommended as a practical strategy for developing elementary PTs' self-efficacy and TPACK knowledge for teaching with robotics.

Ethics Declaration

This study received ethics clearance through the Research Ethics Board at Brock University.

AI Declaration

No AI tools were used in the writing of this paper.

References

Anwar, S., Bascou, N. A., Menekse, M. and Kardgar, A. (2019) "A Systematic Review of Studies on Educational Robotics", *Journal of Pre-College Engineering Education Research,* Vol 9, No. 2, pp 1–24.

Bandura, A. (1977) "Self-efficacy: Toward a Unifying Theory of Behavioral Change", *Psychological Review*, Vol 84, pp 191–215.

Benitti, F. B. V. (2012) "Exploring The Educational Potential of Robotics in Schools: A Systematic Review", *Computer Education,* No. 58, pp 978–988.

Bernard, H.R. (2012) *Social Research Methods: Qualitative And Quantitative,* Sage, Thousand Oaks, California.

Blömeke, S., Gustafsson, J. and Shavelson, R. J. (2015) "Beyond dichotomies: Competence Viewed as a Continuum", *Zeitschrift für Psychologie*, Vol 223, pp 3–13.

Ching, Y. H., Yang, D., Wang, S., Baek, Y., Swanson, S. and Chittoori, B. (2019) "Elementary School Student Development of STEM Attitudes and Perceived Learning in a STEM Integrated Robotics Curriculum", *TechTrends,* Vol 63, pp 590–601.

Chiu, A., Price, C. A., and Ovrahim, E. (2015) "Chicago-area K-8 teacher and Administrator Perceptions of STEM Education", *Museum of Science and Industry,* pp 1–24.

Council of European Union (2018), *Council Recommendation on Key Competences for Lifelong Learning,* European Union.

Darmawansah, D., Hwang, GJ., Chen, MR.A. and Liang, J.C. (2023) "Trends and Research Foci of Robotics-Based STEM Education: A Systematic Review from Diverse Angles Based on the Technology-Based Learning Model", *International Journal of STEM Education,* Vol 10, No. 1 , pp 1–24.

Department of Basic Education (2024), *National Curriculum Statement (NCS): Curriculum and Assessment Policy Statement Pretoria*, Department of Basic Education, Republic of South Africa.

Eguchi, A. (2016) "Educational Robotics as a Learning Tool for Promoting Rich Environments for Active Learning (REALs)", *Human-computer Interaction: Concepts, Methodologies, Tools, and Applications*, Ed. M. Khosrow-Pour, IGI Global, Hershey, PA, pp 740–767.

Eguchi, A. (2021) "Theories and Practices behind Educational Robotics for all", *Handbook of Research on Using Educational Robotics to Facilitate Student Learning*, Eds. S. Papadakis and M. Kalogiannakis, IGI Global, Hershey, PA, pp 68–106.

Eisinga, R., Grotenhuis, M.T., and Pelzer, B. (2013) "The reliability of a Two-item Scale: Pearson, Cronbach, or Spearman-Brown?" *International Journal of Public Health,* Vol 58, pp 637–642.

Kaya, E., Newley, A., Yesilyurt, E. and Deniz, H. (2020). "Measuring Computational Thinking Teaching Efficacy Beliefs of Preservice Elementary Teachers, *Journal of College Science Teaching*, Vol 49, No. 6, pp 55-64.

Fritz, C. O., Morris, P. E. and Richler, J. J. (2012) "Effect Size Estimates: Current Use, Calculations, and Interpretation", *Journal of Experimental Psychology: General,* Vol 141, NO. 1, pp 2–18.

Government of Ontario (2020) *Number of full-time equivalent educators by gender and school board in Ontario*, [online]. Ministry of Education, Ontario, https://data.ontario.ca/dataset/number-of-full-time-equivalent-educators-by-gender-and-school-board-in-ontario

Hendricks, C. C., Alemdar, M. and Ogletree, T. W. (2012) "The Impact of Participation in VEX Robotics Competition on Middle and High School Students' Interest in Pursuing STEM Studies and STEM-Related Careers", Proceedings of ASEE Annual Conference & Exposition, pp. 1–16.

Jaipal-Jamani, K. and Angeli, C. (2017) "Effect of Robotics on Elementary Preservice Teachers' Self-Efficacy, Science Learning, and Computational Thinking", *Journal of Science Education and Technology,* Vol 26, pp 175–192.

Kaya, E., Newley, A., Yesilyurt, E. and Deniz, H. (2020) "Measuring Computational Thinking Teaching Efficacy Beliefs of Preservice Elementary Teachers". *Journal of College Science Teaching*, Vol 49, No. 6, pp 55–64.

Kazempour, M. and Sadler, T. D. (2015) "Pre-Service Teachers' Science Beliefs, Attitudes, and Self-Efficacy: A Multi-Case Study". *Teaching Education (Columbia, S.C.)*, Vol 26, No. 3, pp 247–271.

Koehler, M. and Mishra, P. (2009). "What is Technological Pedagogical Content Knowledge (TPACK)?" *Contemporary Issues in Technology and Teacher Education*, vol 9, No. 1, pp 60–70.

Koehler, M. J., Mishra, P. and Cain, W. (2013) "What is Technological Pedagogical Content Knowledge (TPACK)?", *Journal of Education*, Vol 193, No. 3, pp 13-19.

Margot, K.C. and Kettler, T., (2019) "Teachers' Perception of STEM Integration and Education: A Systematic Literature Review", *International Journal of STEM Education*, Vol 6, No. 1, pp1–16.

Martin, F., Dennen, V.P. and Bonk, C.J. (2020) "A Synthesis of Systematic Review Research on Emerging Learning Environments and Technologies", *Educational Technology Research and Development,* Vol 68, No. 4, pp 1613–1633.

Ontario Curriculum and Resources (2022) *Grades 1–8: Science and Technology*, [online]. Ontario Ministry of Education, Ontario , Canada, https://www.dcp.edu.gov.on.ca/en/curriculum/science-technology.

Papanikolaou, K., Frangou, S. and Alimisis, D. (2008) "Teachers as Designers of Robotics-enhanced Projects: The TERECoP Course in Greece", Proceedings of the SIMPAR 2008 conference/workshop: Teaching
with Robotics: Didactic Approaches and Experiences. University of Padova, Padua, Italy, pp 100–111.

Petko, D., Mishra, P. and Koehler, M.J. (2025) "TPACK in Context: An Updated Model", *Computers and Education Open*, Vol 8, pp 1-5.

Piedade, J., Dorotea, N., Pedro, A. and Matos, J.F. (2020) "On Teaching Programming Fundamentals and Computational Thinking with Educational Robotics: A Didactic Experience with Pre-Service Teachers", *Education Sciences*, vol 10, No. 9, pp 1-15.

Roth, W.M. and Jornet, A. (2013) "Situated Cognition", *Wiley Interdisciplinary Reviews: Cognitive Science*, Vol 4, No. 5, pp 463–478.

Schina, D., Valls-Bautista, C., Borrull-Riera, A., Usart, M. and Esteve-González, V. (2021) "An Associational Study: Preschool Teachers' Acceptance and Self-Efficacy Towards Educational Robotics in a Pre-Service Teacher Training Program", *International Journal of Educational Technology in Higher Education,* vol 18, No. 28, pp 1–20.

Shulman, L. (1987) "Knowledge and Teaching: Foundations of the New Reform", *Harvard Educational Review*, Vol 57, No. 1, pp 1-23.

Sinay, E., Jaipal-Jamani, K., Nahornick, A. and Douglin, M. (2016) *STEM Teaching and Learning in the Toronto District School Board: Towards a Strong Theoretical Foundation and Scaling up from Initial Implementation of the K-12 STEM Strategy. Research Series I, Report No. 15/16-16,* Toronto District School Board, Toronto, Ontario, Canada.

Tondeur J., Van Braak J., Sang G., Voogt J., Fisser P. and Ottenbreit-Leftwich A. (2012) "Preparing Pre-service Teachers to Integrate Technology in Education: A Synthesis of Qualitative Evidence", *Computers and Education*, Vol 59, No. 1, pp 134–44.

Tondeur, J., Trevisan, O., Howard, S.K. and van Braak, J. (2025) "Preparing Preservice Teachers to Teach with Digital technologies: An Update of Effective SQD-strategies", *Computers and Education*, Vol 232, pp 1–17.

Tschannen-Moran, M. and McMaster, P. (2009) "Sources of self-efficacy: Four Professional Development Formats and their Relationship to Self-efficacy and Implementation of a New Teaching Strategy", *The Elementary School Journal*, Vol 110, No. 2, pp 228–245.

Tschannen-Moran, M. and Woolfolk Hoy, A. (2001) "Teacher efficacy: Capturing an Elusive Construct", *Teaching and Teacher Education,* Vol 17, No. 7, pp 783–805.

Vegas, E., Hansen, M. and Fowler, B. (2021) *Building Skills for Life*: *How to Expand and Improve Computer Science Education around the World*, Bookings, Washington, DC.

A Large-Scale Study on the Effects of Motivation on Academic Test Performance

Michael D. Kickmeier-Rust and Katharina Richter
St.Gallen University of Teacher Education, St.Gallen, Switzerland

michael.kickmeier@phsg.ch
katharina.richter@phsg.ch

Abstract: Motivation plays a crucial role in academic performance. In educational research, particularly in technology-enhanced learning, a strong correlation between motivation and performance is often assumed. However, existing studies present inconsistent findings, with some showing only low to moderate correlations between self-reported motivation and actual academic achievement. This study investigates the relationship between intrinsic motivation, restedness, and test performance, including response times, in large-scale assessments in Mathematics. These tests were administered to an extensive sample of over 26,000 and 27,000 students, respectively. The findings indicate significant but relatively small correlations between motivational and performance variables. Notably, post-test motivation proves to be a stronger predictor of test outcomes than pre-test motivation. This suggests a complex dynamic between intrinsic and extrinsic motivational factors, implying that extrinsic incentives may have a more substantial impact on actual test performance. Stepwise linear regression further differentiates the influences, illustrating the roles of personal background, prior academic achievements, and motivation as latent factors contributing to test scores. Although the overall explained variance remains moderate, this study provides valuable insights into a rarely explored aspect of motivation—its assessment after a test and its predictive capacity. While much of the existing literature emphasizes motivation before a test, these findings suggest that motivation measured after an academic task may better capture students' effort and engagement. Additionally, the study raises methodological concerns regarding the reliability of self-reported motivation, highlighting potential issues with survey validity, such as response tendencies like straight-lining. The results have significant implications for educational assessment practices and research methodologies. They underscore the need for a holistic approach to understanding academic performance and the diverse motivational processes involved.

Keywords: Intrinsic Motivation, Restedness, Test Performance, Secondary School Level, Representative Sample

1. Introduction

Human behavior, including academic performance, is shaped by various factors, with motivation playing a central role. As the driving force behind goal pursuit, motivation lacks a universal definition (Bandhu et al., 2024). However, several theoretical models provide insight, such as Arousal Theory (Reisenzein, 2017), Attribution Theory (Weiner, 1972), the ARCS model (Keller, 1987), and Self-Determination Theory (Deci & Ryan, 2008). These frameworks emphasize self-efficacy, attribution styles, and the distinction between intrinsic and extrinsic motivation. In learning contexts, motivation influences engagement and knowledge acquisition (Svinicki & Vogler, 2012), making it a crucial factor in educational success. It also impacts instructional design, didactics, and the development of educational technologies (Urhahne & Wijnia, 2023). Literature on instructional design highlights the importance of intrinsic motivation, notably advanced by Malone and Lepper's (1987) work on making learning enjoyable. While motivation is often assumed to be a key predictor of academic performance, particularly in technology-based education like gamification and serious games, its relationship with achievement remains complex. Empirical evidence is inconsistent, hindered by small sample sizes and methodological limitations, raising concerns about generalizability. Furthermore, the individualized nature of motivational factors in education remains a subject of debate. Motivation is a key factor in academic performance, but its influence varies across different contexts. A critical distinction is made between intrinsic and extrinsic motivation, as well as low-stakes and high-stakes scenarios. High-stakes assessments, such as exams, typically elicit strong extrinsic motivation, driven by rewards, grades, or consequences. Conversely, in low-stakes contexts, such as formative assessments and adaptive learning technologies, intrinsic motivation plays a more central role. Understanding these dynamics is crucial for educators seeking to optimize student learning experiences (Liu, Bridgeman & Adler, 2012).

1.1 The Impact of Motivation on Academic Performance

Intrinsic motivation, characterized by genuine interest in learning, fosters deeper engagement and knowledge retention. In contrast, extrinsic motivation enhances performance, particularly in structured assessments (Cerasoli et al., 2014). While intrinsic motivation encourages persistence and meaningful learning, extrinsic incentives are often better predictors of the quantity of effort exerted. Yu et al. (2020) found that educational games enhance motivation and engagement, suggesting that enjoyable activities promote better learning

outcomes. However, when extrinsic rewards are linked directly to performance, intrinsic motivation tends to decline, a trend observed by Akhtar and Firdiyanti (2023). Afzal et al. (2010) emphasizes the role of educators in fostering student interest, which enhances intrinsic motivation. The combination of gamification and instructional design strategies can increase motivation and engagement, especially in low-stakes assessments where the perceived importance of the test may be diminished (Shell et al., 2019). The relationship between motivation and cognitive learning strategies has been widely researched. A strong correlation exists between motivation and student performance, particularly in settings that encourage deeper engagement with content (Ramírez-Arellano et al., 2018). Motivation also influences students' ability to adapt to academic environments, affecting their resilience and overall learning experience (Lo et al., 2022). Wang (2022) highlights that intrinsic motivation plays a critical role in students' performance in online learning environments, reinforcing the idea that motivation enhances focus and persistence in academic pursuits. Research by Chan et al. (2015) supports these findings, demonstrating that intrinsically motivated students report higher satisfaction with online learning, which improves engagement and academic success. This underscores the need for educators to cultivate motivation through interactive and engaging educational methodologies.

1.2 Nuanced Perspectives on Motivation and Performance

While many studies find a moderate to strong correlation between intrinsic motivation and performance, recent analyses introduce a more complex perspective. Silm, Pedaste, and Tährt (2020) found that self-reported effort showed a moderate correlation with academic achievement ($r = .33$), whereas response time effort (RTE) had a much stronger correlation ($r = .72$). Akhtar and Firdiyanti (2023) further explored test motivation in low-stakes assessments, comparing Self-Reported Effort (SRE) and RTE. Their findings reveal that while these indicators capture different aspects of motivation, RTE is a stronger predictor of test outcomes ($\beta = 0.67$ vs. $\beta = 0.12$ for SRE), suggesting that behavioral measures of effort may provide a more reliable gauge of academic performance. Xu et al. (2020) confirmed these observations in a large sample of 8th graders, finding only moderate correlations between self-reported intrinsic motivation and mathematics test performance ($r = .37$ and $r = .29$). In adults, Ulum and Küçükaydın (2024) found only a weak correlation ($r = .16$) between motivation and math achievements. The research base on motivation in primary and secondary education is smaller than for higher education. Silm, Pedaste, and Tährt (2020) report that test-taking effort correlates more strongly with performance among university students than among school-aged learners. This suggests that academic experience and maturity influence how motivation translates into achievement. These findings highlight the complex interplay between intrinsic and extrinsic motivation and its impact on academic success. While intrinsic motivation fosters engagement and long-term retention, extrinsic incentives drive immediate performance, particularly in structured assessments. However, response time effort (RTE) may serve as a more reliable behavioral indicator of exertion than self-reported motivation, offering valuable insights into student engagement.

A key source of data on student motivation and academic performance in secondary education comes from the OECD PISA studies. Kriegbaum, Jansen, and Spinath (2015) found that self-efficacy and self-concept significantly predict mathematics performance, even in low-stakes tests with minimal direct consequences. However, achievement motivation emerged as only a moderating variable, influencing test success through intelligence and prior achievements. Their analysis identified self-efficacy as the strongest motivational predictor. Wang et al. (2023) conducted a meta-analysis of PISA-related studies, revealing mixed and sometimes contradictory findings on the relationship between intrinsic motivation and mathematics achievement. The authors failed to establish a clear causal pattern of intrinsic motivation affecting academic outcomes, emphasizing the role of analytical methods and other influential factors such as test anxiety and attitudes toward school. Similarly, Mews and Pöge (2019) reported that intrinsic motivation has only limited explanatory power compared to self-efficacy.

A review of existing literature suggests that the role of intrinsic motivation in academic performance may often be overestimated. Its impact is intertwined with various individual factors, such as self-efficacy, attitudes toward subjects and school, and extrinsic motivators. While intrinsic motivation is often highlighted as a driver of academic success, studies indicate that self-efficacy plays a more influential role in determining student achievement. This study aims to clarify the role of intrinsic motivation in low-stakes academic tests by analyzing a large sample of secondary school students. Through rigorous statistical methods and comprehensive datasets, the research seeks to overcome previous study limitations and offer new insights into how motivation influences test performance. A central question explored is whether post-test motivation serves as a more reliable predictor of academic performance than pre-test motivation, thereby challenging traditional methods of assessing motivational factors in educational research.

To analyze the relationship between self-reported intrinsic motivation, restedness, and academic performance, this study employs a robust methodological approach to examine how these psychological factors interact with test outcomes. The research is structured around three key questions:

RQ1: Does self-reported motivation prior to the test affect test scores and test duration?

RQ2: Does self-reported restedness prior to the test affect test scores and test duration?

RQ3: Is self-reported motivation after the test correlated with test scores and test duration?

These questions are crucial for understanding students' psychological states in low-stakes testing environments, where external pressures are minimized, and intrinsic motivation becomes a key driver of performance. By examining the interplay between motivation, restedness, and test results, the study aims to provide insights that inform educational strategies and assessment practices. By analyzing large-scale data, this research seeks to refine current approaches to motivation assessment and provide reliable insights into how intrinsic motivation functions in low-stakes academic tests. The findings will contribute to discussions on student engagement, mental well-being, and effective assessment techniques, ensuring that academic evaluations account for psychological factors that influence learning outcomes.

2. Method

2.1 Participants

This study analyzed two datasets from a standardization study on German and Math test items. The Math dataset included results from 26,226 students across St. Gallen (11,683) and Zürich (14,543); 48% were male and 52% female. Students were distributed across grades: 35% in 7th, 40% in 8th, and 29% in 9th. Typically, 7th graders are around 12.5 years old. The academic distribution was as follows: 29% attended “Realschule” (lowest achievement level), 49% “Sekundarschule” (intermediate level), and 22% “Gymnasium” (highest level). The German dataset consisted of 27,307 students from St. Gallen (11,820) and Zürich (15,487); 49% male and 51% female. Grade distribution was 34% in 7th, 38% in 8th, and 28% in 9th, with 7th graders averaging 12.5 years of age. The academic distribution mirrored the Math dataset: 29% in “Realschule,” 49% in “Sekundarschule,” and 22% in “Gymnasium.”

2.2 Materials

The data were collected in the 2017 standardization of the Stellwerk test (https://stellwerk.ch), a high-stakes computer adaptive test (CAT; Bock & Gibbons, 2021) using Rasch-scaled (Fischer & Molenaar, 1995) dichotomous items. Widely used in German-speaking Swiss cantons, the test is mandatory in some regions (typically in 8th grade) and optional in others. It assesses Mathematics, German (mother tongue), English, French, and Science (Biology, Physics, Chemistry), with results utilized for educational monitoring and student placement. Employers often require test scores for apprenticeships and job applications. The Stellwerk test selects items dynamically from a large pool, necessitating calibration through large-scale standardization studies to determine item difficulty. Results are reported on a standardized 200-800 scale. The Math test assesses algebra, geometry, and data/probability (Figure 1). Item formats include multiple-choice, sorting, selection tasks, and free-text entries. The standardization process employed test booklets, each containing 28 difficulty-balanced items tailored to grade levels. The test duration averaged 50 minutes, with valid completion times ranging from 12 minutes 30 seconds to 2 hours. Outliers were omitted. Motivation was assessed using brief four-item Likert-scale surveys before and after testing. The pre-test survey included statements like “I will make an effort in doing the test,” while the post-test survey adapted them to past tense. A restedness scale gauged student energy levels, ensuring minimal disruption to testing.

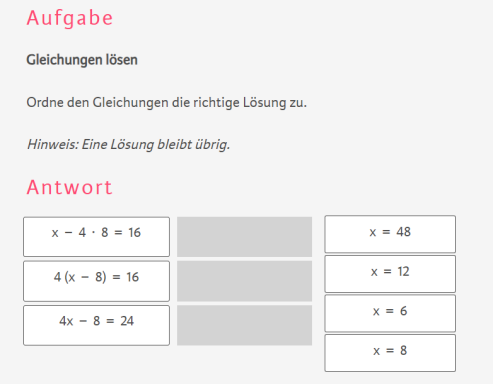


Figure 1: Example test item for Mathematics.

3. Results

For the present paper, we analyzed the data of the Stellwerk test in Mathematics. Prior to analyses, we carried out a data cleaning. Implausible data were omitted from the dataset, that is, to short test times (< 750 sec.) and too long test times (> 7000 sec.). In addition, all incomplete tests were deleted; these are test where students did not work on all tasks (e.g., by clicking "next question" without giving an answer).

Overall, the dependent variables were all normally distributed. The analysis included 26226 cases. The average test score (i.e., correctly solved items) was 9.67 (SD = 5.00, Min = 0, Max = 28), the average test time was 2227.73 seconds (SD = 854.84, Min = 750, Max = 8487), the motivation prior the test (MOT_PRE) was 12.45 (SD = 2.89, Min = 4, Max = 16), the average restedness (ENERGY_PRE) was 9.45 (SD = 1.78, Min = 4, Max = 16), and the average motivation after the test (MOT_POST) was 10.83 (SD = 3.27, Min = 4, Max = 16). The participants, therefore, had an average individual loss in motivation (MOT_DIFF) from prior to after the test of -1.62 (SD = 2.77).

For class types (A, B, C – where A is the type with the highest academic performance) we found the expected differences. As shown in Table 1, the higher the class type the higher were the scores and the time spent on the test. For gender, we did not find substantial differences (Table 1). In terms of motivation (ENERGY_PRE, MOT_PRE, MOT_POST) we did not find differences across class types and gender (Table 2).

Table 1: Descriptive results for test variables for class type and gender (N = 26226).

	Class Type			
	Score		Time	
	M	SD	M	SD
A	11.62	4.54	2346.23	883.09
B	10.22	5.06	2212.09	815.80
C	6.38	3.41	2133.05	869.41
	Gender			
	Score		Time	
	M	SD	M	SD
Male	10.01	5.11	2191.22	845.51
Female	9.49	4.80	2277.99	855.30

Table 2: Descriptive results for motivation variables for class type and gender (N = 26226).

	ENERGY_PRE		MOT_PRE		MOT_POST	
Class Type						
	M	SD	M	SD	M	SD
A	9.68	1.61	12.24	2.67	10.66	3.00
B	9.63	1.48	12.67	2.65	11.13	3.08
C	9.66	1.39	12.82	2.50	11.04	3.00
Gender						
	ENERGY_PRE		MOT_PRE		MOT_POST	
	M	SD	M	SD	M	SD
Male	9.68	1.59	12.47	2.75	10.87	3.14
Female	9.62	1.37	12.70	2.50	11.09	2.94

The Pearson correlations between performance and motivation variables (Table 3), however, are rather low. The highest correlation exists between score and motivation after the test (r = .274). It is noteworthy, that MOT_POST has a clearly stronger relationship to scores than MOT_PRE.

Table 3: Correlation table of performance and motivation variables.

	SCORE	TIME	ENERGY_PRE	MOT_PRE	MOT_POST
SCORE	1.000	0.337	0.007	0.194	0.274
TIME	0.337	1.000	0.006	0.207	0.196

For a statistical comparison of variables, we grouped the participants in high and low motivated individuals. For the variables we used the median as the cut-off score (medians: ENERGY_PRE = 10, MOT_PRE = 13, MOT_POST = 11). The average scores for ENERGY_PRE_LOW were 9.53 (SD = 4.94) for ENERGY_PRE_HIGH 9.77 (SD = 5.04), the average scores for MOT_PRE_LOW were 8.77 (SD = 4. 74) for MOT_PRE_HIGH 10.49 (SD = 5.08), and the average scores for MOT_POST_LOW were 8.38 (SD = 4.53) for MOT_POST_HIGH 10.64 (SD = 5.11). This means that the LOW groups had lower scores than the HIGH groups; the effect is highest for MOT_POST. Figure 2 shows the 2-way interaction diagrams.

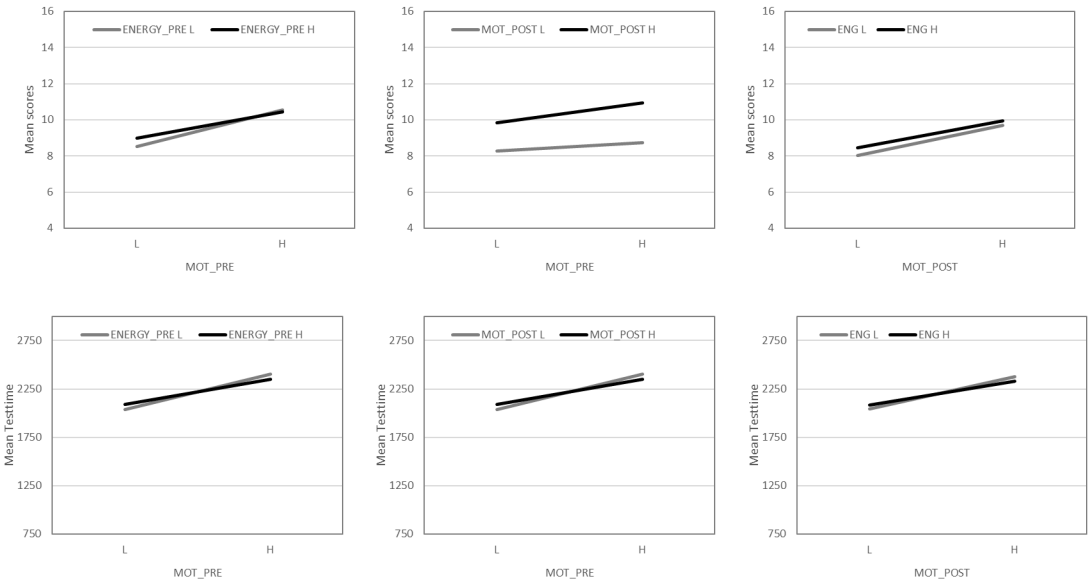


Figure 2: Interactions diagrams of restedness (energy), motivation prior and after the test for scores (top row) and test times (bottom row).

The average test times for ENERGY_PRE_LOW were 2223.34 (SD = 852.21) for ENERGY_PRE_HIGH 2231.05 (SD = 856.82), the average scores for MOT_PRE_LOW were 2068.78 (SD = 825.80) for MOT_PRE_HIGH 2371.65 (SD

= 855.21), and the average scores for MOT_POST_LOW were 2065.36 (SD = 829.40) for MOT_POST_HIGH 2349.35 (SD = 853.43). This means that the LOW groups had lower scores than the HIGH groups; the effect is highest for MOT_POST. Figure 2 shows the 2-way interaction diagrams.

A multivariate analysis of variance (ANOVA) reported a series of statistically significant group differences (Table 4). Given the large sample size, we computed the Cohen's d for the main effects to indicate the effect sizes between the HIGH and LOW groups. For ENERGY_PRE d = .048 for Score and .009 for Time. For MOT_PRE d = .350 for Score and d = .360 for Time. For MOT_POST d = .464 for Score and d = .337 for Time. According to Cohen (1992) these a rather small effect sizes, whereas the strongest effect was found for MOT_POST, meaning the self-reported motivation after the test.

Table 4: Results of a multivariate analysis of variance (ANOVA).

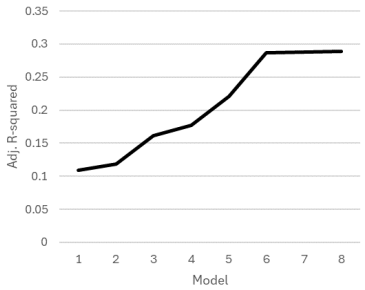
	Variable	SS	df	MS	F	Sig.
EN_PRE_HL	SCORE	3094.35	1	3094.35	131.17	<.001
	TIME	245198198	1	245198198	349.637	<.001
M_PRE_HL	SCORE	61.145	1	61.145	2.592	0.107
	TIME	859670.107	1	859670.107	1.226	0.268
M_POST_HL	SCORE	16767.332	1	16767.332	710.772	<.001
	TIME	147637921	1	147637921	210.522	<.001
EN_PRE_HL * M_PRE_HL	SCORE	268.004	1	268.004	11.361	<.001
	TIME	8474728.37	1	8474728.37	12.084	<.001
EN_PRE_HL * M_POST_HL	SCORE	429.554	1	429.554	18.209	<.001
	TIME	3584592.59	1	3584592.59	5.111	0.024
M_PRE_HL * M_POST_HL	SCORE	11.29	1	11.29	0.479	0.489
	TIME	1778162.44	1	1778162.44	2.536	0.111
EN_PRE_HL * M_PRE_HL * M_POST_HL	SCORE	5.475	1	5.475	0.232	0.63
	TIME	862265.267	1	862265.267	1.23	0.268

For a deeper analyses of the manifest variables, we specified two multiple linear regression models, one without motivation variables and one including them in the model. The results are shown in Table 5. The model without motivation variables resulted in an adjusted R^2 of 0.2212 ($F(5, 13823) = 786.08$, $p < .001$); the model including motivation variables in an adjusted R^2 of 0.2888 ($F(8, 13823) = 703.1$, $p < .001$). There is an increase in explained variance with the motivation variables, however, overall, the variance explained by these predictor variables is unexpectedly low. An ANOVA between the two models in R yielded that the model including motivation variables is a significantly better predictor for test scores ($F(-3) = 438.8$, $p = <.001$). When we investigate the adjusted R^2s upon stepwise inclusion of variables, we see that the variables school grades in mathematics (GRADE_M) and MOT_POST have the strongest explanatory power to predict test scores, followed by the parents' educational level (EDU_IX) and the achievement level of the class (CLASS_TYPE).

4. Discussion

This study examined the impact of self-reported motivation on academic test performance, focusing on standardized test data in Mathematics from the Swiss Stellwerk test. The research explored whether self-reported restedness and motivation—before and after the test—affected test duration and scores. While the hypothesis suggested a clear influence of motivation, statistical significance played only a minor role due to the large sample size. Unexpectedly, correlations between motivation and performance variables were weak. Self-reported restedness showed the smallest effect, followed by motivation before the test, while motivation after the test had the strongest impact. Despite examining several key predictors, the latent and manifest variables accounted for no more than 30% of test score variability, likely due to high variance in performance measures.

Table 5: Results of stepwise regression.

Model*	Adj. R^2	Summary
GRADE_M	**0.1087**	
GRADE_D + GRADE_M	0.1188	
GRADE_D + GRADE_M + EDU_IX	**0.1617**	
GRADE_D + GRADE_M + EDU_IX + LANG	0.1771	
GRADE_D + GRADE_M + EDU_IX + LANG + CLASS_TYPE	**0.2212**	
GRADE_D + GRADE_M + EDU_IX + LANG + CLASS_TYPE + MOT_POST	**0.2868**	
GRADE_D + GRADE_M + EDU_IX + LANG + CLASS_TYPE + MOT_POST + MOT_PRE	0.2875	
GRADE_D + GRADE_M + EDU_IX + LANG + CLASS_TYPE + MOT_POST + MOT_PRE + ENERGY_PRE	0.2888	

* GRADE_M = Mathematics grade in the last report card; GRADE_D = German grade in the last report card; EDU_IX = educational level of the parents; LANG = langue (mother tonge, primary langue, secondary langue, novice); CLASS_TYPE = achievement level of the school class; MOT_PRE = motivation prior to the test, MOT_POST = motivation after the test; ENERGY_PRE = restedness prior to the test.

A potential explanation for the limited predictive power of motivation lies in the context of standardization studies. These studies, conducted periodically in Swiss schools, are seen as burdensome by teachers and students, offering little direct benefit. Furthermore, schools are selected through representative sampling rather than voluntary participation. Unlike OECD PISA studies, Stellwerk standardization tests are administered by regular class teachers rather than external proctors, potentially influencing student commitment. For instance, PISA 2018 showed a correlation of r = .57 between math grades and PISA math scores (Pulkkinen & Rautopuro, 2022), while this study found a lower correlation of r = .25. Additionally, self-report surveys face challenges such as straight-lining—when respondents select uniform responses across Likert-scale items without differentiation.

Straightlining may indicate differences in participant motivation. Positive straightliners (n = 24) did not differ significantly from other respondents in their scores (M = 10.21, SD = 2.52 vs. M = 10.27, SD = 2.39; t(74) = -0.11, p = .912), suggesting consistent attitudes or response patterns. In contrast, negative straightliners (n = 7) scored notably lower (M = 7.86, SD = 2.27; t(57) = -2.38, p = .021), which may reflect low motivation, frustration, or protest behavior. However, interpreting straightlining as a motivation indicator is not straightforward. Without additional evidence—such as response time, quality of open-ended answers, or performance on attention checks—it remains unclear whether the behavior reflects genuine attitudes or systematic bias. Straightlining alone is insufficient for valid motivation assessment. Researchers should therefore combine multiple indicators to better evaluate data quality and participant engagement. While straightlining can serve as a potential signal, it only becomes meaningful when considered alongside other metrics. A nuanced interpretation is essential to avoid misjudging participant intent or data reliability.

This study highlights that academic performance in Mathematics is shaped by multiple factors. The strongest predictors include: (i) school type (e.g., Realschule, Sekundarstufe, Gymnasium, or achievement levels A, B, C), (ii) main language spoken by students, (iii) parental educational background, (iv) self-reported math grades from prior school reports, and (v) intrinsic motivation reported before and after the test. Factors such as test booklet versions, student preferences for Mathematics, and gender showed no substantial effects on performance. Structural equation modeling suggests that performance is primarily influenced by personal background, academic achievements, and motivation. Future research should focus on better ways to evaluate intrinsic motivation and its role in academic effort.

In conclusion, in educational research—particularly within technology-enhanced learning—intrinsic motivation is often regarded as a crucial factor for successful knowledge acquisition, retention, and recall. Game-based learning, gamification, and multimedia learning are frequently cited as methods that enhance intrinsic motivation, thereby improving performance, engagement, and diligence. However, research on the actual effects of intrinsic motivation remains inconclusive, often limited by methodological weaknesses, selective sampling, or small sample sizes. This study analyzed a representative dataset in Mathematics and found surprisingly weak correlations between self-reported motivation and test performance. One clear limitation of the study is that motivation and restedness were assessed using only a few questionnaire items rather than a

comprehensive, theory-based scale. Nevertheless, these findings suggest that the role of intrinsic motivation and restedness in education—particularly in technology-enhanced learning—warrants further scrutiny. Additional analyses, including structural equation modeling and an evaluation of the same dataset in German as a first language, yielded similar results, though they are beyond the scope of this paper. A plausible explanation for the lack of correlation is that students may reach a substantial level of effort with only moderate motivation, meaning that higher motivation does not necessarily translate into improved academic performance. Future experimental studies should explore this hypothesis in greater depth to determine under what conditions intrinsic motivation significantly influences learning outcomes.

Ethics Declaration

This study is a re-analysis of existing data sets. The data were originally collected under the supervision and with approval of the cantonal departments of education.

AI Declaration

AI was used to edit, optimize the text body and adjust its length. AI was not used to generate any content and not for surveying the existing literature.

References

Afzal, H., Ali, I., Khan, M. and Hamid, K. (2010) 'A study of university students' motivation and its relationship with their academic performance', *International Journal of Business and Management*, 5(4). Available at: https://doi.org/10.5539/ijbm.v5n4p80.

Akhtar, H. and Firdiyanti, R. (2023) 'Test-taking motivation and performance: Do self-report and time-based measures of effort reflect the same aspects of test-taking motivation?', *Learning and Individual Differences*, 102, p. 323. Available at: https://doi.org/10.1016/j.lindif.2023.102323.

Bandhu, D., Mohan, M. M., Nittala, N. A. P., Jadhav, P., Bhadauria, A. and Saxena, K. K. (2024) 'Theories of motivation: A comprehensive analysis of human behavior drivers', *Acta Psychologica*, 244, p. 104177.

Bock, R. D. and Gibbons, R. D. (2021) 'Computerized adaptive testing', in Bock, R. D. and Gibbons, R. D. *Item response theory* (Chapter 8). Wiley. Available at: https://doi.org/10.1002/9781119716723.ch8.

Botnaru, D., Orvis, J., Langdon, J., Niemiec, C. P. and Landge, S. M. (2021) 'Predicting final grades in STEM courses: A path analysis of academic motivation and course-related behavior using self-determination theory', *Learning and Motivation*, 74, p. 101723.

Chan, D. et al. (2015) 'In-lecture learning motivation predicts students' motivation, intention, and behaviour for after-lecture learning: examining the trans-contextual model across universities from UK, China, and Pakistan', *Motivation and Emotion*, 39(6), pp. 908–925. Available at: https://doi.org/10.1007/s11031-015-9506-x.

Cerasoli, C. P., Nicklin, J. M. and Ford, M. T. (2014) 'Intrinsic motivation and extrinsic incentives jointly predict performance: A 40-year meta-analysis', *Psychological Bulletin*, 140(4), pp. 980–1008. Available at: https://doi.org/10.1037/a0035661.

Cohen, J. (1992) 'Statistical power analysis', *Current Directions in Psychological Science*, 1(3), pp. 98–101. Available at: https://doi.org/10.1111/1467-8721.ep10768783.

Deci, E. L. and Ryan, R. M. (2008) 'Self-determination theory: A macro theory of human motivation, development, and health', *Canadian Psychology*, 49(3), pp. 182–185.

Fischer, G. H. and Molenaar, I. W. (1995) *Rasch models: Foundations, recent developments, and applications*. Berlin: Springer.

Keller, J. M. (1987) 'Development and use of the ARCS model of instructional design', *Journal of Instructional Development*, 10, pp. 2–10.

Kriegbaum, K., Jansen, M. and Spinath, B. (2015) 'Motivation: A predictor of PISA's mathematical competence beyond intelligence and prior test achievement', *Learning and Individual Differences*, 43, pp. 140–148. Available at: https://doi.org/10.1016/j.lindif.2015.08.026.

Lo, K., Ngai, G., Chan, S. and Kwan, K. (2022) 'How students' motivation and learning experience affect their service-learning outcomes: a structural equation modeling analysis', *Frontiers in Psychology*, 13. Available at: https://doi.org/10.3389/fpsyg.2022.825902.

Malone, T. and Lepper, M. (1987) 'Making Learning Fun: A Taxonomy of Intrinsic Motivations for Learning', in Snow, R. and Farr, M. J. (eds.) *Aptitude, Learning, and Instruction Volume 3: Conative and Affective Process Analyses*. Hillsdale, NJ.

Mews, S. and Pöge, A. (2019) 'Das Zusammenspiel von Selbstbildern, motivationalen und emotionalen Orientierungen sowie deren Einfluss auf die Mathematikleistung in der PISA-Studie 2012', *Zeitschrift für Erziehungswissenschaften*, 22, pp. 899–924.

Pulkkinen, J. and Rautopuro, J. (2022) 'The correspondence between PISA performance and school achievement in Finland', *International Journal of Educational Research*, 114, p. 102000.

Ramírez-Arellano, A. et al. (2018) 'Factors affecting student learning performance: a causal model in higher blended education', *Journal of Computer Assisted Learning*, 34(6), pp. 807–815. Available at: https://doi.org/10.1111/jcal.12289.

Reisenzein, R. (2017) 'Varieties of cognition-arousal theory', *Emotion Review*, 9, pp. 17–26.

Reuning, K. and Plutzer, E. (2020) 'Valid vs. Invalid Straightlining: The complex relationship between straightlining and data quality', *Survey Research Methods*, 14(5), pp. 439–459.

Silm, G., Pedaste, M. and Täht, K. (2020) 'The relationship between performance and test-taking effort when measured with self-report or time-based instruments: A meta-analytic review', *Educational Research Review*, 31, p. 100335.

Svinicki, M. D. and Vogler, J. S. (2012) 'Motivation and learning: Modern theories', *Encyclopedia of Science Learning*, pp. 2336–2339.

Urhahne, D. and Wijnia, L. (2023) 'Theories of Motivation in Education: an Integrative Framework', *Educational Psychology Review*, 35, p. 45.

Ulum, H. and Küçükaydın, M. A. (2024) 'The interaction of mathematics achievement, academic motivation and social context among Turkish adolescents', *Learning and Motivation*, 88, p. 102050.

Vu, T. et al. (2022) 'Motivation-Achievement Cycles in Learning: a Literature Review and Research Agenda', *Educational Psychology Review*, 34, pp. 39–71. Available at: https://doi.org/10.1007/s10648-021-09616-7.

Wang, L. (2022) 'Student intrinsic motivation for online creative idea generation: mediating effects of student online learning engagement and moderating effects of teacher emotional support', *Frontiers in Psychology*, 13. Available at: https://doi.org/10.3389/fpsyg.2022.954216.

Wang, M. D. and Hau, K.-T. (2024) 'In Likert scale, is ticking options consecutively at two ends equally problematic as ticking in the middle?', *Journal of Official Statistics*, 40(1), pp. 123–145.

Wang, X. S. et al. (2023) 'Factors predicting mathematics achievement in PISA: a systematic review', *Large-scale Assessments in Education*, 11(24).

Weiner, B. (1972) 'Attribution theory, achievement motivation, and the educational process', *Review of Educational Research*, 42, pp. 203–215.

Xu, U. et al. (2020) 'Intrinsic motivation, favorability, time management, and achievement: A cross-lagged panel analysis', *Learning and Motivation*, 72, p. 101677.

Yu, Z., Ming-le, G. and Wang, L. (2020) 'The effect of educational games on learning outcomes, student motivation, engagement and satisfaction', *Journal of Educational Computing Research*, 59(3), pp. 522–546. Available at: https://doi.org/10.1177/0735633120969214.

Zhang, C. and Conrad, F. G. (2014) 'Speeding and straightlining: Survey satisficing and its implications', *Public Opinion Quarterly*, 78(4), pp. 955–968.

Educational Paradigm Shifts Among Generation Z University Students

Peter Krajčovič and Vladimíra Jurišová
Faculty of Mass Media Communication, University of Ss Cyril and Methodius, Trnava, Slovak Republic

peter.krajcovic@ucm.sk
vladimira@jurisova@ucm.sk

Abstract: The paper focuses on the educational paradigm shifts of Generation Z university students, which can be characterized as a 'digital generation' growing up in an environment of intensive use of technology. One of the areas where the specificities of this generation are particularly evident is education. The aim of the paper is therefore to explore the extent to which university students belonging to Generation Z prefer digital information resources to traditional ones, and how these preferences influence their exam preparation and overall study style. Particular attention is paid to the selection and use of information sources, learning strategies and attitudes towards electronic forms of learning. The research conducted on a sample of 863 university students from Slovak republic focuses on several areas: dominant learning styles, selection and use of information resources, forms and tools of study, as well as technical devices used when working with study content. The research was guided by an attempt to answer the following research questions: Do Generation Z university students prefer new digital information resources over traditional ones? Which learning method do Generation Z university students prefer during their studies? Do Generation Z university students prefer electronic learning materials over print materials? Are there differences in preferences by year or level of study? The results have yielded several interesting insights into the current preferences of Generation Z university students. The results show that digital resources, such as articles from websites or videos on YouTube, play a complementary but not dominant role. Materials directly from teachers and their own notes remain the most used resources, indicating a strong link to traditional and proven sources. While digital tools find use, they do not serve as a primary source. The results also provide an up-to-date view of the changing educational preferences of this 'digital generation' and point to the importance of traditional information resources and learning styles during higher education.

Key words: Education, Generation Z, Learning, Technologies.

1. Introduction

Generation Z (born mid 1990's and 2010), often referred to as the digital generation or digital natives, is the subject of intense research in various fields - from sociological and psychological to consumer and educational aspects. Nevertheless, much remains open regarding this generation, and the dynamic evolution of the social and technological environment requires a constant revision of knowledge. Generation Z, like previous generations, is undergoing a continuous process of change, which is also reflected in its educational preferences and attitudes.

One of the areas where the specificities of this generation are particularly evident is education. Current research points to specific attributes of Generation Z that shape pedagogical strategies, learning styles and approaches to teaching. This is not just about the use of digital technologies in the traditional sense, but about their deeper integration into the educational process, including artificial intelligence tools. As Chairunisa et al. (2024) and Pavlíčková et al. (2024) point out, technologies such as virtual reality (VR) and augmented reality (AR) play an important role in creating immersive learning experiences and increasing student engagement.

Personalised approaches to learning, using artificial intelligence and real-time feedback, as described by Chardonnens (2025), promote self-regulated learning and make the whole learning process more efficient. In addition, gamification is also coming to the fore, which according to Islawati et al. (2025) and Čekrlija (2024) positively affects the motivation and attention of Generation Z students.

However, despite these technological opportunities, practice in higher education environments shows that Generation Z students still often prefer traditional forms of learning, with digital technologies playing a rather complementary role. This ambivalence between the generation's technological background and its actual behaviour in the context of studying poses a significant research problem.

Therefore, the aim of this paper is to investigate to what extent undergraduate students belonging to Generation Z prefer digital information resources over traditional ones, and how these preferences influence their exam preparation and overall study style. Particular attention is paid to the selection and use of information resources, learning strategies and attitudes towards electronic forms of learning.

2. Literature Overview

The current research literature agrees that Generation Z, growing up in a highly digitalised environment, has different learning needs and preferences compared to previous generations. Their digital orientation, multitasking ability and creative thinking require new, responsive approaches in teaching (Wajdi et al., 2024; Hendrastomo & Januarti, 2023).

Generation Z is characterized by high levels of technological proficiency, self-awareness, but also short attention spans (Huss, 2023; Hendrastomo & Januarti, 2023). According to Putri (2024), these characteristics translate not only to the academic environment, but also to the work environment, where Generation Z values security, comfort, and inclusiveness (Nasrudin et al., 2024).

At the same time, it appears that despite the technological background, students often face challenges with critical thinking, analysis, and original content creation (Collantes & Jerkovic, 2024), pointing to the need to develop metacognitive skills.

Generation Z's preferences are clearly towards interactivity, visuality and personalisation (Chairunisa et al., 2024). The use of virtual and augmented reality, gamification and mobile applications is seen as an effective tool for increasing motivation and engagement (Pavlíčková et al., 2024; Čekrlija, 2024).

According to Putri et al. (2024), the use of appropriate technologies in specific subjects such as history can significantly promote critical thinking and creativity. At the same time, Annuš and Takáč (2023) point out that the combination of digital and traditional materials enhances the effectiveness of learning, especially for Generations Z and Alpha.

Nevertheless, students do not reject traditional forms of learning but demand their supplementation with interactive elements (Pavlíčková et al., 2024; Blachowska-Szmigiel, 2024), thus confirming the need for hybrid approaches in education.

Several authors have addressed the topic of artificial intelligence (AI) in education. Chardonnens (2025) recommends its responsible integration alongside active and metacognitive strategies as part of a holistic approach to education. Surjandy et al. (2024) identify eight key factors that influence the success of AI implementation - for example, perceived stress, risk, ethics and quality of service.

At the same time, however, research shows mixed results for the implementation of AI in teaching, which calls for a deeper analysis of the impacts on the quality of learning and the student experience (Surjandy et al., 2024). Personalising learning pathways with AI (Chardonnens, 2025) and combining it with gamification is also a challenge (Chairunisa et al., 2024).

Socio-demographic factors also play an important role in student behaviour. Berková et al. (2024) found that gender, field of study and form of study influence the use of digital platforms. The largest differences were found among students in engineering, economics and humanities.

Effective teaching for Generation Z requires redefining traditional pedagogical approaches. According to Čekrlija (2024), classical methods such as long lectures are losing their effectiveness and there is a need to shift the emphasis to hands-on, research-based and data-driven activities. At the same time, Atmaja and Khalid (2023) highlight the importance of autonomy, differentiation of content and real-world problem solving, which leads to greater student engagement.

Nasrudin et al. (2024) extend the discussion to the importance of character education, which should be implemented across family, school, and community settings using strategies that resonate with the digital context.

The findings above show that Generation Z requires flexible, interactive and technology-enabled education that reflects their digital socialisation and individualised needs. Effective educational strategies should link innovation with proven principles of pedagogy, while reflecting the social background and cognitive specificities of this generation. Thus, the literature agrees on the need for hybrid and personalized approaches, while the emphasis should be on metacognition, engagement, character education, and a balance between technology and the human element in education.

3. Methodology

The aim of this paper is to analyse the preferences of students belonging to Generation Z in the use of information resources during their university studies. Specifically, we focus on finding out whether they prefer digital information resources over traditional ones, how these preferences affect their exam preparation and overall learning style, and whether there are differences in these preferences depending on the year and level of study.

The research was carried out at the Faculty of Mass Media Communication at the University of Ss Cyril and Methodius in Trnava. The sample consisted of 863 respondents - full-time students of bachelor's and master's degrees. The research set was non-probabilistic, purposive, and the criterion for inclusion in the research was belonging to Generation Z and active study at the faculty.

Data collection was conducted between September 24 and October 7, 2024, through an electronic questionnaire consisting of four main questions and two identification items. Two of the main questions employed a Likert scale to measure respondents' attitudes. The questionnaire was anonymous, and completion was voluntary. Respondents were informed of the purpose of the research and the voluntary nature of participation prior to the start of the questionnaire.

The research focused on three main areas:

1. Preferred information sources (monographs, textbooks and scripts, professional books, articles from websites, blogs, videos, lecture materials from teachers, own lecture notes, ...).
2. Mode of learning (reading, watching, listening, doing assignments)
3. Preferred sources of study (materials in electronic, printed or combined form)

The data obtained were analyzed using descriptive statistics. The research was guided by an attempt to answer the following research questions (RQ):

RQ 1: Do Generation Z university students prefer new digital information resources over traditional ones?

RQ 2: Which learning method do Generation Z university students prefer during their studies?

RQ 3: Do Generation Z university students prefer electronic learning materials over print materials?

RQ 4: Are there differences in preferences by year or level of study?

4. Results and Discussion

We focused on 3 main areas of inquiry: (1) what resources students use while studying, (2) what learning style they prefer, and (3) what materials they prefer while studying.

We classified the study resources into the following categories: monographs, textbooks and scripts, professional books, articles from websites that cover the topic, blogs, videos (e.g., on YouTube), webinars or other online courses, podcasts, lecture materials from faculty (presentations and other), self-reported lecture notes, worked-out questions from upper-level students, worked-out questions available on the Internet. We defined the frequency of their use in the following range: use as a priority, use as a supplementary source, use exceptionally, if I cannot find information in other sources, do not use.

We defined the way of learning in the following categories: reading books, study materials, watching videos, webinars, listening to recordings, podcasts, doing assignments, assignments, term papers. We defined the degree of preference in the following range: prefer, partially prefer, do not prefer.

We have defined study materials into the following categories: printed materials, electronic materials, and combined materials.

Several interesting findings emerged from the results of the investigation. The most frequently used resources for studying and preparing for exams are lecture materials from teachers and their own lecture notes. These resources are used by students on a priority basis. As a supplementary source, articles from websites dealing with the topic, videos on platforms such as YouTube, and professional books or textbooks and scripts are most frequently used. Conversely, podcasts, professional books and webinars or other online courses are among the sources that students use only exceptionally if they do not find the information in other sources. Monographs, blogs, and webinars are among the resources that students use minimally when preparing for exams. More detailed results are shown in Figure 1.

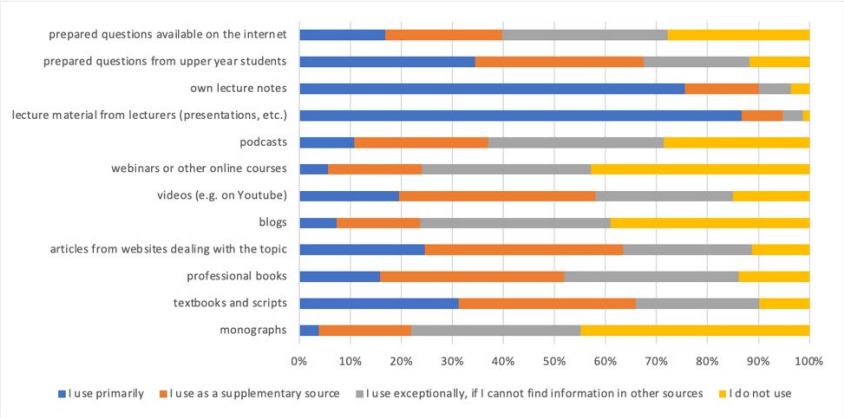


Figure 1: Resources used in studying and preparing for the exam (n = 863 respondents)

However, a comparison of the resources used by students in different years of study (1st Bachelor, 2nd Bachelor, 3rd Bachelor, 1st Master, 2nd Master.) yielded interesting findings. According to the results, there is a difference between the years in the preference and choice of information sources. While the lower grades prefer formal materials, the upper grades are more likely to prefer practical, shared and informal materials. In general, however, digital resources are strongly preferred over printed books and monographs, while traditional academic resources are perceived as more complementary. Differences can be seen in the following areas surveyed:

1st Bachelor students are more likely to use textbooks and scripts and materials from lecturers. These results suggest that these students are still strongly anchored in formal or so-called traditional forms of teaching, which may be a consequence of their previous mode of study in secondary schools. With increasing years of study (especially 2nd and 3rd Bachelor and Master), there is an increasing preference for quickly available, anecdotal sources such as elaborated questions from older students, their own lecture notes, videos or articles from topical websites. Senior students (3rd Bachelor, 1st and 2nd Master.) are more likely to use worked-out questions and their own or shared notes.

Another interesting finding is that although not all digital resources (e.g. podcasts) are popular, videos and web articles are gaining in importance, especially in 2nd and 3rd Bachelor. Figure 2 shows the results in more detail.

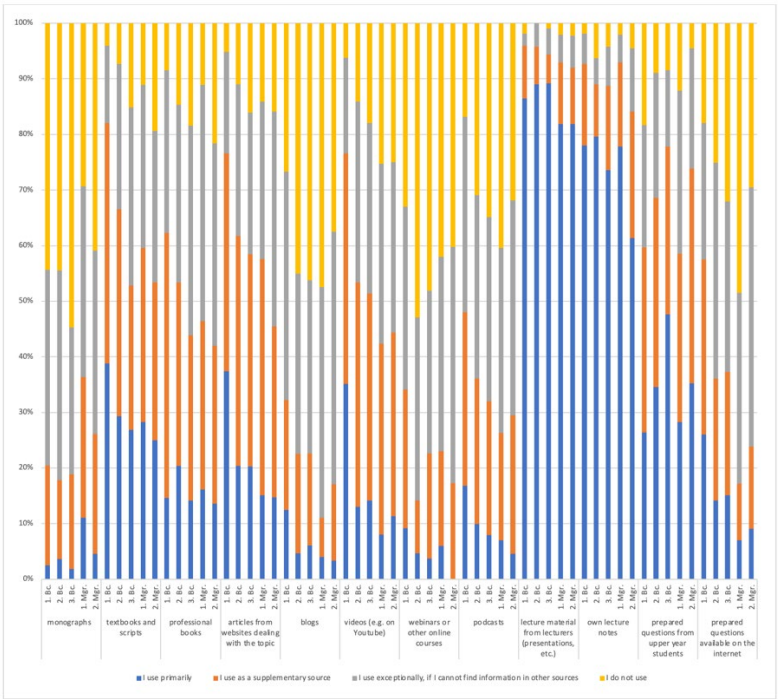


Figure 2: Resources used for study and exam preparation by year of study (n = 273 respondents - 1st Bachelor, 191 respondents – 2nd Bachelor, 212 respondents – 3rd Bachelor, 99 respondents – 1st Master, 88 respondents – 2nd Master)

The results of the survey indicate the preferred resources and their use among university students, based on which we can categorize them in the following table:

Table 1: Type of resource and trend of its use

Source of Study	Trends in Use
lecture materials from lecturers, own lecture notes	most frequently prioritised resources
articles from websites dealing with the topic, videos, elaborated questions from senior students	supplementary resources for study
professional books, monographs	rather exceptionally used resources
podcasts	least used

In terms of the way of learning, Generation Z most prefers the classical way of learning in the form of reading study materials and books. Conversely, the least preferred learning style is listening to recordings or podcasts. An interesting finding is that a significant proportion of Generation Z students prefer or partially prefer to use assignments, tasks or term papers as a learning style. This suggests a practical focus and an emphasis on linking knowledge. More detailed results are shown in Figure 3.

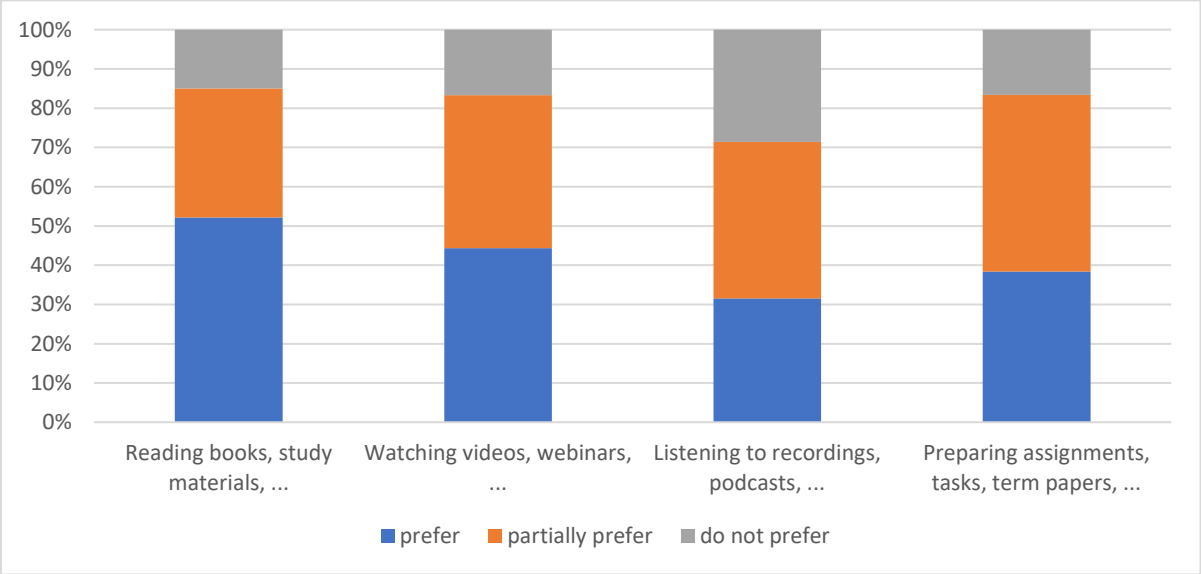


Figure 3: Generation Z's preferred mode of learning during their university studies (n = 863 respondents)

In terms of individual years, we can observe a number of trends and gradual changes in study preferences, especially between Bachelor and Master students. While the reading of study materials and books has a stable representation in the whole sample, we can see the highest preference in the 1st Master and, conversely, the lowest in the 2nd Master. We can also observe a decrease in 'partially prefer' and an increase in 'prefer' such learning style in the master's degree.

Another interesting finding is the gradual decline in watching videos and webinars as a way of learning. The highest preference can be seen among students in the 1st Bachelor studies. Subsequently, we can observe a gradual decline through the years, with the proportion of students who do not prefer this form increasing with each year.

Listening to recordings and podcasts is the least preferred way of learning, and this is the case in all years of bachelor's and master's degree, with a significantly increasing proportion of 'not preferred' in the final year of study.

Interesting findings can be seen in so-called active learning in the form of tasks, assignments or term papers. This style has a clearly increasing trend within the Bachelor studies, with the highest proportions of partial preference across all years (including Master studies). Figure 4 shows the results in more detail.

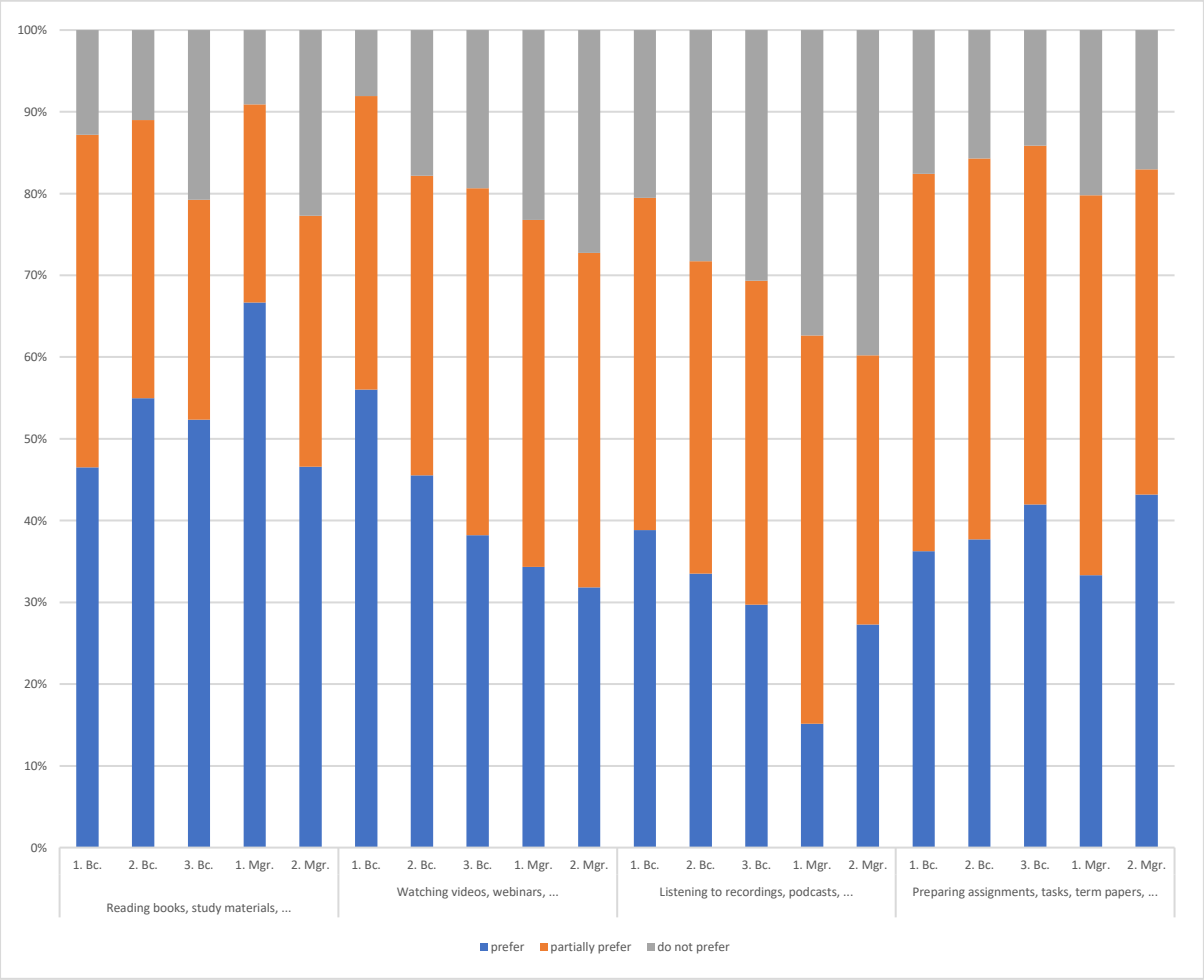


Figure 4: Comparison of the generation's preferred ways of learning during higher education by year of study (n = 273 respondents - 1st Bachelor, 191 respondents – 2nd Bachelor, 212 respondents – 3rd Bachelor, 99 respondents – 1st Master, 88 respondents – 2nd Master)

The results of the investigation indicate a trend in the learning style preferences of Generation Z students during their undergraduate studies, which can be summarised in Table 2.

Table 2: Trends in Generation Z learning style preferences during their undergraduate studies

Learning Style	Trend
Reading	Stable or increasing preference in master studies
Watching videos	Significant decrease in preference in higher grades
Listening	Lowest popularity, gradually increasing rejection
Active learning (tasks)	Increasing popularity, stronger in master degree

In terms of resources used for studying, the combined form (studying from printed materials and materials in electronic form) dominates, while we can observe a slight change in the preferences of students for bachelor's degree, namely a slight decrease in the preference for the combined form and a slight increase in the preference

for studying from electronic sources. In the case of Master, we can also observe a similar trend. More detailed results are shown in Figure 5.

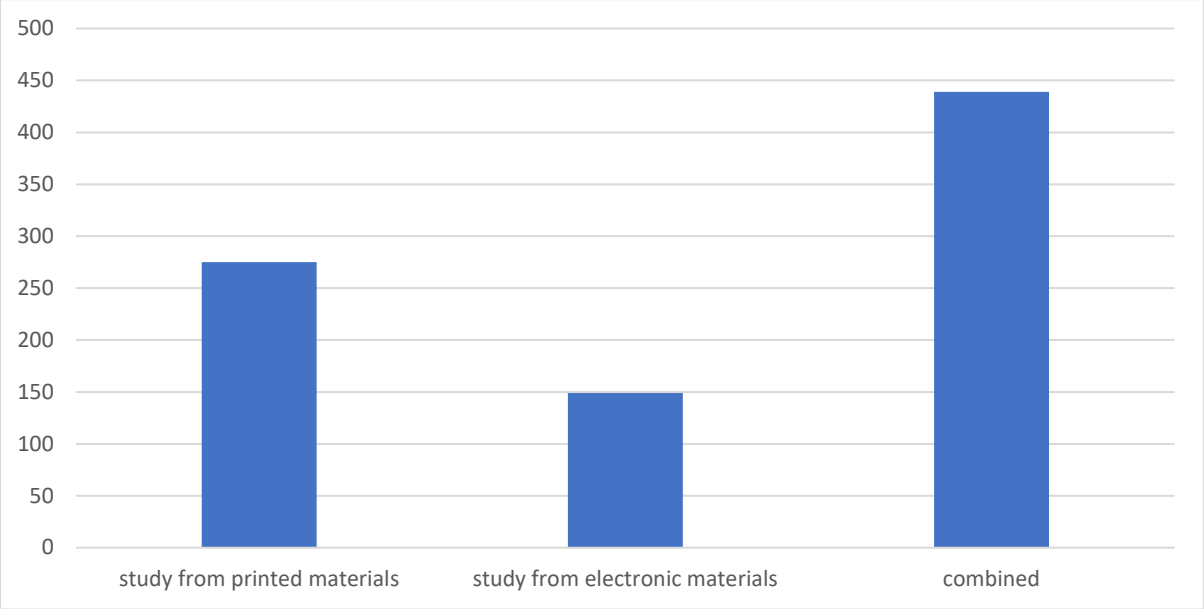


Figure 5: Preferred sources of study generation during university studies (n = 863 respondents)

When comparing preferred sources of study by year, we can observe several interesting trends. Although combined study is preferred by the highest number of students overall, the proportion of students preferring combined study gradually decreases as the year and degree level increases. However, an interesting finding is that although it is Generation Z that is digitally savvy, e-learning remains the lowest preferred form of study in every year group. Conversely, the preference for printed materials is relatively stable, with a more significant increase seen in the first year of the Bachelor studies. More detailed results are shown in Figure 6.

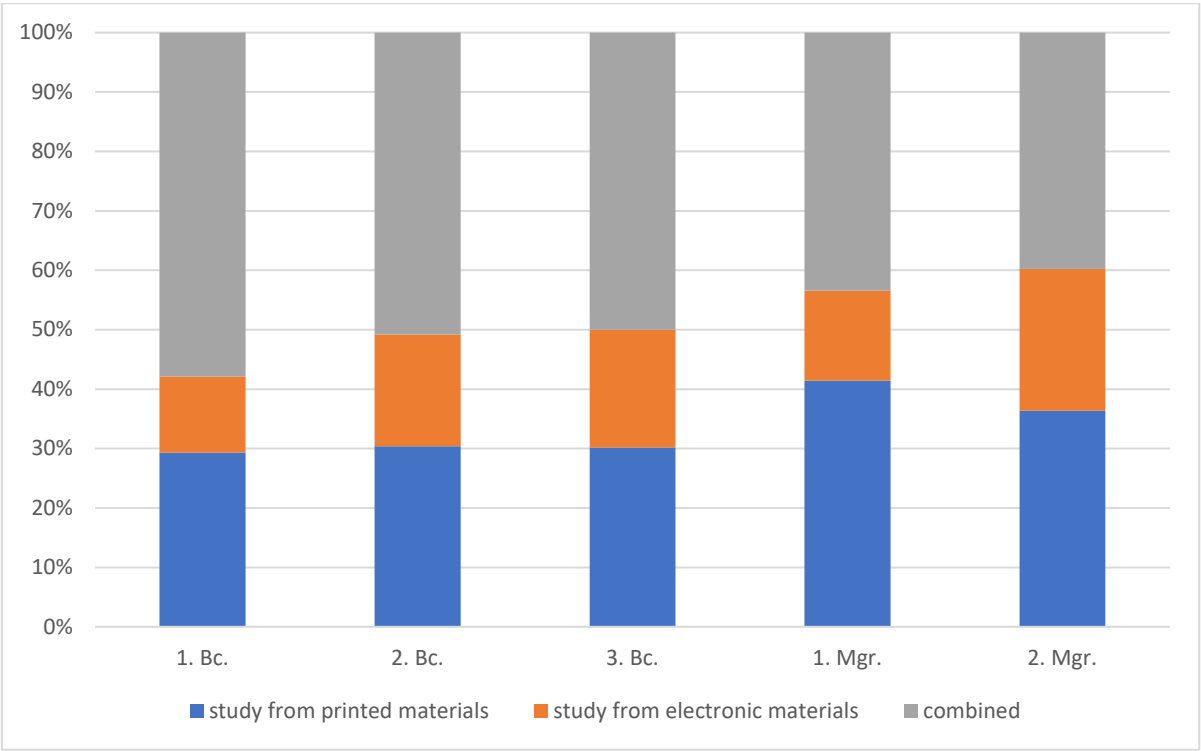


Figure 6: Preferred sources of study generation during higher education by year of study (n = 273 respondents - 1st Bachelor, 191 respondents – 2nd Bachelor, 212 respondents – 3rd Bachelor, 99 respondents – 1st Master, 88 respondents – 2nd Master)

The results of the survey indicate trends in preferred resources during undergraduate study, which can be summarised in Table 3.

Table 3: Trends in preferred resources with Generation Z during university studies

Trend	Development
Combined studies	Dominant mainly in the 1st Bachelor studies, subsequent decline across all years.
Printed materials	Stable preference within Bachelor studies, more significant increase in preference in Master studies.
Electronic materials	Slight increase in higher years, but remain the least preferred forms.

5. Conclusion

The results of the investigation have yielded several interesting insights into the current preferences of Generation Z university students in terms of information resources, learning styles and study materials used. The results show that digital resources, such as articles from websites or videos on YouTube, play a complementary but not dominant role. Materials directly from teachers and their own notes remain the most used resources, indicating a strong link to traditional and proven sources. While digital tools find use, they do not serve as a primary source.

Another interesting finding is that reading is the most preferred method of learning, confirming that despite the digital environment, Generation Z students still prefer traditional cognitive learning methods. At the same time, however, there is a significant group of students inclined towards active forms of learning - in particular task-based learning, which points to the growing importance of practice-oriented learning.

The results of the survey further revealed that the most preferred form is combined resources (print + electronic), reflecting students' desire to flexibly adapt their study habits to their current needs. While electronic resources alone are not dominant, their importance is slightly increasing, especially at higher levels of study. The findings also suggest a slight shift in preferences between levels of study, with students at Master studies more inclined towards electronic resources than their undergraduate counterparts.

The results point to an interesting fact. While Generation Z is referred to as the digital generation and several studies point to the necessity of integrating new technologies into education, learning and exam preparation are still dominated by more traditional methods and resources. This suggests that although technology is facilitating and streamlining the learning process, in the case of exam preparation and in the learning process, students themselves still prefer traditional ways with a combination of new and modern technologies as a complementary form. These findings can contribute to making higher education more effective. First and foremost, it is essential to promote the creation and systematic sharing of learning materials by educators, as these represent a primary source of knowledge. At the same time, these materials should be offered in both print and electronic formats to suit the diverse preferences of students.

Another area of application is the integration of practical assignments and term papers into teaching, which can increase engagement and link theory to practice. It is also recommended to use multimedia tools as a supplement to teach - especially for complex topics that require visualisation or demonstration.

Despite the valuable findings, the research has some limitations, particularly the focus on one group of university students, which may not reflect the preferences of all Generation Z university students. Future research should therefore extend the survey to other groups of university students and compare the results. A good complement to this is to conduct qualitative research in the form of individual interviews or focus groups, which can provide a better understanding of the reasons for students' preferences. It would also be useful to analyse the influence of the field of study on the choice of information sources or learning methods and also use the questionnaire in

other universities across the country to see of the trend is the same. Interesting might be also the comparison with the other European countries. In this respect, preferences may differ significantly. It is also important to investigate how these preferences change over time, e.g. during the transition from bachelor to master's degree or the impact of technological innovations.

Finally, it is important to track the impact of generative AI tools that are significantly changing the way information is searched, processed and applied in higher education.

Acknowledgement

This study was written within the project supported by the Cultural and Educational Grant Agency of the Ministry of Education, Research, Development and Youth of the Slovak Republic (KEGA) No. 021UCM-4/2024 entitled "Creation of interactive multimedia study materials for the study programme Marketing Communication".

Ethics and AI Declaration

Ethical clearance was not required for the research. No artificial intelligence tools were used in the creation of this paper.

References

Annuš, N., Takáč, O. (2023) "Z and alpha generation teaching methods: digitalization of learning material", *International Journal of Applied Nonstandard Research*, Vol 7, No. 4, pp 224–229.

Atmaja, S., Khalid, I. (2023) "Investigation of Optimal Pedagogical Approaches for Generation Z to Develop a High-Caliber Generation", *Enigma in Education*, Vol 1, No. 1, pp 21–25.

Berková, K., Kubišová, A., Krpálková Krelová, K., Krpálek, P., Holečková, L. (2024) "The Impact of Socio-Demographic Factors on the Use of Digital Learning Platforms and Forms of Learning by Generation Z Engineering Students", *International Journal of Engineering Pedagogy*, Vol 14, No. 8, pp 4–23.

Blachowska-Szmigiel, M. (2024) "Pokolenie Z w przestrzeni edukacji formalnej: potrzeby i wyzwania", *Studia Edukacyjne*, Vol 70, No. 11, pp 167–184.

Chardonnens, S. (2025) "Adapting educational practices for Generation Z: integrating metacognitive strategies and artificial intelligence", *Frontiers in Education*, Vol 10.

Chairunisa, H., Sahara, S., Karimah, M., Lubis, W. M., Gultom, D., Limayasi, C. N. (2024) "Strategi Komunikasi Pendidikan untuk Meningkatkan Kualitas Pendidikan di Era Gen Z", *El-Mujtama: Jurnal Pengabdian Masyarakat*, Vol 4, No. 5, pp 2205–2214.

Collantes G., R. D., Jerkovic, M. (2024) "Generación Z: desafíos para la educación superior en el nuevo milenio", *Acción y reflexión educativa*, Vol 49.

Čekrlija, S. (2024) "Challenges of Teaching Methods for Generation Z at Universities, Case Study China", *SDMT 2024: International Scientific Conference - Sustainable Development: Modern Trends and Challenges*.

Hendrastomo, G., & Januarti, N. (2023) "The Characteristics of Generation Z Students and Implications for Future Learning Methods", *Jurnal Kependidikan*, Vol 9, No. 2, pp 484–495.

Huss, J. A. (2023) "Gen Z Students Are Filling Our Online Classrooms: Do Our Teaching Methods Need a Reboot?", *InSight: A Journal of Scholarly Teaching*, Vol 18, pp. 101–112.

Islawati, I., Samsuddin, Y. B., Sugiarti, S. (2025) "Strategi Pengembangan Profesionalisme Guru di Era Digital untuk Menghadapi Tantangan Pembelajaran Gen Z", *Indo-MathEdu Intellectuals Journal*, Vol 6, No. 1, pp. 635–645.

Nasrudin, E., Sumarna, E., Surahman, C. (2024) "Examining the Characteristics of Generation Z and Their Implications for Students' Character Education", *Jurnal Iman dan Spiritualitas*, Vol 4, No. 4, pp. 363–372.

Pavlíčková, R., Škrabal, J., Poledna, M. (2024) "Interaktivní vzdělávání generace Z. Inovácie v medziuniverzitnom vzdelávaní", [online], https://www.maneko.sk/pdf/articles/QDKM7795.pdf

Putri, K., Ismana, O., Wibowo, T. U. S. H. (2024) "Peranan Guru dalam Meningkatkan Kualitas Pembelajaran Sejarah bagi Generasi Z", *Jurnal Bima*, Vol 2, No. 3, pp. 48–59.

Surjandy, S., Nathanael, A., Wijaya, D., Orlando, L. (2024) "The Implications of Utilizing AI for Learning on Generation Z", *Conference: 2024 International Seminar on Intelligent Technology and Its Applications (ISITIA)*, pp. 442–447.

Wajdi, M., Susanto, B., Sutiarso, M. A., Hadi, W. (2024) "Profile of generation Z characteristics: Implications for contemporary educational approaches", *Kajian Pendidikan, Seni, Budaya, Sosial Dan Lingkungan*, Vol 1, No. 1, pp. 33–44.

Lecture Capture in Finnish High Schools: Teachers' Perspectives

Ilkka Kukkonen[1] and Outi-Maaria Palo-oja[2]
[1]City of Kuopio, Kuopio; University of Jyväskylä, Jyväskylä, Finland
[2]LAB University of Applied Sciences, Lappeenranta, Finland

ilkka.kukkonen@kuopio.fi
outi-maaria.palo-oja@lab.fi

Abstract: The introduction of lecture capture technology has had a significant impact on teaching practices and forced teachers to rethink how lessons are delivered and experienced. While its use is widely examined in higher education context, its role in secondary education, particularly in high schools, has received less attention. Teachers are at the heart of how lecture capture becomes part of everyday classroom practice. As they work to integrate the technology into their teaching, many find themselves navigating a tricky balance between their educational goals and the demands that technology can bring. Some worry that using lecture capture might lead to less interaction with students, a loss of spontaneity during lessons, or even a shift in their role from being a responsive educator to feeling more like a performer in front of a camera. Nonetheless, teachers acknowledge the potential of lecture capture to support differentiated and self-paced learning. This study explores Finnish high school teachers' perspectives on lecture capture through interviews with eight STEM teachers. The study also includes a longitudinal dimension, as two teachers were interviewed in 2012 and 2017, and their legacy regarding lecture capture in the case high school was frequently referenced in the 2022 interviews. This long-term perspective reveals that teachers consistently view lecture capture as a student-centred service. They are generally willing to produce recordings to support student learning, even though it demands additional effort. Editing and distributing materials is time-consuming and only partially supported financially by school administration. As a result, the use of lecture capture rely heavily on the individual commitment of teachers. Furthermore, the interviews highlight a need for formal training that addresses both the pedagogical and technical aspects of lecture capture. While schools may benefit reputationally from offering recorded content, the responsibility for implementing and maintaining the system often falls on individual teachers without adequate institutional backing or financial compensation. These findings highlight the importance of recognizing teachers' perspectives in the development and implementation of lecture capture practices in secondary education. If the technology is to enhance rather than burden teaching, greater institutional support, sustainable practices, and subject-specific professional development are essential.

Keywords: Lecture Capture, High School, STEM, Teachers' Perspective

1. Background

The use of lecture capture technology – i.e. the use of digital technology to record, store, and distribute lectures (Witthaus & Robinson (2015) – changes the way teachers deliver, organize, and share their instructional content. While the majority of research has focused on universities, there is growing interest in its use in secondary education, particularly in high schools. This research avenue brings valuable insights from high school teachers themselves, who are in a key role to comment on how lecture capture fits with their teaching style, lesson planning, and the everyday dynamics of their classrooms.

Teachers' reflections often reveal a tension between pedagogical objectives and technological practices. Freed et al. (2014) observed that teachers reflected on how recordings negatively affected their classroom dynamics, spontaneity, and sense of control. Similarly, Hall and Ivaldi (2017) found that institutional efforts to standardize lecture capture frequently conflicted with teachers' desire for autonomy and flexible pedagogy.

Dommett, Gardner, and Van Tilburg (2019) highlighted concerns among teachers that recording lectures could reduce student interaction in the classroom. When students rely too heavily on recorded materials, the communal and real-time aspects of learning may diminish. This apprehension about the potential decline in lecture quality was further validated in later studies (Dommett et al., 2020), although students continued to value the flexibility recordings offered.

Divergences between teacher and student perspectives often stem from differing conceptions of the lecture. For students, lecture captures represent alternative ways to deliver instructional content, while teachers emphasize interaction and pedagogical methods that support learning (Dommett et al., 2020). This divergence is significant in high school context in particular because high school teachers serve not only as content experts but also as developmental guides who support students' broader growth.

Recording lectures introduces new cognitive and emotional demands on teachers. Johnson and Renner (2012) found that high school teachers implementing flipped instruction experienced empowerment and uncertainty. The shift from content deliverer to learning facilitator requires both training and re-evaluation of professional identity. Teachers may come to view themselves as performers on camera rather than educators engaged in authentic classroom interaction (Sumer, et al., 2018).

Subject-specific perspectives influence how lecture capture is perceived and used. In STEM education, Rahman and Shah (2018) found that social and behavioural factors shaped attitudes toward recording. Teachers were worried about cognitive load, misunderstandings, and depersonalization as potential challenges. On the other hand, recordings can address learning gaps and facilitate deeper understanding of challenging topics. Al Nashash and Gunn (2013) showed that engineering students used recordings to review difficult topics, improving comprehension and exam performance. Wiese and Newton (2013) found that biology students strategically used recordings to support learning, especially before assessments.

In computer science courses, recordings support self-directed, data-informed learning. Mark and Vrijmoed (2016) reported that students who watched recordings demonstrated better content mastery than those who did not. The ability to pause and replay step-by-step explanations was particularly beneficial for learners with varying skill levels. This function was seen as helpful in subjects like mathematics and other quantitative disciplines. E.g. Owston, Lupshenyuk, and Wideman (2011) reported that students used recordings effectively to understand problem-solving methods and review calculations.

In social sciences and humanities, benefits are less clear-cut. Dona, Gregory, and Pechenkina (2017) noted that while students appreciated the accessibility of recordings in fields such as education and communication, they also valued interactive classroom settings for engaging with abstract ideas. In these subjects, recordings often serve as supplementary rather than replacement resources.

French and Kennedy (2017) emphasized that successful integration of lecture capture requires alignment with subject-specific learning goals. In theoretically and technically oriented fields, recordings support efficient review. In contrast, experiential disciplines like performing arts or architecture benefit less from recorded formats.

Witthaus and Robinson (2015) argue that while lecture capture can benefit most disciplines, its pedagogical application must be tailored. For example, science teachers may focus on clarity and pacing, while humanities teachers may emphasize narrative flow and thematic structure.

Banerjee (2021) and O'Callaghan, Neumann, and Jones (2017) stress the importance of discipline-specific research to avoid oversimplification and one-size-fits-all solutions. Educational institutions must consider subject-specific needs, student behaviour, and pedagogical goals when adopting lecture capture technologies.

Implementing lecture capture is not merely a technical shift but a pedagogical transformation that requires new competencies from teachers. Thus, teacher training is essential for effective and learning-supportive use of recording technologies (O'Callaghan, Neumann, & Jones, 2017).

Teachers need technical training covering equipment and software use, including microphones, recording tools, and editing platforms. While many teachers adopt technology quickly, technical support alone is insufficient. Without pedagogical support, some teachers may feel insecure while recording and may limit creativity or interaction in their teaching (Freed, Bertram, & McLaughlin, 2014).

Pedagogical training should help teachers design instruction with recordings in mind, focusing on clarity, structure, and the use of visual aids. Witthaus and Robinson (2015) highlight the need for subject-specific approaches. For instance, math teachers may benefit from guidance on capturing board work, while language teachers require support for vocal delivery and nonverbal communication.

Teacher education should also address attitudes toward technology. Banerjee (2021) notes that positive attitudes and experiences support technology adoption, while concerns about student passivity or declining instructional quality can hinder uptake. Also, opportunities for teachers to share experiences and learn from peers are essential. Barokas, Ketterl, and Brooks (2010) emphasize that without proper support, teachers may feel that technology distracts them from their core activities, namely teaching.

In summary, lecture capture can function as a valuable and effective tool to support teaching and learning, but its implementation must be context-sensitive and guided by teacher perspectives. In high school education, where developmentally appropriate pedagogy, student-teacher relationships, and institutional structures differ considerably from the norms of higher education, teachers' voices are essential to the successful adoption of this technology. As this perspective has received limited attention in recent empirical research, this paper explores how Finnish high school STEM teachers make sense of and navigate the use of lecture capture technology in their classrooms, and what kinds of institutional support or challenges shape its long-term use.

2. Methodology

The research data was collected through interviews conducted in 2012, 2017, and 2022. Two interviewees remained the same in the 2012 and 2017 interview rounds, but in the last interview round, six other STEM teachers were interviewed. However, the first interviewed and later retired teachers were frequently mentioned as pioneers of lecture capturing at the case high school. Some of the interviews were done in pairs due to the teachers' preferences and schedules.

The semi-structured interviews included factual questions concerning, among other things, the duration of the teachers' teaching experience, the use of lesson recordings in teaching, and training related to the use of recordings. Most of the questions focused on the teachers' goals, experiences, and evaluations regarding the use of lesson recordings as a support for teaching and learning.

A temporal dimension was added to the second and third interview rounds, in which teachers were asked, for example, how the use of lesson recordings had changed over the past five years. In the most recent interviews, teachers were also asked about their experiences of possible changes in the use of lecture recordings caused by the COVID-19 pandemic. However, this topic is beyond the scope of this paper.

The recorded interviews were transcribed and carefully read before more systematic analysis using the Atlas.ti analysis software (cf. Robson et al. 2022). We focused on teachers' motivation for and understanding of lecture capture and their personal attitudes towards it. The open codes of the first inductive analysis round were later classified into 18 sub-categories and further into five categories: service, value creation, external motivation, organizing, and capabilities. All of these categories are summarised and explained with quotations in the next section.

3. Findings

3.1 Lecture Capture as a Service for Students

Teachers treat lecture capturing as a service for their students that they are willing to do without an extensive financial reward. Although lecture capture was highly automated at the high school in this case, requiring only starting and stopping the recording, teachers still invested time in editing and sharing it. Some teachers uploaded captures to the blog, where they also provided more information and homework for those who have been absent. Even teachers who made only minor modifications to the capture wrote some corresponding messages for their students.

"Well, let's say if it's just one assignment [one teaching hour capture], then it's about 20 minutes and everything's done. That includes the written message and all. I've done a few of those this winter too. Just trying to support the students that way." (interview 2/2017)

All teachers tried to share lecture captures in the same day.

"Usually I upload it, or 90% of the time, right after the lesson, so it's available to watch immediately, because the [absent] student is at home and might only be able to study between eight and four." (Interview 4/2022)

The volumes of lecture capture were tremendous at the case high school. In 2012, teachers reported that both of them had captured 300 hours of lectures a year. By spring 2012, both interviewed teachers said they had systematically recorded their teaching for about three years. What had changed during the years was that at first, teachers tried to capture the same lectures separately for each student group, although the content remained the same. The teachers justified this overlap, among other reasons, by noting that students preferred their own teacher's instructional style and recordings specific to their class.

"You can't use the old recording because it doesn't quite fit. It's different. Each group has its own, even if it's just a presentation in front of the class, there's still something about it. You really have to make a separate one for each group." (Interview 2/2017)

By 2022, teachers said that they made several recordings, chose the best one and shared that with all the students regardless of their group. Sometimes, teachers also encouraged students to watch recordings from a parallel course taught by another teacher.

"And then students might ask, if they've gotten used to a certain teacher's style, they might say, like, hey, did you teach this course last year too?" (Interview 5/2022)

However, teachers were not willing to share their videos with teachers of other schools although it was technically possible.

"It might partly be because there's such a high threshold for putting something out there — like, 'This is my teaching, my remote lessons,' and feeling like it's not good enough, like it's just silly stuff. So the teacher doesn't feel comfortable sharing it." (Interview 1/2012)

3.2 Value for the Students

Lecture capturing was, for the most part, a voluntary initiative on the part of the teachers.

"I do it more because some students find it helpful, so that's why I keep doing it. I've never really thought of it like, "I'm publishing this because I think it's great" or "this is a really good video of mine." I've seen it more as if some students benefit from it, then I'll upload it so that those who find it useful can take advantage of it." (Interview 4/2022)

The value for students varied due to their personal needs. For some, the value was realized so that they did not have to take notes during the live lesson. For others, it covered absences due to sickness or for athletes, absences due to training or competition trips.

"Just today, I had a student who had been in Portugal for a week and a half, two weeks, on a training camp, and they said it was nice to come back and feel like they'd still been part of the teaching the whole time. In the old system, you could say the course would've basically ended there for them." (Interview 1/2012)

Teachers, however, reminded that lecture captures are only supplementary means for students, and cannot cover the whole course. By 2017, teachers said that the frequency of watching captures decreased with one exception: Some athletes watched all the lecture captures and did not participate in live sessions. The number of users, however, was not important for teachers.

"Ultimately, if even one student benefits greatly from this, then it's worth it." (Interview 6/2022)

3.3 Motivation to Capture and Share Lectures

Teachers' willingness to serve students and their learning was not the only motivation for teachers to record their lectures. The recordings also served as background material for teachers if they had to be absent.

"And what if we think of a scenario where there's a one-day or one-week training session, and a substitute teacher comes in to teach the same material. The teacher still thinks, 'I'll make sure to provide a recording too, just in case.' Even if the substitute is good, the students can watch my explanation afterwards to see if it helps them understand even better." (Interview 1/2012)

Lecture captures diminished the need for remedial instruction. The monetary compensation for recording lectures was first based on the costs for remedial instruction hours, but changed into a fixed payment over the years.

"So yeah, the monetary compensation, well, I think it's at a pretty reasonable level. It's not exactly a goldmine, but it doesn't have to be. It's just a small extra on the side of teaching, and that's fine." (Interview 5/2022).

Teachers were happy with this change because it decreased bureaucracy. Still, the money was not reason to record lectures but a nice bonus for the job they might have otherwise do.

"I had been at this high school for a couple of years already and had been recording like crazy. Then at some point, [another teacher] just came up to me and said, 'You know, you get paid for those recordings.' --- These days, I'm the one who makes sure to tell the new people right away 'Did you know you can get compensation for this?" (Interview 5/2022)

Although lecture capture is widely used these days, in the 2010s, it was also a way to attract high-quality students to the case high school. This was seen in student surveys about their criteria to choose a high school over others.

"46% of the students said that it partly influenced their decision to apply to this school that we advertised the active use of videos to support teaching, including lecture capturing and so on. I'd argue that it's still one of the key factors behind our school's popularity." (Interview 2017)

3.4 Organizing the Lecture Capturing to Meet Expectations

Teachers wanted to serve their students by providing "full-service package" (Interview 1/2023) that included a lecture capture, written description of the content, related homework and sometimes other additional material. Individual teachers, however, used different media to deliver this content such as a blog, an online platform provided by the case high school, or the comprehensive digital learning platform widely used in the Finnish education system. Teachers gradually started to record only the more concise theoretical parts with few examples, rather than the entire lecture as in the 2010s. As a result, the need for tagging the thematic content declined over time.

Similarly, teachers spent more time in editing their lecture capture videos and adding new features between video clips.

"When I made those videos for Chemistry 1, I enriched them using H5P tools to include things like interactive multiple-choice quizzes. The idea was to activate the student a bit — to give them some kind of feedback on how they're doing and what they might need to focus on. Good multiple-choice questions help check whether the previous topic has been understood." (Interview 6/2022)

This transformed teaching more towards a self-study direction. Previously, teachers kept it rare to study the whole course from the videos, but later attitudes changed. This might have been due to better technology and the fact that students were more capable of utilising video-based teaching after COVID-19.

On the other hand, teachers had changed their lecture structures to capture.

"I've also started to think a bit more about the structure of the lesson from the perspective of the recording. I aim for a concise, teacher-led segment of about 20 minutes at the beginning and that's the only part I record. Once the students move on to independent work, that part is not included in the recording." (Interview 4/2022).

After tightening data security regulation and introduction of GDPR, teachers also became conscious to students' visibility and voices in recordings. At the beginning of each semester, students or their parents if they were underage, signed consent form allowing lessons to be recorded. However, many teachers reported edited out individual students from the recording.

All this editing was to support their self-studying and reviewing for exams.

"I just saw from the stats on the math course that students had been regularly watching the videos right before the matriculation exams — they were clearly using them to revise for advanced math." (Interview 5/2022)

3.5 Teacher Training and Technical Capabilities

Teachers were sorry that they did not have enough time to watch their own or other teachers' captures as often as they wanted to.

"Mainly, I just check whether the audio on the video is working, if it's clear, poor, or missing altogether. That's about as much as I've reviewed the videos. I'm sure it would be valuable for my professional development to watch them more thoroughly, but honestly, there just isn't time for that." (Interview 4/2022)

All the interviewed teachers reported that they continuously wanted to develop as teachers and lecture recordings enabled that.

"As a teacher and educator, of course, I would also like to develop professionally— to take the time to watch my videos calmly and carefully, and pick out the parts that worked well. To reflect on what I consider, pedagogically, to be effective," (Interview 1/2012)

In addition, recordings provided didactical freedom to teach same issues through different practices, or to memorise and evaluate the previous years' experiences.

"I use the recordings for two purposes. One, of course, is that students can go back and watch them whenever they need to. But I also use them myself when planning my lessons for the next school year — I go back and watch how I taught the lesson the previous year." (Interview 5/2022)

Although teachers were allowed to watch each other's videos, they rarely did that.

"It could be generally allowed to watch other teachers' recordings and use them as a source of ideas, as training material for teaching a particular topic. You could, for example, take a specific example from a recording and reflect on how the teacher approaches the subject. That, too, could be a potential way to make real use of these recordings." (Interview 6/2022)

Peer teachers, however, were the best support when teachers faced troubles with capturing technology or video pedagogy in general. The first two interviewed teachers were treated as pioneers of lecture capturing, and they helped many take their first steps in video pedagogy.

"The support definitely came from within our own school. When [the first two informants] were getting started with it, I followed, the rest of us followed along after them." (Interview 8/2022)

The technical training had been minimal, and teachers were left to study technology mainly on their own. Thus, some of the features may have not been fully utilised as one of the teachers complained.

"I feel like there are so many features in there that I don't even know about. Maybe a short training session wouldn't have been a bad idea. I just upload the recording, add some explanations, and do a bit of editing, but even that took some digging to figure out." (Interview 4/2022).

4. Discussion

Our analysis brought forward more optimistic views on lecture capturing than was expected in previous literature (e.g Dommett, Gardner, and Van Tilburg, 2019; Dommett et al. 2020). Lecture capture was seen as a service provided by teachers for their students. It serves as an alternative means of course completion, for instance during absences, but also as an option enabled by a familiar teacher when a student is required to transfer to a group taught by another instructor. For students, the value of lecture captures was shaped in a student-centred manner, according to their individual needs. At its simplest, merely being aware that a lecture was being captured was enough for students to focus on following the teacher's instruction during the lesson, rather than taking notes in haste. This potentially indicates that students rely on the recordings and thus develop their study strategies with better timing and precision, identifying the parts where they need clarification (see Kukkonen & Palo-oja, 2014).

Although teachers got a minor financial compensation for lecture captures, the biggest motivation was driven by the willingness to provide students the best possible learning opportunities. Some even recorded their lectures without asking for payment for it. Just as lecture captures helped absent students keep up with the course, they also served as backup material during teachers' absences. Recordings from previous years or parallel courses ensured that teaching could continue even if a substitute teacher was not immediately available. These aspects about clear benefits for teachers themselves were not identified in previous studies.

Recordings were also used for capability development. Teachers were willing to watch their own recordings to develop their pedagogical and didactical skills. Especially in technical skills, they relied on their peer teachers since formal technical training was very limited. The interviewed teachers were experienced, so video pedagogy was either rare or absent from their teacher education. However, there is clearly need for both technical and pedagogical training for lecture capture and other video-based teaching especially if no peer support is available.

Some timely changes were also identified in our study. Teachers aimed to make recordings more concise and engaging as technology advanced in the 2020s. The lesson structure was adapted to meet the demands of recording, and capturing only the teacher-led theoretical part at the beginning of the lesson also aligned with

the tightened data protection regulations in the 2020s. This readiness to change the lecture structures was radically changed from the findings by Freed et al. (2014) and Hall and Ivaldi (2017). One explanation might be that technology, in general, and editing, in particular, have become easier, so reacting to students' requests did not force teachers to change their teaching practices too much. Over time, teachers' use of lecture capture has shifted from recording entire lessons to more intentional video teaching, with edited and curated content tailored for student use, as our longitudinal study shows.

5. Conclusions

The widespread adoption of social media has significantly reshaped the role of video in students' lives, potentially influencing how they engage with educational video content as well. Compared to the literature of lecture capture from the 2010s, our findings provide more flexible and positive insights into the current high school context. Teachers want to serve their students by offering diverse and effective ways to learn, with lecture capture being one of them. On the other hand, capturing the entire lectures has changed into producing shorter and more concise, theoretically driven videos that enable more time for teacher-student communication and training during the lessons. When we conceptualise videos as a form of pedagogical service from teachers to students, we can approach the scaffolding nature between technology and pedagogy with greater detail. As with any service development, iteratively refining the concept and process allows us to meet students' expectations and harness technological opportunities without compromising teachers' pedagogical autonomy. In future research, we need more understanding about both how teachers can guide and inform students to fully benefit from the lecture captures, and second, what teachers can learn from how students watch and use lecture recordings.

Ethics Declaration

This study did not require ethical approval, as it did not involve sensitive personal data or vulnerable groups. Informed consent was obtained from all interview participants prior to data collection.

AI Declaration

The artificial intelligence tool Grammarly was employed to support language editing and assist with reference formatting in accordance with the required style guidelines. All intellectual contributions, including interpretations and critical analyses, are solely the work of the authors. The use of AI tools had no impact on the research design, data collection, analysis, or conclusions.

References

Al Nashash, H and Gunn, C. (2013) "Lecture Capture in Engineering Classes: Bridging Gaps and Enhancing Learning", *Journal of Educational Technology & Society*, Vol 16 No. 1,pp. 69–78.

Banerjee, S. (2021) "To Capture the Research Landscape of Lecture Capture in University Education", *Computers & Education*, Vol 160 No. 104032. https://doi.org/10.1016/j.compedu.2020.104032

Barokas, J., Ketterl, M. and Brooks, C. (2010) "Lecture Capture: Student Perceptions, Expectations, and Behaviors", in *eLearn: World Conference on EdTech*, October, Association for the Advancement of Computing in Education (AACE), pp. 424-431.

Dona, K. L., Gregory, J., and Pechenkina, E. (2017) "Lecture-Recording Technology in Higher Education: Exploring Lecturer and Student Views across the Disciplines", *Australasian Journal of Educational Technology*, Vol 33 No. 4.

Dommett, E. J., Gardner, B., and Van Tilburg, W. (2019) "Staff and Student Views of Lecture Vapture: A Qualitative Study", *International Journal of Educational Technology in Higher Education*, Vol 16 No. 1. https://link.springer.com/article/10.1186/s41239-019-0153-2

Dommett, E. J., Gardner, B. and Van Tilburg, W. (2020). "Staff and Students Perception of Lecture Capture", *The internet and Higher Education,* Vol 46 No. 100732.

Freed, P. E., Bertram, J. E., and McLaughlin, D. E. (2014) "Using Lecture Capture: A Qualitative Study of Nursing Faculty's Experience", *Nurse Education Today*, Vol 34 NO. 4), pp. 598–602. doi: https://doi.org/10.1016/j.nedt.2013.06.021

French, S., and Kennedy, G. (2017) "Reassessing the Value of University Lectures", *Teaching in Higher Education*, Vol 22 No. 6, pp. 639–654. https://doi.org/10.1080/13562517.2016.1273213

Hall, G. and Ivaldi, A. (2017) "A Qualitative Approach to Understanding the Role of Lecture Capture in Student Learning Experiences", *Innovations in Education and Teaching International*, Vol 54 No. 1, pp. 3–10. doi: https://doi.org/10.1080/1475939X.2016.1263805

Johnson, L., and Renner, J. (2012) *Effect of the Flipped Classroom Model on a Secondary Computer Applications Course: Student and Teacher Perceptions, Questions and Student Achievemen*t, Doctoral Dissertation, University of Louisville, Louisville, Kentucky. Available at: https://theflippedclassroom.wordpress.com/wp-content/uploads/2012/04/johnson-renner-2012.pdf

Kukkonen, I. and Palo-oja, O.- M. (2014), "Making Sense of Lecture Capture: A Case Study of Peer and Teacher Influence", in *EdMedia+ Innovate Learning*, June, Association for the Advancement of Computing in Education (AACE), pp. 813-820.

Mark, K. P., and Vrijmoed, L. L. (2016) "Does Lecture Capturing Improve Learning?: A Data Driven Exploratory Study on the Effectiveness of Lecture Capture on Learning in a Foundation IT Course", in *2016 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE),* IEEE, pp. 338-344.

O'Callaghan, F. V., Neumann, D. L., and Jones, L. (2017) "The Use of Lecture Recordings in Higher Education: A Review of Institutional, Student, and Lecturer Issues", *Education and Information Technologies*, Vol 22 No. 1, pp. 399–415.

Owston, R., Lupshenyuk, D., and Wideman, H. (2011) "Lecture Capture in Large Undergraduate Classes: Student Perceptions and Academic Performance", *The Internet and Higher Education*, Vol 14 No. 4, pp. 262-268.

Rahman, A., and Shah, M. A. R. (2018) "Lecture Capture Use in Engineering Education: Influence of Students' Social and Behavioral Factors and Teachers' Perceptions", *Computer Applications in Engineering Education*, Vol 26 No. 5, pp. 1915–1928. https://doi.org/10.1002/cae.21902

Sumer, O., Goldberg, P., Sturmer, K., Seidel, T., Gerjets, P., Trautwein, U., and Kasneci, E. (2018), "Teachers' Perception in the Classroom", in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops,* pp. 2315-2324.

Wiese, C. and Newton, G.(2013) "Use of Lecture Capture in Undergraduate Biological Science Education," *The Canadian Journal for the Scholarship of Teaching and Learning*: Vol 4 No. 2, doi: http://dx.doi.org/10.5206/cjsotl-rcacea.2013.2.4

Witthaus, G. R., & Robinson, C. L. (2015), *Lecture Capture Literature Review: A Review of the Literature From 2012–2015,* Loughborough: Centre for Academic Practice, Loughborough University.

Bridges to the Future: The Case of Business Mill

Emma Latvala[1] and Pasi Rantanen[2]
[1]LAB University of applied science, Finland
[2]Ikigaia Oy, Finland

emma.latvala@lab.fi
Pasi.rantanen@ikigaia.fi

Abstract: Higher education institutions are no longer just centers disseminating knowledge - they are increasingly active players in regional development. Community engagement in higher education means an interactive relationship where the institution, students, businesses, and the local community build a sustainable future together. This commitment is particularly evident in business collaboration, which provides tangible benefits for both the school and the region. There are many good examples of cooperation between higher education institutions and the region in South Karelia, but this study deals with the business incubator Business Mill. The purpose of the study was to describe the South Karelian model of community commitment to education, in this case, entrepreneurship education. This study was an explanatory case study. The theoretical part described the Triple Helix collaboration model, which should be favored in cooperation between regions and higher education institutions. In addition, the current state of the region's R&D cooperation was described in the theoretical part. The theoretical part was compared to the description of the operation of Business Mill, the subject of the case study, and the results of the comparison were presented in the summary. Community commitment to higher education creates a positive spiral: The region develops when knowledge and innovations are utilized locally. The higher education institution strengthens when it acts as an active player in society and attracts students who want to make a change. Students benefit when they get meaningful learning experiences and better readiness for working life. The results show that a comprehensive business incubator can be an effective way to organize cooperation between the region and the higher education institution and increase commitment. The results also showed that a named expert, who agilely combines the expertise of the higher education institution and the needs of the company, improves the quality of cooperation and facilitates communication. As an explanatory case study, this study does not aim to create new theory but to describe the current situation, its possible successes, and challenges. In South Karelia, a municipal-funded business incubator has been implemented in collaboration with a higher education institution with good results since 2018, now the results of the study show that similar commitment and cooperation would also be beneficial in building R&D cooperation.

Keywords: Business Mill, Business Collaborations, University Industry Co-operation, RDI.

1. Introduction

The cooperation between universities and businesses has a significant impact on education, local businesses, and other actors in the region. Business collaboration provides students with the opportunity to apply what they have learned in practice and create contacts with the working life during their studies. At the same time, companies gain fresh perspectives, research information, and the opportunity to recruit motivated experts. The collaboration can be, for example, project courses and case tasks, internships and thesis work, or joint research and development projects. This kind of interaction strengthens the vitality and competitiveness of the region.

This study aims to describe one case of the region's commitment to education in South Karelia. This is an explanatory case study, which describes the results of the Business Mill business incubator since 2018, as well as the results of a recently completed RDI research project about RDI cooperation in the region. The study provides a new perspective on the region's commitment to education and companies' RDI investments.

South Karelia, as an eastern province of Finland, needs to raise labor productivity and new innovations to remain vital and inhabited now and in the future. In South Karelia, in Lappeenranta, is located the reputable LUT University (LUT, 2025), LAB University of Applied Sciences, and the Land Defense College and vocational school, yet the region's companies still make little use of new technology or new innovations (Innovation strategy 2022-2025). Cooperation, as demonstrated in the Business Mill business incubator, could also solve the challenges of the region's companies' RDI investments.

2. Overview of RDI Collaboration in South Karelia

In January 2025, the Finnish government set a goal that by 2030, Finland's research and development expenditures will be 4% of the gross domestic product, currently being at about 2.7% level. Finland has lagged behind in economic growth in terms of labor productivity compared to peer countries. (Government Program, 2023.) In South Karelia, the views of local companies on research, development, and innovation activities were surveyed in the spring of 2025.

In the South Karelia region, the innovation ecosystem has historically faced challenges in activating collaboration between companies and higher education institutions. To assess the current situation and opportunities for development, a regional RDI survey was conducted in spring 2025 by the authors in collaboration with the City of Lappeenranta and The Finnish Innovation Fund Sitra (Rantanen, City of Lappeenranta & Sitra, 2025). The survey was part of Sitra's *Innovations for Sustainable Growth* program and collected 303 responses from businesses and regional stakeholders.

The City of Lappeenranta's involvement reflects a broader shift in the role of public administration from passive enabler to active co-creator. In contemporary regional innovation ecosystems, municipalities are increasingly acting as "civic laboratories" that facilitate collaboration, experimentation, and co-development between local actors (Torfing, 2019). This perspective aligns well with the aims of the Sustainable Growth Innovations subproject, which integrates public and private sector efforts under a shared sustainability agenda.

The results revealed a strong interest among local companies in engaging more actively in research and innovation cooperation. Specifically, 44 respondents identified collaboration with higher education institutions as a key area where they needed support (Rantanen, City of Lappeenranta & Sitra, 2025). Additionally, 109 respondents expressed interest in participating in workshops or increasing their involvement in RDI activities in the near future (Rantanen, City of Lappeenranta & Sitra, 2025). These findings indicate a significant demand for more structured and accessible university-business interfaces that enable applied innovation.

These insights reinforce the strategic relevance of initiatives such as Business Mill. The initiative connects academic expertise with the needs of local companies by offering tailored support and acting as a regional interface for innovation collaboration. As Rantanen and Bogdanova (2024) argue, regional innovation platforms that follow the Triple Helix model can improve commercialization outcomes and enhance regional competitiveness. This model is based on close cooperation among academia, industry, and public sector actors. In this context, South Karelia's coordinated efforts to strengthen RDI partnerships represent a timely and necessary step toward meeting both national policy goals and the region's long-term development objectives.

3. Business Mill

Business Mill is a business incubator established in 2018, located at the LUT Universities in Lappeenranta. Business Mill's funding consists of joint financing from the municipalities of the region and LAB University of Applied Sciences, in which the city of Lappeenranta plays a significant role. The primary task of the incubator is to help businesses in the South Karelia region grow and internationalize, utilizing the resources of the university campus. The core of the operation is to direct both student and expert resources to support the region's businesses. The incubator operates on a two-year funding cycle. Goals have been set for Business Mill for each two-year period by its financiers. The goals have included the number of new businesses and the number of new business concepts. The goals for the 2024-2025 period are to establish 15 new businesses and 30 new business concepts.

Currently, Business Mill is in its fourth funding round, and the fifth is in the process of decision-making. Therefore, it is highly likely that the operation will continue for the next two years, 2026-2027.

The expert team of the incubator consists of five experts. Expertise mirrors the strategic edge of LAB University of Applied Sciences: sustainable growth. (LAB, 2025)

Business Mill's customer segments are micro and small businesses in South Karelia, as well as student entrepreneurship and startups. While traditional incubators focus solely on startups, Business Mill aims to combine growth-oriented businesses and startups in the region, thus ensuring sustainable business and growth. The operation mainly consists of 1to1 counseling and sparring, but in addition, two startup trainings are organized annually, specifically intended for idea-level teams, and also the business idea competition Idearace.

Idearace is a kind of stage where campus idea-stage startups get to present their ideas to investors, stakeholders, and local entrepreneurs (Idearace).

The service range includes products for the entire life cycle of a company, from idea to renewal (Business Mill).

The municipalities of South Karelia have wanted to participate in business development at the University of Applied Sciences for several years, demonstrating strong commitment to co-development from the region.

4. Trible Helix

The Triple Helix model (figure 1.) is a framework of innovation theories that describes the collaboration between universities, businesses, and the public sector to promote innovation and economic development. The model emphasizes that innovations do not arise solely within individual organizations, but in their interaction. (Lahtonen & Tokila, 2014.) The Triple Helix model refers to the development of a tripartite network of organizations between the university, government, and industry, where the university (and similar research and educational institutions) should be considered the primary source where knowledge is produced and from where it spreads (MSM 2021). The role of universities is due to the assumption that it is the most adaptable of the three institutions of the Triple Helix. Adaptability, in turn, is a result of the constant turnover of students (Lahtonen & Tokila, 2014).

Institutional and evolutionary perspectives within the Triple Helix can also be treated as separate sub-areas. The institutional Triple Helix model describes the emergence and development of relationships between the university, business life, and public administration based on scientific knowledge, usually retrospectively. The evolutionary Triple Helix model seeks to explain how different functions affect the development of the innovation system. The evolutionary model can also provide policy recommendations aimed at reorganizing the Triple Helix network and thereby accelerating innovation activity. Often, the examination is limited to the development of a specific geographical area or innovation cluster. (Lahtonen & Tokila. 2014.)

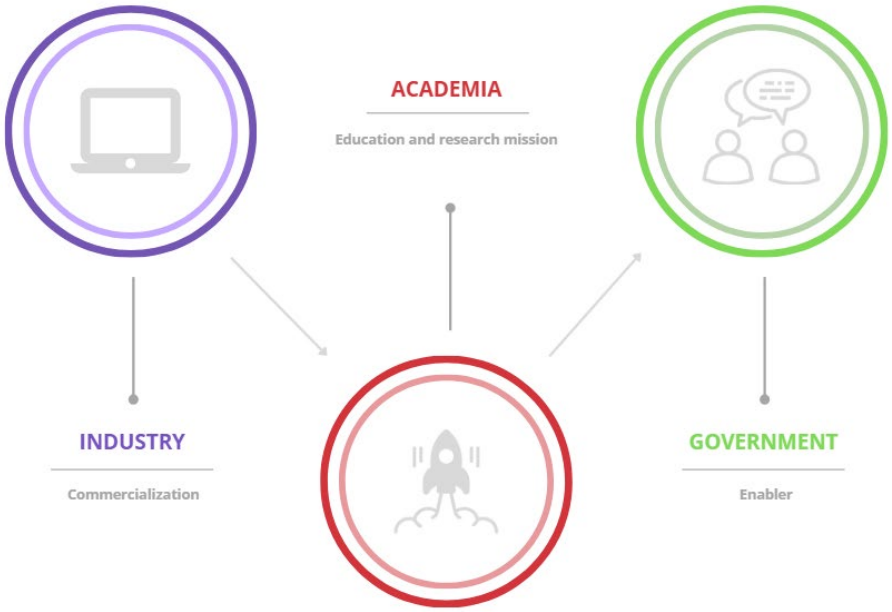


Figure 1: The second phase of the Triple Helix model.

The figure one is based on the description of the second phase of the Triple Helix model by Lahtonen & Tokila 2014, where cooperation is already underway, and the role of each actor is clear. In the next, i.e., the third phase, the Triple Helix 3 division of tasks becomes blurred, and institutions take on each other's roles situationally and flexibly, if this is believed to improve innovation activities. On the other hand, in the first phase, the government has the largest role in defining roles and initiating cooperation. (Lahtonen & Tokila, 2014.)

These theoretical phases are increasingly observable in South Karelia's ongoing innovation efforts.

Recent insights from the South Karelia region indicate a growing momentum toward deeper integration between academia, industry, and the public sector. Feedback collected during a regional survey in 2025 highlights recurring calls from businesses for more systematic engagement with universities, not only in research collaboration but also in co-developing innovative environments. Companies are increasingly open to participating in shared development efforts, such as thematic workshops and long-term partnerships, which suggests a rising willingness to break down institutional silos.

This trend points toward a maturation of the regional innovation ecosystem, where actors are not merely fulfilling predefined roles but actively shaping new ones in response to emerging challenges and opportunities. The Business Mill initiative serves as a practical interface in this evolution, bridging academic expertise and

entrepreneurial needs through co-creation processes. Such developments align with the third phase of the Triple Helix model, characterized by role hybridization and institutional reflexivity. In this context, South Karelia is demonstrating how local ecosystems can gradually transition into agile innovation arenas, where the boundaries between knowledge production, application, and regulation are increasingly blurred.

Similar patterns have been identified in other European regions, particularly in countries like the Netherlands and Sweden, where regional innovation platforms serve as active intermediaries between universities, industry, and government. These contexts similarly show that institutional hybridization and overlapping roles support innovation capacity and adaptability (Etzkowitz & Leydesdorff, 2000). This suggests that South Karelia's development trajectory fits into a broader trend of place-based innovation ecosystems grounded in Triple Helix logic.

5. Methodology

The research method of this article is an explanatory case study. The study aims to answer the question of why the case is exactly as it is, or why it has developed in a particular way. The object to be explained describes the relationship between complex real-life events or the methods associated with them. (Eriksson & Koistinen, 2014.) In the theme analysis method, data triangulation is utilized, and perspectives and analysis are offered on the impact of the Business Mill incubator located at LAB University of Applied Sciences on university-business cooperation and the region's commitment to education. The connection to the theory was sought by examining the whole, interpreting, and linking phenomena to the theory used. General and recurring phenomena were sought from the material, and their relationships and connections were examined. (Ojasalo, 2018. 110–111.)

Data for this study was mostly qualitative, consisting of the results of Business Mill since 2018 and the results of the ongoing Sustainable Growth Innovations project. In addition, the data for the study has utilized a regional RDI cooperation result report commissioned by Sitra.

The purpose has been to describe one way of cooperation between universities and the region to increase vitality and entrepreneurship in the area.

In addition to qualitative case data, the study incorporated the results of a regional RDI survey carried out in collaboration with the City of Lappeenranta and The Finnish Innovation Fund Sitra as part of their *Innovations for Sustainable Growth* program. The survey gathered responses from 303 stakeholders across South Karelia and included both quantitative and qualitative questions about RDI practices, collaboration readiness, and regional challenges. Notably, 44 respondents identified a need for stronger collaboration with higher education institutions, while 109 expressed willingness to participate in joint development activities such as workshops. These findings enriched the thematic analysis by grounding observations in a broader regional context and supporting the explanatory logic of the case.

6. Results

6.1 Business Mill Results From 2018 to 2025

Business Mill's customer numbers have been growing throughout its operation. The latest year, 2024, included exactly 200 customers, of which 143 were companies from South Karelia and 57 were teams in the idea phase.

In the spring of 2025, Business Mill is conducting a customer satisfaction survey, the preliminary results of which (response rate 15%) indicate that customers see a very significant role for incubator-like operations in the development of their companies. Over 79% of respondents said that Business Mill genuinely had an impact on the growth of their company (Figure 2.) and over 66% said they believe that Business Mill is a good partner for growth and internationalization in the future.

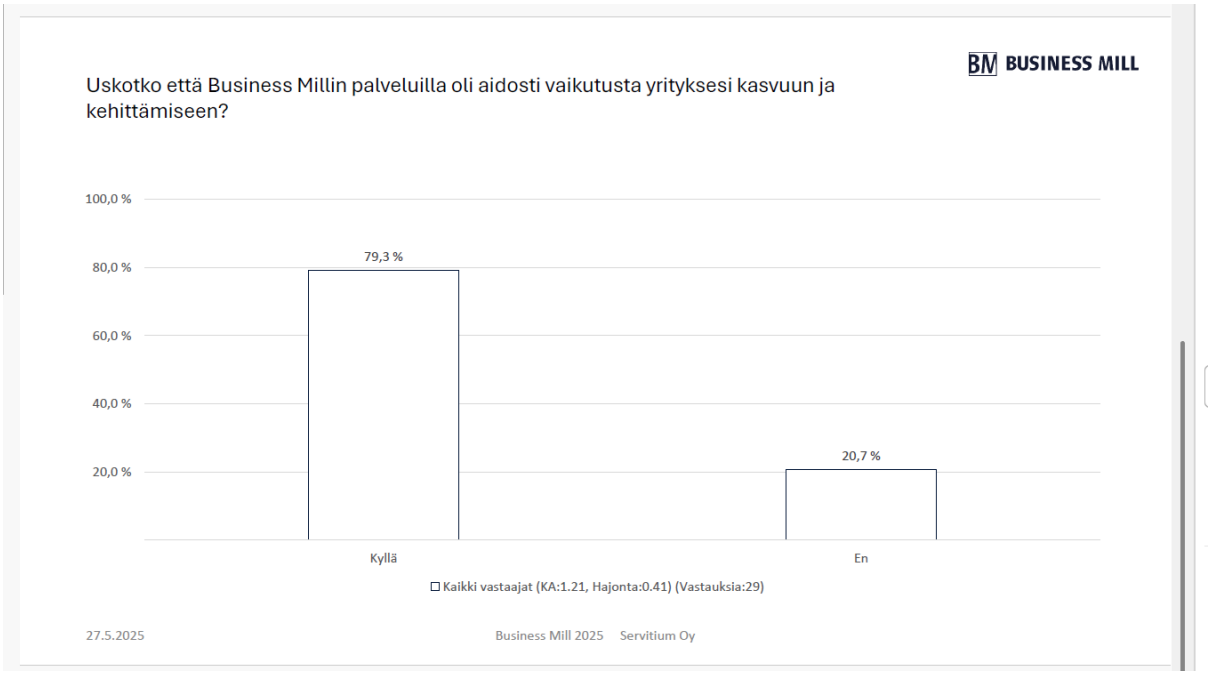


Figure 2: Preliminary results of Business Mill's customer satisfaction survey 2025. Do you believe that Business Mill's services genuinely impacted on your company's growth and development? Not yet published, it will be published at LAB Focus in September 2025.

Between 2018 and 2024, Business Mill successfully connected a total of 283 South Karelian companies to education, projects, and expertise at LUT Universities. Most of the corporate collaboration has taken place through courses and teaching. Communication, marketing, forecasting, construction technology, and various market surveys have been the most common themes around which students have been able to work in companies.

The year 2024 was the seventh working year for the Business Mill business incubator and at the same time the busiest of the operating years so far. A total of 200 customers visited for advice, of which 143 were companies. Business Mill's customers established a total of nine new companies in 2024. Of these, six were established in Lappeenranta, two in Imatra, and one in Luumäki. In total, 57 business ideas were heard in the counseling during the last year. Business Mill's corporate clients received a total of €2.5M in public and private funding for their operations development in 2024. The funding launched new products, explored the market, and developed services. In total, Business Mill's clients hired 39 new employees during the year. (Latvala, 2025)

The employees hired by Business Mill's customers are often university students, who come to work to complete an internship or to implement a development project.

One concrete way for collaboration between students and businesses is through innovations. In this process, a group of students innovate around a company's theme for either 12 or 24 hours, creating a solution that is finally presented to the company's representatives. The students work on the company's needs together for that entire time. In Lappeenranta, a cooperative of marketing students carries out these innovations. (Soikkeli, 2022.) The popularity of these innovations among businesses and other regional actors has been immense. Twelve-hour innovations have been utilized in the area by business service providers such as Lappeenranta City Business Services, municipalities like Rautjärvi municipality, and even businesses.

In total, from 2018 to 2024, Business Mill has helped over 650 South Karelian businesses to grow and internationalize. Over the years, these companies have hired numerous university graduates, who have further improved their productivity.

The positive outcomes observed at Business Mill align with recent research on university–industry collaboration. For example, Rantala et al. (2025) found that Finnish small and medium-sized enterprises (SMEs) highly value research produced by universities and primarily use it to build their knowledge. Business Mill serves as a conduit for such knowledge-based collaboration, providing SMEs and startups access to cutting-edge research and expertise. In line with the Triple Helix model, the incubator demonstrates how an intermediary organization can enhance innovation in a region by blurring the traditional boundaries between academia, industry, and

government. The strong municipal involvement in Business Mill's funding and operations exemplifies the government's role in facilitating these interactions.

6.2 Sustainable Growth Innovations – Subproject Process and Starting Point

The *Sustainable Growth Innovations* subproject was established to experiment with new forms of collaboration between higher education institutions and regional companies. It focused in particular on fostering sustainability-driven innovation. The process was designed to operationalize the strategic goals of LAB University of Applied Sciences by embedding sustainability into business support services and by leveraging the university's expertise for regional economic development.

Business Mill functioned as the primary interface for this collaboration. By integrating academic resources, including student projects, expert consultations, and entrepreneurship coaching, into the growth paths of SMEs and early-stage startups, the initiative created a flexible and agile innovation pipeline. In addition to serving regional business needs, the Business Mill model functions as a pedagogical environment that connects students with real-world challenges. This approach is supported by research on cooperative and experiential learning, which suggests that student engagement is significantly enhanced when tasks involve authentic problem-solving with tangible outcomes (Smith et al., 2005). As students participate in startup support, expert consulting, and project-based co-development, they develop entrepreneurial competencies that complement academic learning. A major component was the Idearace startup competition. It provided visibility and feedback for early-phase ideas, while structured one-to-one sparring offered more personalized support for existing companies.

At the launch phase, regional innovation cooperation appeared fragmented and unevenly distributed across sectors. However, findings from a regional survey commissioned by Sitra in spring 2025 indicated strong interest in deepening university collaboration. Specifically, 44 respondents identified research collaboration with higher education institutions as a key development need. This emphasized a latent demand for more integrated innovation services.

These results align with broader European studies that highlight the role of universities in building regional innovation ecosystems. As previously noted by Rantanen and Bogdanova (2024), regional hubs such as Business Mill play a pivotal role in translating academic knowledge into marketable outcomes. This is particularly effective when such initiatives are embedded in a Triple Helix structure involving academia, industry, and public institutions. The South Karelia case demonstrates that sustainable growth can be supported through localized, university-driven mechanisms, assuming there is municipal commitment, strategic alignment, and an active interface such as Business Mill.

7. Conclusions

The impact of real business cases on a student's employability is specifically formed through critical work-life skills. When students get to implement real cases from local businesses during their studies, they learn such critical work-life skills that enable them to succeed well in working life. (Juvonen, 2025)

LUT universities have done an excellent job in achieving worldwide recognition, and for this reason, the region is very committed to developing education in South Karelia. LUT University has, among other things, occasionally received a significant 4-million-euro research environment with the help of partners. The research environment is studying a substitute for fossil fuels. (Hannus & Toijonen, 2025.) In addition, in early 2025, LUT University and LAB University of Applied Sciences received over 2- million euros in donations from South Karelian companies and communities to establish a professorship in artificial intelligence and particle technology at the university, and the University of Applied Sciences received a senior lecturer in early childhood education (Väisänen, 2025). In 2023, LAB University of Applied Sciences received information that, thanks to extensive corporate cooperation and funding from the company, it was able to start electrical and automation engineering education in Lappeenranta in 2024 (LAB 2023).

Since this is often only possible for medium or large companies, it is important that the region also supports the participation of small businesses in education. In South Karelia, this is realized in the form of Business Mill.

University-business cooperation is important for the region's small businesses, as cooperation helps them develop their own products and gain more understanding of future development trends (Husso, 2024).

The Ministry of Employment and the Economy has studied corporate university and research institute cooperation from a development perspective in 2024 and continued the same theme also in a business barometer conducted together with Finnish Yrittäjät and Finnvera (Suomen Yrittäjät, 2024).

Interaction between companies and universities produces various benefits according to companies' views. Companies that have worked with universities and research institutes felt that cooperation most often led to the strengthening of knowledge and skills and understanding of future development trends and markets. The most significant result of cooperation between universities of applied sciences and companies was the development of new and improved products. (Husso et al, 2024.)

This case study supports the Triple Helix proposition that active university–industry–government partnerships can be a catalyst for regional innovation. Business Mill shows how a university's third mission (contribution to society) can be operationalized through an incubator that actively engages with external stakeholders. The structured interactions in this case led to measurable business development outcomes, affirming the value of collaborative innovation frameworks in practice.

In the future, cooperation between the community and the university can deepen further, for example, through community learning environments, regional innovation platforms, and digital networks. The most important thing is to maintain open dialogue and a common goal: to build a knowledgeable, participatory, and sustainable society.

The findings in this paper reinforce the relevance of the Triple Helix model as a practical framework for regional innovation development. In South Karelia, initiatives such as Business Mill and targeted survey-based RDI assessments demonstrate how universities, businesses, and municipalities can move beyond traditional collaboration models toward dynamic, co-created ecosystems. The results suggest a growing regional readiness for hybrid innovation roles and stronger interfaces between actors. To maintain momentum, continuous feedback loops, tailored support mechanisms, and inclusive platforms like startup competitions and co-development workshops will be essential. These localized models may offer broader lessons for other regions seeking to unlock sustainable growth through knowledge-based collaboration.

For practitioners and policymakers, the Business Mill model provides a blueprint for fostering regional vitality. Key practical insights include the importance of having dedicated personnel who act as brokers between academia and companies, and the benefit of combining support for existing firms with support for new startups. Other regions aiming to increase community commitment to higher education and local innovation may consider establishing similar incubator programs that involve multi-year public funding and close university collaboration.

This study is limited by its focus on a single case in one region, which may affect the generalizability of the findings. The data used (such as internal reports and a preliminary survey) were largely self-reported and specific to the Business Mill context. There is also a potential response bias in the customer satisfaction survey due to its modest response rate. Future research could examine comparable incubator initiatives in other regions or employ longitudinal designs to assess the long-term impacts of university–community engagement on regional development.

Ethics Declaration

The study did not require ethical declarations.

AI Declaration

An artificial intelligence (AI) tool called Future Objects has been used for checking and editing the language of the study. The AI tool has translated some of the Finnish terms and checked the spelling.

References

Business Mill (2025). *Your business best friend*. [Accessed 27 May 2025]. Available at: https://businessmill.fi/en/

Etzkowitz, H. & Leydesdorff, L. (2000). The dynamics of innovation: From National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research Policy*, 29(2), pp.109–123.

Eriksson, P. & Koistinen, K. (2014). *Monenlainen tapaustutkimus*. [Online]. Available at: https://helda.helsinki.fi/server/api/core/bitstreams/fecd7913-7363-4d9f-9e2e-2d9f3e597230/content

Finnish Government (2023). *Formula for Growth: Government Programme*. Helsinki: Council of State. [Accessed 27 May 2025]. Available at: https://valtioneuvosto.fi/hallitukset/hallitusohjelma#/6/0

Hannus, T. & Toijonen, V. (2025). *A laboratory built in Lappeenranta could revolutionize Finland's energy industry*. YLE, 27 May 2025. [Accessed 3 June 2025]. Available at: https://yle.fi/a/74-20164118

Husso, K., Lai, S. & Palko, T. (2024). *University and research institute collaboration with companies in Finland: Strengthening cooperation as a development target*. Helsinki: Ministry of Economic Affairs and Employment.

Idearace (2025). *Business idea competition*. [Accessed 27 May 2025]. Available at: https://idearace.fi/en/

Innovation strategy 2022-2025. eKarjalan älykäs erikoistuminen. [Accessed 27 May 2025]. Available at https://liitto.ekarjala.fi/wp-content/uploads/2022/01/INNOVAATIOSTRATEGIA_netti.pdf

Juvonen, P. (2025). *Towards sustainable value creation – Students' perspective of team learning*. Forthcoming publication at ECIE 2025, September 2025.

LAB University of Applied Sciences (2025). *We Enable Responsible Growth – LAB Strategy 2030*. [Accessed 3 June 2025]. Available at: https://lab.fi/en/info/about-us/strategy

LAB University of Applied Sciences (2023). *LAB to launch electrical and automation engineering degree programme in Lappeenranta*. [Accessed 3 June 2025]. Available at: https://lab.fi/en/node/13757

Lahtonen, J. & Tokila, A. (2014). *Triple Helix: A model for a successful regional innovation hub*. [Accessed 27 May 2025]. Available at: https://www.taloustieteellinenyhdistys.fi/wp-content/uploads/2014/09/lahtonen_tokila1.pdf

Latvala, E. (2025). *In South Karelia, people believe Finland is a good place to live and do business*. LAB Focus blog, 16 May 2025. [Accessed 3 June 2025]. Available at: https://blogit.lab.fi/labfocus/etela-karjalassa-luotetaan-etta-suomessa-on-hyva-elaa-ja-yrittaa/

LUT University (2025). *LUT University maintains its top reputation in Finland*. 22 May 2025. [Accessed 23 June 2025]. Available at: https://www.lut.fi/en/news/lut-university-maintains-its-top-reputation-finland

Maastricht School of Management (2021). *Definition of a Triple Helix Partnership: What is it and what is it not?* 11 March 2021. [Accessed 27 May 2025]. Available at: https://www.msm.nl/news-events-and-blogs/blog/definition-of-a-triple-helix-partnership

Ojasalo, K., Moilanen, T. & Ritalahti, J. (2018). *Methods of development work: New kinds of expertise for business*. Helsinki: Sanoma Pro Oy.

Rantala, T., Saunila, M., Ukko, J., & Rinkinen, S. (2025). *SMEs as cutting-edge research utilizers: The strategies, motivations, and barriers of forerunners*. *The Journal of Technology Transfer*. Advance online publication. https://doi.org/10.1007/s10961-025-10239-1

Rantanen, P., City of Lappeenranta & Sitra (2025). *Survey on RDI collaboration and innovation activity in South Karelia 2025*. Forthcoming report under Sitra's Innovations for Sustainable Growth programme

Regional Council of South Karelia (2022). *Innovation Strategy 2022–2025*. [Accessed 23 June 2025]. Available at: https://liitto.ekarjala.fi/wp-content/uploads/2022/01/INNOVAATIOSTRATEGIA_netti.pdf

Rantanen, P. & Bogdanova, O. (2024). *The bottlenecks of commercialization for innovations in higher education institutions and accelerators*. In: ICERI2024 Proceedings. 17th International Conference of Education, Research and Innovation. IATED. Available at: https://doi.org/10.21125/iceri.2024.2396

Smith, K.A., Sheppard, S.D., Johnson, D.W. & Johnson, R.T. (2005). Pedagogies of Engagement: Classroom-Based Practices. *Journal of Engineering Education*, 94(1), pp.87–101. https://doi.org/10.1002/j.2168-9830.2005.tb00831.x

Soikkeli, J. (2022). *Opportunities of multidisciplinary collaboration*. LAB Focus blog, 21 December 2022. [Accessed 3 June 2025]. Available at: https://blogit.lab.fi/labfocus/monialaisen-tyoskentelyn-mahdollisuudet/

Väisänen, R. (2025). *Two million euro donation to higher education – enough for two professors and a principal lecturer in Lappeenranta*. YLE, 18 February 2025. [Accessed 3 June 2025]. Available at: https://yle.fi/a/74-20144447

Suomen yrittäjät, Finnvera & Ministry of Economic Affairs and Employment (2024). *SME Barometer 2/2024*. [Accessed 3 June 2025]. Available at: https://www.yrittajat.fi/ajankohtaista/tutkimukset/pk-yritysbarometri-2-2024/

Torfing, J. (2019). Collaborative innovation in the public sector: The argument. *Public Management Review*, 21(1), pp.1–11. https://doi.org/10.1080/14719037.2018.1430248

Reskilling and Upskilling in Portugal Amidst Digital and Green Transformation

Carolina Marques and Florinda Matos
Iscte - University Institute of Lisbon - DINÂMIA'CET-IUL - Centre for Socioeconomic Change and Territorial Studies, 1649-026 Lisbon, Portugal

Carolina_mendonca@iscte-iul.pt
Florinda.Matos@iscte-iul.pt

Abstract: Continuous learning has become a critical priority in the global economic environment nowadays, driven by rapid digital transformation, environmental challenges and shifts in production and organisational models. The study focuses on reskilling and upskilling to prepare the Portuguese workforce for the evolving demands of the labour market. Its objective is to investigate the gap between current human capital skills and future labour market requirements. By identifying structural mismatches between educational provisions and business sector demands, the research employs a qualitative, documentary methodology, analysing secondary data from international reports that consider skills development, labour market forecasts, and global skilling trends. The findings indicate discrepancies between national qualification frameworks and the skills required by firms in emerging economic markets. There is an urgent need to accelerate qualification processes and implement future-oriented strategies to address the skills gap, as adapting to new business models and technological innovation is crucial for maintaining competitiveness. The study aims to promote coordinated efforts among policymakers, educational institutions, and stakeholders to establish agile and adaptable qualification systems that equip the workforce for a complex global economy. It provides valuable insights for decision-makers seeking to enhance the resilience, adaptability, and competitiveness of the national workforce, based on European forecasts of future skills.

Keywords: Reskilling, Upskilling, Policymakers, Sustainability, Digital Transformation, Green Transformation

1. Introduction

Globalisation, technological advancement, and demographic shifts are major trends significantly influencing the labour market. These are affecting the quantity and quality of accessible employment, as well as the execution of tasks and the competencies required in an increasingly competitive environment (OECD, 2018).

From 2000-2015, significant advancements in the global economy included reductions in working poverty and child labour, though wage growth has stalled and inequality has risen. Resource extraction and waste generation continue to be relied upon in economic growth patterns (International Labour Organization 2018). The green transition is expected to significantly transform the global labour market, with macro-trends such as technological advancements, economic instability, environmental stability, and demographic shifts reshaping employment dynamics (World Economic Forum, 2025).

Mechanisms examples for a just transition towards environmentally sustainable economies and societies to integrate and promote decent work are the Sustainable Development Goals (SDGs) and the International Labour Standards (ILO) Guidelines (CEDEFOP & UNESCO-UNEVOC, 2025).

Based on projections to 2030 alighned with the established policy objective of restricting global warming to 2°C, ILO analysis assesses assesses employment losses and gains during the transition to a green economy. More broadly, it concludes that the environmental enhancement of economies can yield a beneficial impact on growth and employment (International Labour Organization, 2018).

The European Green Deal was introduced by the European Commission in 2019 to transform the EU into the first climate-neutral continent by 2050 (European Commission, 2019). The "Fit for 55" package proposes revising EU regulations to align with climate objectives (European Council, 2025; Regulation (EU) 2021/1119 European Climate Law, 2021). Although mitigation measures may cause temporary job losses, legislation can mitigate their negative effects on GDP growth, employment, and inequality (International Labour Organization, 2018).

Digital transformation, green transition and continuous change, reskilling and reskilling have become increasingly essential in the context of the global economy. This exploratory study investigates the gap between current human capital skills and future labour market trends in Portugal, using a qualitative, document-based methodology. It analyses secondary data from international reports on skills development, labour market forecasts and global skilling trends.

In the OECD Survey of Adult Skills (2022-23), adults in Portugal aged 16 to 65 scored below the OECD average in literacy, numeracy, and problem-solving skills. For instance, older adults (aged 55-65) demonstrated lower

proficiency than young people (aged 25-34) in literacy, numeracy, and adaptive problem-solving. Therefore, the skill gaps between older and younger adults may reflect effects associated with ageing, as well as differences in the quality and quantity of education and training between generations (OECD, 2024).

Additionally, CEDEFOP (2023b) identifies 12 skills challenges for Portugal, including improving equity and quality education; improving VET responsiveness to labour market demands; promoting adult education and lifelong learning for low-skilled individuals; addressing youth unemployment and NEETs (Not in Employment, Education and Training) (CEDEFOP, 2025), facilitating labour market re-entry for long-term unemployed; lowering employment barriers; encouraging entrepreneurship and innovation; creating high-skilled jobs; providing incentives for SMEs to invest in skills development; financing fair and efficient skills system; aligning decision-making with local needs; and fostering partnerships for evidence-based skills policy (CEDEFOP, 2023b).

This paper begins with an introduction to various concepts alongside current forecasts of future jobs and skill needs in the labour market, which include data on the aspects considered most relevant in international reports. The methodology is then presented, and the paper concludes with the results and brief discussion of the top 5 skills of the future in Europe and Portugal, respectively, followed by the concluding remarks and references.

2. Literature Review

The literature review consolidates terms such as reskilling, upskilling, digital skills, and green skills, as defined by renowned international institutions. Currently, there is no universal glossary to standardise these concepts, leading to varied, context-dependent interpretations by different organisations. This research utilises definitions primarily from international entities, such as the World Economic Forum (WEF), OECD, CEDEFOP, and International Labour Organization, acknowledging that a comprehensive literature review would necessitate further study.

2.1 Conceptualisation: Skills, Skill Gap, Reskilling, Upskilling, Green Skills and Digital Literacy

Skills refer to the proficiency and competence to execute methods and to apply one's knowledge responsibly to attain a specific objective. They form part of the broader idea of competency, which encompasses values, knowledge, skills, and attitudes (OECD, n.d.).

According to the OECD Learning Compass 2030, skills can be categorised into three main types: cognitive and meta-cognitive skills (including critical thinking, creative thinking, learning-to-learn, and self-regulation), social and emotional skills (encompassing empathy, self-efficacy, responsibility and collaboration) and practical and physical skills (which involve the use of new information and communication technology tools) (OECD, n.d.).

Concomitantly, a skill gap occurs when an individual lacks the necessary level of skills to perform their job effectively. Such gaps may result from an insufficient overall qualification or from a workforce that, despite possessing the appropriate qualifications, lacks certain specific skills (e.g., managerial abilities) or the experience required to carry out a task or role competently (CEDEFOP, 2014a).

Moreover, a skill mismatch occurs when an employee's competencies have diverged with the labour market's requirements. It can be vertical (mismatches referring to higher or lower education levels) or horizontal (mismatches referring to the type of skills that are inappropriate for the job) (CEDEFOP, 2014a).

Mismatches can lead to reduced job satisfaction, earnings, and societal welfare, as well as reduced productivity and human capital investments (OECD 2024). A proper alignment between workers' skills and job demands is crucial for a productive economy. Individually, misalignment can lead to job-to-job dissatisfaction and lower salaries, while at a broader level, it may cause diminished productivity and waste of human capital investment (OECD, 2024).

Reskilling and upskilling are key practices for sustaining competitiveness, allowing individuals to acquire new skills or enhance existing ones to meet evolving job needs. An interrelation between reskilling and upskilling is occasionally made. Nevertheless, they signify two distinct processes. Reskilling entails acquiring new capabilities for a different profession or sector, whereas upskilling involves enhancing existing skills or acquiring new ones (Hasan et al., 2024; Kilag et al., 2024).

Additionally, according to CEDEFOP (2014a), short-term, targeted training provided after initial education and designed to enhance, update, or supplement the knowledge, skills and competencies previously acquired is referred to as upskilling (CEDEFOP, 2014a).

Abiities that individuals possess which are applicable to jobs or occupations beyond their current or most recent role are known as transversal skills. These skills may be acquired through non-work-related or leisure activities, as well as through participation in education or training. More broadly, transversal skills are learned in a single context or developed addressing a specific situation or problem and that can be relocated and applied effectively to other contexts. (European Lifelong Guidance Policy Network, 2014).

The ability to effectively use information and communication technology (ICT) is known as Digital competence or digital literacy. It is reinforced by elementary skills in ICT, including computers usage to archive, display, evaluate, retrieve and disseminate information, as well as to communicate and participate in collaborative networks via the Internet (CEDEFOP, 2014a).

Green skills refer to the competencies required to modify goods, services and procedures in response to environment change and associated ecological mandates and guidelines. They will be needed across all sectors and at every level of the workforce (CEDEFOP, 2014).

Green skills are crucial for enabling the transition to a low-carbon economy. The successful transition to a low-carbon economy necessitates the ability of the labour force to shift from declining employment sectors to emerging industries, alongside the availability of sufficient human capital to cultivate new sectors arising from climate change mitigation and adaptation efforts. Skills development initiatives will significantly influence each of these shifts (CEDEFOP, 2014).

2.2 Competencies Development, Anticipation and Policy Alignment in Europe

The creation of new job opportunities that require new skill profiles and training frameworks, causing structural changes that make some jobs more in demand and others less so, and making existent professions change their job standards, which means current training systems need to be updated are all aspects taken into consideration when transitioning to a greener economy (CEDEFOP, 2014). Additionally, employee productivity, educational level and information-processing co-exist positively correlated (OECD, 2024).

Critical thinking, creativity, collaboration, language skills and problem-solving are all related to transversal skills, whereas knowledge and practices related to circular economy, energy efficiency, energy transition, and environmental sustainability are incorporated in green skills. Entrepreneurial and managerial skills, including the ability to create value, innovate, lead teams, and manage resources in uncertain and changing contexts, are also essential for navigating evolving job requirements and maintaining employability over time (European Commission, 2023).

Unchecked climate change bring repercussions that will consequently impede GDP growth, productivity, and labour conditions. Soil pollution, water, and local air, along with additional arrangements of environmental degradation, have an adverse impact on workers' healthiness, revenue, food and fuel security, and productivity (International Labour Organization, 2018).

CEDEFOP & UNESCO-UNEVOC (2025) report that skills mismatches are a major barrier to the greening of the economy in 21 out of 27 examined nations. An inadequate understanding of the environment-skills connection, a lack of routinely conducted employment forecasts, the absence of financial mechanisms to promote investments in skills development for the green transition, and weak involvement of social partners continue to obstruct the realisation of an effective transition (CEDEFOP & UNESCO-UNEVOC, 2025).

Social partners piece a key part in identifying skills deficiencies, implementing training programs, and recognising employment competencies. However, their involvement in discussions, particularly regarding workers, is limited. Nonetheless, where they are present, specialised bodies have improved training for sectors such as renewable energy and waste management (International Labour Organization, 2018).

The European Commission has communicated a European Skills Agenda, setting out a five-year approach, between 2020 and 2025, structured in the following blocks: strengthening skills intelligence, skills to support digital and green transitions, increasing the number of STEM graduates and promoting entrepreneurial and transversal skills and tools for lifelong learning, such as micro-credentials and Europass (European Commission, 2023).

The future skills combine foundational, technical and transversal skills necessary to respond to digital, green and demographic shifts, such as basic skills in literacy, numeracy, digital skills and citizenship, STEM skills (digital literacy to advanced skills in science, technology, engineering and mathematics), crucial to innovation and sustainability, according to the European Commission (2023).

The advancement and integration of artificial intelligence (AI) are expected to significantly influence labour markets, affecting employment rates and job quality, as well as the organisation of work, the kind of activities performed by workers, and the requisite skills. To adjust to fast changes, such as skill makeup of employment and the allocation of occupations within the economy, adult education systems must adjust swiftly (OECD, 2023).

The necessity of possessing fundamental digital skills to engage with AI may restrict participation among individuals with lower skill levels. At the same time, the propensity of certain algorithms to amplify human biases may diminish inclusivity. The integration of AI in training is expected to alter the skill requirements for educators and trainers significantly. These topics require meticulous consideration (OECD, 2023).

The demand for advanced skills will arise from the necessity to design and manage AI systems, as well as from the utilisation and interaction with AI applications. Positions focused on the development and maintenance of AI systems are predominantly technical, with certain roles being novel, as they entail activities unique to AI that are not found in current professions (OECD, 2023).

2.3 Bridging Skill Gaps: Learning Strategies and Labour Market Needs

According to the 2023 Survey of Adult Skills, the likelihood of employment is positively correlated with both education and skills (OECD, 2024). This strong correlation suggests that individuals with higher skills are more likely to secure employment, and their simultaneous work experience offers additional opportunities for skill improvement (OECD, 2024). This report indicated that, on average, proficiency in skills considerably influences both well-being and civic involvement. Nonetheless, the intensity and character of this link differ among nations (OECD, 2024).

Lower-skilled persons are less likely to secure full-time employment than their highly skilled counterparts. On average, 91% of high-skilled workers in OECD countries are employed full-time, compared to 82% of low-skilled workers (OECD, 2024). Czechia and Poland stand out as exceptions, with a higher share of low-skilled workers employed full-time.

By contrast, the Netherlands has the lowest overall rate of full-time employment, primarily due to 34% of its low-skilled workforce working part-time, the highest proportion among participating countries (OECD, 2024).

Policies and programs regarding skills for the green transition typically employ a sectoral approach. Interventions in renewable energy and energy efficiency skills have been executed in accordance with the legal stipulations for vocational certification and training established in the legislation. They emphasise the significance of the regulatory framework in incorporating environmental and equitable labour results (CEDEFOP & UNESCO-UNEVOC, 2025).

Additionally, legal norms can facilitate progress toward equitable employment during and after the transition to environmental sustainability (International Labour Organization, 2018). Public policies are crucial in fostering enhanced training opportunities provided by companies, ensuring a cohesive strategy for skills development in AI throughout its lifecycle, from early education to lifelong learning, and promoting diversity within the AI workforce (OECD, 2023).

While skills development programs for firms and people aid the transition to a green economy, they have not yet been integrated into policy considerations. Attaining a just transition is greatly enabled by skills development courses. According to the International Labour Organization (2018), amongst the 27 studied nations, almost two-thirds have developed platforms to forecast skills requirements and training provisions; however, these platforms are not universally utilised to address the skills ramifications of the green transition.

Portugal's Qualification Needs Anticipation System (SANQ) constitutes the foundation of the skills anticipation strategy. It is a diagnostic instrument that employs systematic procedures, various quantitative and qualitative approaches, and a synthesis of diagnosis, forecasting, and planning to determine qualification requirements at both national and regional levels (CEDEFOP, 2023b).

SANQ is managed by ANQEP, a governmental body overseen collaboratively by the Ministry of Education, the Ministry of Labour, Solidarity and Social Security and the Ministry of Economy and Maritime Affairs (CEDEFOP, 2023b).

Even so, around 14% of Portuguese workforces report being overqualified (OECD average: 23%), and another 14% report being underqualified (OECD average: 9%), i.e. they consider their academic qualifications to be overhead or underneath the level stereotypically required for their existing job (OECD, 2024).

Moreover, workers (around 7%) state that some of their skills fall short of what remains required for their careers (OECD average: 10%). Portugal's labour force frequently cite the necessity to enhance their computer or software competencies (35%), suceeded by their organisational or project management skills (32%) (OECD, 2024).

The 2015 OECD Skills Strategy Diagnostic Report outlines the main goal of the collaborative initiative between the OECD and the Portuguese government: to develop an effective Skills Strategy for Portugal. This strategy aims to provide a strategic assessment of the national skills framework and the mechanisms for cultivating, mobilising, and utilising skills. A thorough understanding of these issues is crucial for devising effective policies and strategies that meet Portugal's future skill needs and enhance the alignment between skill supply and demand (CEDEFOP, 2023b; OECD, 2015).

3. Methodology

This study employs an exploratory and comparative research design, utilising secondary data through descriptive content analysis of international reports. The analysis considers skills development, labour market forecasts, and global skilling trends.

The field of future-oriented skills in relation to reskilling and upskilling in Portugal amidst digital and green transformation is still emerging. Therefore, an exploratory approach enables the identification of patterns, gaps, and potential misalignments without imposing a rigid hypothesis that may overlook the complexity of the topic.

Secondary data is initially collected for purposes other than the current research, often by organisations, institutions, or other researchers, and is later reanalysed for new objectives (Greener, 2008; Saunders et al., 2016, 2019).

Unlike primary data, which is collected directly by the researcher, secondary data can be documentary, survey-based, or derived from multiple sources. Documentary secondary data, in particular, can be rearranged across time and space, allowing for reuse in different contexts (Saunders, Lewis, and Thornhill, 2019).

The secondary analysis primarily utilises information from reputable sources, including the OECD, the ILO, UNESCO, the WEF, the European Commission, and the European Council.

In the following chapter, *"Results and Discussion," the top 5 skills are presented as identified in reports by the World Economic Forum (2025), CEDEFOP (2015, 2023d),* and the OECD (2024). The accompanying definitions reproduce the official formulations provided in these sources rather than interpretations by the present authors. Accordingly, all secondary data reported here is drawn directly from external publications, with the corresponding references indicated alongside each definition.

4. Results and Discussion

Skills enable adults to perform their work more effectively, thereby enhancing employability and increasing earning potential. The relationship between skills, productivity and income is well established in economic theory and supported by empirical evidence (OECD, 2024).

According to the WEF (2025), the top five skills are identified as analytical thinking, resilience, flexibility and agility, leadership and social influence, creative thinking, and motivation and self-awareness. At the same time, major drivers of skills disruption are highlighted, including technological change, geoeconomic fragmentation, economic uncertainty, demographic shifts, and the green transition (World Economic Forum, 2025).

The following table presents definitions drawn directly from recognised international organisations, reflecting the concepts as set out in the Future of Jobs report by the World Economic Forum.

Table 1: Top 5 skills

Future Skill	Definition
Analytical thinking/ Critical Thinking	Critical thinking involves the mental processes and strategies used to solve problems, make decisions and learn. It is a higher-order cognitive skill that encompasses reasoning, analysis, inference and evaluation. Although definitions vary, most agree that critical thinking is intentional, goal-directed thinking.
Resilience	Resilience involves enduring focus on challenging tasks for long-term goals, linked to conscientiousness and grit. Persistence and resilience are defined as the disposition to maintain effort and interest despite obstacles.

Future Skill	Definition
Flexibility and agility	Cognitive flexibility is the capacity to shift perspectives, reframe problems and adapt to changing demands or priorities. It involves seeing issues from different viewpoints, adjusting strategies when needed and recognising mistakes while seizing unexpected opportunities. It is the ability to adapt one's behaviour appropriately to a changing environment.
Leadership and social influence	The set of characteristics that make a good leader; the position or fact of being the leader; and the person or people in charge of an organisation (Dictionary of Cambridge 2025).
Creative thinking	Creative thinking is the process of generative innovative ideas, methods or insights. Creativity is intrinsically linked to innovation. It involves individual focused creation of beneficial concepts, while innovation involves team of organisational focused introduction and execution of ideas.
Motivation	Motivation refers to the inner states that drive the pursuit of knowledge, skills, goals, values, and actions. It is commonly divided into intrinsic and extrinsic forms. Intrinsic motivation stems from personal values, identity, or growth, while extrinsic motivation arises from external rewards or reinforcement, such as praise or money.
Self-awareness	Self-awareness is the ability to understand one's emotional state, recognise personal strengths and limitations, and identify preferences. It includes emotional awareness, accurate self-assessment, and recognition of behavioural tendencies.

Source: Table developed by the authors, based on World Economic Forum (2025) and OECD (n.d.).

In the Portuguese context, the evidence points to a similar set of priorities in skills. The most frequently identified and pressing skills areas to be strengthened include digital and technological literacy, analytical and problem-solving skills, lifelong learning and adaptability, strong foundation skills such as literacy and numeracy, and sector-specific capabilities to address shortages in areas such as ICT and health (CEDEFOP 2015, 2023, DGERT 2019, Ferreira 2016).

Table 2: Top 5 Skills in demand in Portugal

Skills in Demand (PT)	Definition	References
Digital and technological skills	Digital technology and technical skills emphasise the comprehension, use, and creation of digital systems and technologies effectively and responsibly. This area encompasses technical skills such as programming and data analysis, as well as proficiency in digital platforms (like Zoom or Instagram), and the ethical use of digital technology.	(World Economic Forum, 2025) and (University of Cambridge, 2025)
Analytical thinking/ Critical Thinking	Critical thinking involves the mental processes and strategies used to solve problems, make decisions and learn. It is a higher-order cognitive skill that encompasses reasoning, analysis, inference and evaluation. Although definitions vary, most agree that critical thinking is intentional, goal-directed thinking.	(World Economic Forum, 2025) and (OECD, n.d.)
Lifelong learning/adaptability and flexibility	All educational endeavours pursued throughout life that enhance knowledge, expertise, skills, competencies, and/or qualifications for personal, social, and/or professional purposes.	(World Economic Forum, 2025) and (European Lifelong Guidance Policy Network, 2014)
Foundation skills: literacy and numeracy	Fundamental skills include literacy, numeracy, and social-emotional competencies. The essential abilities cultivated from early childhood to secondary education are crucial for academic achievement and lifelong learning. Foundational literacy encompasses the skills of hearing and speaking with comprehension, as well as the capacity to read and comprehend elementary texts. Foundational numeracy encompasses understanding of number sense, proficiency in counting, fundamental operations, and mathematical reasoning.	(UNESCO, 2025), (UNICEF et al., n.d.) and (World Economic Forum, 2025)
Leadership/social influence/soft skills	The set of characteristics that make a good leader; the position or fact of being the leader; and the person or people in charge of an organisation.	(University of Cambridge, 2025) and (World Economic Forum, 2025)

Source: Table developed by the authors, based on CEDEFOP (2023, 2015).

The skills priorities in Portugal broadly align with Europe's future-oriented agenda, yet a gap persists between emergind digital and green skills and those prevailing in the workforce. This misalignment, specifically in advanced cognitive and technological competencies may hinder innovation, slow technologiy adoption and constrain Portugal's long-term labour productivity and competitiveness. Therefore, skills significantly impact income, job opportunities and well-being (Tables 1 and 2).

Lower literacy proficiency is correlated with poorer health, political apathy, and reduced trust in others. Strengthening the link between education and employment is essential for vocational education programs to lower dropout rates (CEDEFOP, 2023b). Portugal is enhancing its vocational education system through a strategy that focuses on improving qualifications for both youth and adults, alongside ongoing investment in reskilling and upskilling (Tables 1 and 2, CEDEFOP, 2023b).

By 2030, according to current forecasts, new job growth and job displacement resulting from macrotrends will constitute a combined total of 22% of the existing formal employment. A generation of new jobs driven by macro trends is projected to reach 170 million, or 14% of the current total employment.

This expansion is anticipated to be counterbalanced by the displacement of 92 million existing jobs (representing 8% of total employment), culminating in a net increase of 78 million jobs (or 7% of current total employment) (World Economic Forum 2025).

The demand for skills is evolving due to several trends, including technological advancement, such as higher internet access, developments in artificial intelligence (AI), demographic shifts and information processing, as well as robotics and autonomous systems technologies, which are trends that substantially drive the fastest growing and declining jobs (World Economic Forum 2025, OECD 2018).

The future workforce requires a balance between technological proficiency and human capital, with digital competencies (including data analysis, programming and digital literacy) and advanced cognitive skills (such as problem-solving, critical thinking and active learning) becoming increasingly vital for navigating complex tasks in an era of automation. Nonetheless, socio-emotional skills such as cooperation, communication, adaptability, and resilience are essential for collaboration and leadership in heterogeneous and rapidly evolving work environments.

Furthermore, management and innovation skills, including project management, creativity, and leadership, are key for guiding organisational change, driving transformation, and sustaining competitiveness in knowledge-driven economies. Taken together, these skills embody the competencies that are most likely to influence employability and productivity (CEDEFOP & UNESCO-UNEVOC, 2025; World Economic Forum, 2025).

5. Concluding Remarks

Equipping the Portuguese workforce for the future requires the successful formulation of reskilling and upskilling programs, along with holistic and comprehensive methods to evaluate their effectiveness. Additionally, the efficacy of these programs is crucial to ensure that training investments yield tangible benefits in terms of employability and productivity.

The ongoing monitoring of the alignment between skills and the increasing demands of industries is equally important, as labour market transformations are rapidly advancing due to digital transformation, automation and sustainability transitions.

Furthermore, governments, organisations, and individuals must engage in thorough assessments and continuous improvement to ensure that lifelong learning systems remain responsive, inclusive, and resilient against future challenges in the labour market.

6. Future Implications/Considerations

This study highlights the centrality of skills to employability, productivity and income, underscoring their importance for both individuals, organisations and public policies. Based on information gathered from international organisations such as the OECD, the World Economic Forum, and the International Labour Organization, it was demonstrated that the importance of analytical, emotional, and adaptive skills is crucial, as is the urgency of preparing workforces for disruptive trends, including technological change, demographic shifts, and the green transition. The Portuguese context mirrors these global trends, with pressing needs identified in

digital literacy, problem-solving, lifelong learning, and sector-specific skills (World Economic Forum, 2025; OECD, 2024).

Henceforward, policy and practice must respond proactively to evolving labour market demands. Addressing skill gaps, needs, and shortages requires coordinated efforts in strategies across education, training, and employment systems, while tackling underqualification, undereducation, and underskilling. This involves proposing tailored interventions that depend on different needs. The integration of green skills into vocational and lifelong learning programmes is critical, as it aligns with sustainability and climate goals (OECD, 2018; CEDEFOP, 2014b; REGULATION (EU) 2021/1119, European Climate Law, 2021; European Council, 2025; European Commission, 2019).

Declaration of Ethics

This study is based exclusively on the analysis of secondary data obtained from publicly available reports and publications by international organisations. As no primary data was collected from individuals, ethical clearance was not required.

Declaration of AI

Artificial intelligence tools were employed to support language editing of the manuscript. All interpretations, analyses, and selections of information remain the responsibility of the authors.

References

Bryman, A. (2012) *Social Research Methods*, 4th Ed, Oxford University Press, Oxford University Press.

CEDEFOP (2023) *Skills Anticipation in Portugal (2023 Update)*.

CEDEFOP (2015) *2025 Skills Forecast - Portugal*.

CEDEFOP (2014a) *Terminology of European Education and Training Policy Terminology of European Education and Training Policy - A Selection of 130 Key Terms* [online], Luxembourg, available from http://europass.cedefop.europa.eu.

CEDEFOP (2014b) *OECD Green Growth Studies: Greener Skills and Jobs* [online] OECD Green Growth Studies, OECD, available from https://www.oecd.org/en/publications/greener-skills-and-jobs_9789264208704-en.html.

CEDEFOP & UNESCO-UNEVOC (2025) *Meeting Skill Needs for the Green Transition, Skills Anticipation and VET for a Greener Future* [online], Luxembourg, available from http://data.europa.eu/doi/10.2801/6833866.

DGERT (2019) *Vocational Education and Training in Europe Portugal 2018*.

Dictionary of Cambridge (2025) *Concept of Leadership*.

European Commission (2023) *European Skills Agenda*, [Publications Office of the European Union].

European Commission (2019) *The European Green Deal* [online] Brussels, available from https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF.

European Council (2025) *Fit for 55*.

European Lifelong Guidance Policy Network (2014) *Lifelong Guidance Policy Development: Glossary* [online], Jyväskylä, available from http://elgpn.eu.

Ferreira, F. (2016) *Key Competences in Vocational Education and Training - Portugal*.

Greener, Sue. (2008) *Business Research Methods*. BookBoon

Hasan, M., Haque, Md.A., Nishat, S.S., and Hossain, Md.M. (2024) 'Upskilling and Reskilling in a Rapidly Changing Job Market: Strategies for Organisations to Maintain Workforce Agility and Adaptability', *European Journal of Business and Management Research* [online], 9 (6), 118–126, available from https://www.ejbmr.org/index.php/ejbmr/article/view/2502.

International Labour Organization (2018) *World Employment Social Outlook 2018 - Greening with Jobs* [online], Geneva, available from www.ilo.org/publns..

Johnston, M.P. (2014) 'Secondary Data Analysis: A Method of Which the Time Has Come', *Qualitative and Quantitative Methods in Libraries (QQML)* 3, 619–626.

Kilag, O.K.T., Padilla, K.S., Yorong, F.S., and Merabedes, J.G.A. (2024) 'Importance of Upskilling and Reskilling in Educational Leadership and Management', *European Journal of Learning on History and Social Sciences* [online] 1 (1), available from https://journal.silkroad-science.com/index.php/EJLHSS|49.

OCED (2024) *Inquérito Às Competências Dos Adultos de 2023*.

OECD (2024) *Do Adults Have the Skills They Need to Thrive in a Changing World? Sruvey of Adult Skills 2023* [online] OECD Skills Studies, Paris: OECD, available from https://www.oecd.org/en/publications/do-adults-have-the-skills-they-need-to-thrive-in-a-changing-world_b263dc5d-en.html.

OECD (2023) *OECD Employment Outlook 2023 - Artificial Intelligence and the Labour Market* [online], OECD Employment Outlook, OECD, available from https://www.oecd.org/en/publications/oecd-employment-outlook-2023_08785bba-en.html.

OECD (2018) *Skills for Jobs* [online], available from www.oecdskillsforjobsdatabase.org.

OECD (2015) *OECD Skills Strategy Diagnostic Report*.
OECD (n.d.) *OECD Learning Compass 2030-Glossary*.
REGULATION (EU) 2021/1119 European Climate Law, 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R1119&from=EN.
Saunders, M., Lewis, P., and Thornhill, A. (2016) *Research Methods for Business Students (7th Ed.), Harlow Pear*, 9th edn, Pearson.
Saunders, M., Lewis, P., and Thornhill, A.K. (2019) *Research Methods for Business Students* [online] 8th edn. Ed, Pearson, available from www.pearson.com/uk.
UNESCO (2025) *Foundational Learning*.
UNICEF, J-PAL, Pratham, and Delivery Associates (n.d.) *Assessing Foundational Literacy and Numeracy*.
University of Cambridge (2025) *Digital Technology & Technical Skills*.
World Economic Forum (2025) *The Future of Jobs Report 2025* [online], available from www.weforum.org.

Investigating Ethical Issues for Workplace Lifelong Learning Digital Technologies: A Survey Study

Kadri Mettis[1], Abiodun Afolayan Ogunyemi[2] and James Sunney Quaicoe[2]
[1]School of Educational Sciences, Tallinn University, Narva mnt 25, 10120, Tallinn, Estonia
[2]School of Digital Technologies, Tallinn University, Narva mnt 25, 10120, Tallinn, Estonia

abnogn@tlu.ee
paasanni@tlu.ee
kadrimet@tlu.ee

Abstract: Lifelong learning in the workplace has expanded rapidly, accelerated by the COVID-19 pandemic and the integration of Artificial Intelligence (AI). While many studies explore the digital adoption using within the post-COVID periods, limited attention has been given to the ethical implications of these technologies used at the workplaces for lifelong learning, particularly with the increasing integration of Artificial Intelligence (AI) usage. This paper investigates ethical issues surrounding digital technologies for workplace lifelong learning, focusing on Estonia, a digitally advanced society. Holistically, the research sought answers for questions bordering on i) main motivations underpinning the quest to pursue lifelong learning, ii) digital tools being used for lifelong learning at the workplace, and iii) ethical awareness, concerns or violations perceived or encountered in the use of digital technologies for lifelong learning. The study adopted a survey as the research design, using both quantitative and qualitative approaches. A total of 70 participants were engaged in the study, and they were recruited through purposive and snowball sampling techniques. The qualitative and quantitative data were collected using thematic and descriptive statistical approaches, respectively. The study established that i) upskilling, staying active, health, productivity and reskilling were the drivers for lifelong learning; ii) Zoom, Microsoft Teams and Google Meet were frequently used for virtual meetings; for MOOC platforms for lifelong learning, EdX, Coursera, Udacity and Udemy were technologies used; and for social media, YouTube, Facebook and WhatsApp are the topmost three digital technologies used. The study further established Ethical consciousness and accountability gaps in lifelong learning technologies are explained by three broad themes, namely i) awareness vs. perceived ethical violations, ii) caring about ethics vs. reported violations and iii) ethical violations vs. systemic issues. Based on the outcome of the study, the following recommendations were made: i) Increased awareness and training on digital ethics for employees and employers in organisations, and ii) structures to monitor ethical breaches and accountability are needed at the work settings.

Keywords: Lifelong learning, Workplace Learning, Ethics, Digital Technologies

1. Introduction

The adoption of digital technologies for workplace learning has grown rapidly, driven by workforce demands and market dynamics. Platforms such as GetSetUp, Chinese EdTech solutions, and Lido Learning exemplify this trend. The COVID-19 pandemic accelerated adoption, creating new opportunities and challenges. National strategies in Estonia, Germany, and the US emphasise digital tools to support evolving job markets, where upskilling and reskilling are essential. Immersive and experiential learning technologies are increasingly seen as viable complements to traditional education. However, rapid digitalisation raises ethical questions. Fairness, inclusiveness, transparency, and accountability are critical to avoiding bias, misuse, and privacy breaches (Gaskins, 2023). AI-powered tools, while promising, require scrutiny to ensure ethical design and equitable service delivery. This study investigates user perceptions of these ethical issues, focusing on Estonian professionals across industries. To this end, this paper reports on the ethical issues surrounding the use of digital technologies for workplace lifelong learning in Estonia. Holistically, the research sought answers for questions bordering on i) main motivations underpinning the quest to pursue lifelong learning, ii) digital tools being used for lifelong learning at the workplace, and iii) ethical awareness, concerns or violations perceived or encountered in the use of digital technologies for lifelong learning.

2. Literature Review

2.1 Lifelong Learning in Workplaces

Workplace learning is integral to lifelong education, encompassing both formal and informal contexts (Jacobs & Park, 2009). Digital technologies have shifted learning from physical to virtual spaces (Karhapää et al., 2025), supporting constant skill adaptation in response to technological and market changes (Pammer-Schindler & Rosé, 2022). Motivations extend beyond career advancement. Older adults engage in lifelong learning to stay active, healthy, and socially connected (Merriam & Kee, 2014; Tam & Gray, 2016) or to share knowledge with

younger generations (Charungkaittikul et al., 2022). Self-directed learning for professional competence is also common (Curran et al., 2019).

2.2 Ethics of Digital Technologies

The recent advances in digital technologies, especially those used in lifelong learning and education, have necessitated the need to consider the ethical aspects of these technologies increasingly. ChatGPT is one of the digital technologies powered by artificial intelligence (AI) innovations that have entered mainstream education and learning. However, recent studies have raised concerns about these technologies. In a study by (Hsiao and Tang, 2024), the authors cautioned against not weighing technological advantages with ethical factors and personal motivations for using Generative AI tools. Similarly, (Rawas, 2024) reiterates that it is essential to proceed with care and have a thorough grasp of both the potential benefits and the obstacles present in ChatGPT implementation.

Ethical Considerations in the face of human and technology interactions have become a topical subject. Answers are being sought for human values to be sustained. For instance, (Van de Poel, 2020) advocates a proactive approach to designing AI technologies. This approach should support ethical lifelong practices and ensure AI-powered systems enhance rather than undermine human values. Additionally, (Zirar, Ali, Islam, 2023) highlight the importance of developing ethical guidelines and policies to address the balance between AI (technology) integration and preserving human work in lifelong learning environments.

Researchers' views of ethical concerns about AI-enabled systems are quite diverse. In their study, (Pammer-Schindler and Rosé, 2022) explored how AI-driven scaffolding and situated learning in the workplace can tackle ethical issues related to data in informal professional learning.

They identified three main themes:

1. Relevant data for learning analytics extends beyond just the learner to include colleagues, clients, and contextual factors, often involving private or proprietary information.
2. Manual tracking allows learners significant control over their data.
3. Informal professional learning often lacks a shared goal, which is ethically concerning since much relevant data is not collected for learning purposes.

These themes present challenges for AI in education (AIED) research that must be overcome to develop effective technologies for informal and situated learning contexts.

Through a Delphi study, (Mouta, Torrecilla-Sánchez, Pinto-Llorente, 2024), to create a toolkit for educators to facilitate a smooth and ethical integration of artificial intelligence into education while prioritising educational development, found that examining the ethics of AI in education also prompts a broader reflection on educational ethics overall. The scenarios illustrate the necessity of balancing the advantages and disadvantages of AI systems, particularly regarding educational objectives and the dynamics among various educational participants.

Privacy is one of the most important ethical concerns for workplace digital technologies. Studies such as (Chowdhary et al, 2022) show how averse, workers can be to well-being sensing technologies regarding privacy issues.

3. Method

3.1 Participants

The study adopted a survey research design, and both quantitative and qualitative approaches were used. The qualitative and quantitative data were collected using thematic and descriptive statistical approaches. The study is within the Republic of Estonia. In all, 70 participants participated in the study. Purposive and snowball sampling techniques were used in recruiting the subjects of the study. All the questions were presented in both English and Estonian languages. This encouraged the participation of both indigenous and international employees in the study. Data analysis was done in collaboration with a native Estonian speaker.

3.2 Materials and Procedure

A bilingual (English/Estonian) Google Form included closed questions used in eliciting qualitative data, four open-ended questions used in gathering the qualitative data (see Table 1), and demographic questions.

Table 1: Contents of data collection material

Research Approach	Focus or Theme(s) for Data/Information Elicitation
Quantitative	Motivation/Reason for Engaging in Lifelong Learning
	Educational technologies/digital tools used for lifelong learning
	Ethical concerns associated with the use of the educational technologies/digital tools
Qualitative	Awareness about ethical issues inherent in the use of technologies for lifelong learning
	Extent of care about whether technologies should or should not be ethically compliant
	Instances of ethical violation encounters or unethical observation during technology usage for lifelong learning
	Description of a specific case of ethical violation

During the data collection process, no identifiable personal data were collected. The survey link was disseminated online and through professional networks over three weeks, as well as using snowball sampling to reach prospective respondents.

3.3 Data Analysis

Quantitative data were analysed using descriptive statistics. Open-ended responses underwent thematic analysis (Braun & Clarke, 2012), following iterative coding and validation among co-authors. The data analysis was done in collaboration with the native Estonian language speaker; this ensured that the original meaning of the inputs from the native Estonian language speakers was not diluted.

4. Results

4.1 Demographic Data

Most respondents were young professionals (67% aged 26–40), highly educated (93% tertiary degrees), and working in Estonia's technology (31%) or finance (29%) sectors. This reflects the country's digital economy and the researchers' networks. These results could be influenced by the lists and groups chosen to spread the questionnaire. As the authors are more in the technology discipline, the network reached might be skewed.

4.2 Quantitative Data

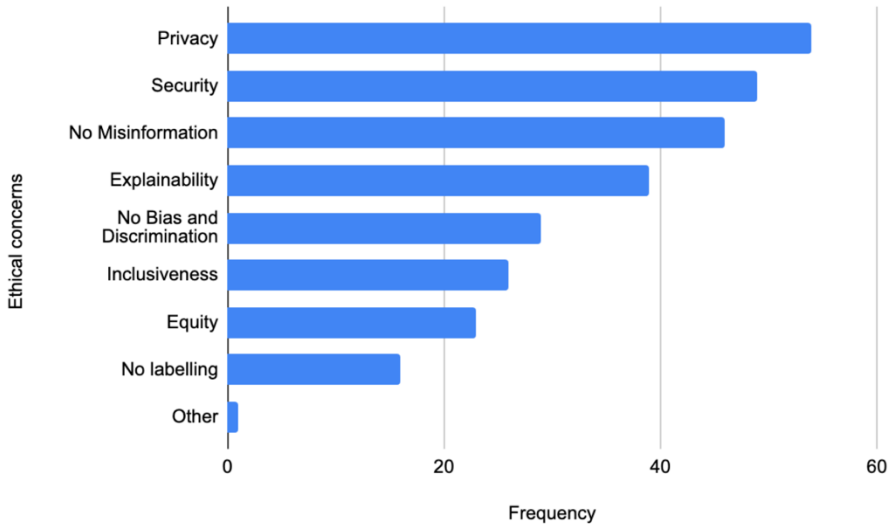
Motivation/Reason for Engaging in Lifelong Learning

The results reveal that the vast majority of the respondents are motivated by the need for upskilling (77%), followed by the need to stay active, healthy, and productive (49%). This is especially true for sustainable aging societies, where older adults, for example, can earn income by reskilling (29%) and staying socially responsible (23%), such as retirees providing training for younger people.

4.2.1 Educational Technologies/Digital Tools Used for Lifelong Learning.

The results show that Virtual learning/meeting environments such as Zoom, Microsoft Team, and Google Meet (70%), MOOC platforms such as EdX, Coursera, Udacity, and Udemy (63%), and Social-media such as YouTube, Facebook, and WhatsApp (63%), webinars (46%), and podcasts (46%) are the three most popular lifelong learning digital technologies used by the respondents.

The most pressing ethical issues were privacy (77%), security (70%), and misinformation (66%) (Figure 1). Other concerns included bias, inclusiveness, and transparency.



Note: Other - Avoiding AI-generated content consumption

Figure 1: Ethical concerns.

Awareness about ethical issues inherent in the use of technologies for lifelong learning

4.2.2 Qualitative Data

Ethical awareness varied: 22 respondents reported full awareness, while most others were partially aware, uncertain, indifferent, or unaware. Many equated awareness with data privacy policies but admitted limited technical understanding. The awareness levels are thus defined with a five-point scale, namely

1. **Not Aware** - means respondents who clearly stated they were unaware of ethical considerations.
2. **Partial Awareness -** means respondents who indicated they have some awareness level but lacked in-depth knowledge.
3. **Full Awareness** - means respondents who claim to be well-informed about ethical considerations and are concerned.
4. **Indifference** - means respondents who did not consider ethical issues relevant to their learning experience.
5. **Uncertain** - means respondents who were unsure of ethical considerations.

The results suggest that most respondents answering the question on awareness were unaware or partially aware. Further insights about the subject under review are presented in Tables 2a and 2b to showcase additional comments from the respondents regarding their positions about ethical awareness.

Table 2a: Full awareness respondents

Full Awareness Respondents (FAR)	Responses to Ethical Awareness Question(s)
FAR 1	"I am aware that many technologies for lifelong learning incorporate ethical considerations, though the extent varies by platform. For example, MOOC platforms like Coursera and EdX focus on inclusivity and privacy, ensuring equal access to learning materials while protecting user data. Maxybyte, which offers learning via Zoom, also emphasises inclusiveness and privacy. However, not all platforms are transparent about their bias prevention strategies or how they handle misinformation. I prioritize technologies that address concerns like data privacy, inclusiveness, and the absence of discrimination or bias in their educational content."
FAR 2	"Yes, usually they use cookies to get the consent of the visitors that come to their sites with options to select OK, reject all and select preferences."' and 'select preferences'."

Full Awareness Respondents (FAR)	Responses to Ethical Awareness Question(s)
FAR 3	"Yes, I know that some technologies used for lifelong learning consider ethics, like protecting user data and making sure everyone has equal access. However, I don't always look into the specific details of these policies. I am aware that platforms have rules about data use, but I usually don't read them closely."

Table 2b: Partial awareness respondents

Partial Awareness Respondents (PAR)	Responses to Ethical Awareness Question(s)
PAR 1	"Partially yes, but not technically competent enough [to] comprehend how these are addressed."
PAR 2	"I will try to make sure that [the] platform that I use [is] led in an ethical manner." Another respondent said, "I am aware to some extent based on the information available to me." On being indifferent, one respondent said, "I don't pay attention to the ethical considerations"
PAR 3	"I'm not aware since I do not know the technical part of those technologies. I cannot check the declarations of technology owners."

The analysis suggests that ethical considerations in lifelong learning technologies are not uniformly recognised, emphasising the need for increased awareness and education on this critical topic.

Care about ethical issues, fifty-three responses were received regarding the question, "How much do respondents care about whether lifelong learning technologies are ethical?" The majority (36 respondents) of the 53 respondents who answered the question indicated that they are concerned about the ethical use of digital technologies for lifelong learning.

Twelve had little concerns, two were unconcerned, and three were indifferent. We further coded the respondents' responses to determine what they care about, and the results show broad themes: Data privacy, well-being and security concerns (20), and Algorithmic bias and misinformation (10). Eight responses also reveal that the individual is responsible for ensuring the ethical use of digital technologies, and one indicated addictive or influential content. However, 14 respondents indicated nothing, regardless of their concern level.

Concerning data privacy, well-being, and security, the positions of selected respondents are as presented in Table 3 as follows:

Table 3: Response to concerns about data privacy, well-being, and security question(s)

Respondent (R)	Response to Concerns About Data Privacy, Well-being, and Security,
R1	"I care a great deal about ethics in lifelong learning technologies." Another indicated, "I care so much. As I put my data to sign up and use it almost regularly, I [am] most concerned [about] what my data is used for and if it is ethical or if they have some ethical law protecting [us], the consumer."
R2	"I am genuinely concerned about the ethics of lifelong learning technologies because they play a crucial role in shaping trust, fairness, and accessibility. It's important that these platforms safeguard privacy and security to protect personal data. Ensuring inclusiveness and equity means that everyone, regardless of their background or ability, can take part. Avoiding bias and misinformation is key to creating a learning environment that is free from discrimination and inaccuracies. In the end, ethical technologies help create a more just, transparent, and effective learning experience."
R3	"I care. I want to learn good stuff from good places; I don't want to do or support any harm with my personal growth."

With respect to responses to algorithmic bias and misinformation, selected responses showcasing the responds' position is presented on Table 4. The findings highlight a strong collective concern for creating a fair, secure, and trustworthy learning environment.

Cases of experiencing unethical lifelong learning technologies and the exploration of ethical challenges associated with digital technologies employed for lifelong learning revealed a diverse array of respondent experiences. Out of fifty-four participants, seven reported encountering ethical issues, thirteen expressed uncertainty. Thirty-four denied any experiences of ethical violations, and sixteen chose not to respond to the question.

Table 4: Responses to algorithmic bias and misinformation

Respondents	Responses to Algorithmic Bias and Misinformation
R1	"Understanding the attitudes and needs of culturally diverse populations is crucial. Today, the internet makes this process much easier than in the past. When administering e-learning surveys to culturally and linguistically diverse groups, academic researchers must first build trust and rapport with community partners to foster a safe space for communication. From a subjective standpoint, focusing on lifelong learning technologies is essential for creating a fair, responsible, and trustworthy learning environment. For example, adhering to ethical standards is not only required by regulations such as GDPR in the EU, CCPA in California, etc., but it also reflects a commitment to the responsible development and implementation of technology."
R2	"Not so much, as the priority is learning and acquiring a skill and my contact with such learning technologies [is] usually short-lived in each situation (until the skill is acquired)." Finally, another respondent said,
R3	"Yes. It is the responsibility of the information consumer to filter what is accurate."

The reported ethical issues were varied, encompassing both the technologies themselves and the pedagogical practices employed. Further insights about the subject of the discussion are present in Table 5.

Table 5: Response to Cases of Unethical Experiences

Respondents	Responses to Instances of Experiencing Unethical Situations During the Use of Digital Technologies
R1	"Yes, some use indirect ways to obtain personal information."
R2	"For example, some platforms have been found to collect and share user data without clear consent, compromising privacy. In other cases, AI-driven tools used biased algorithms, leading to unequal learning opportunities or skewed recommendations. Additionally, some learning apps have embedded manipulative advertising or monetisation tactics that exploit users, particularly younger learners. These situations reflect the ongoing challenges in ensuring that lifelong learning technologies consistently adhere to ethical standards."
R3	"For example, YouTube has addictive features. Suggestions in Kindle books are most of the time related to topics one is interested [in], but it is also possible to find books with harmful ideas. Not all philosophy is good, but some of it is good. Some educated people might be able to read those harmful books, identifying what is good from them and what is harmful. However, some people less prepared might develop wrong ideas that become behaviours. But the problem might not be in the technologies but in the ethical education we have, or we lack."

These insights stress the necessity for rigorous ethical standards and considerations in the development and application of digital technologies for lifelong learning.

5. Discussion

Findings align with prior studies showing that upskilling and reskilling drive workplace learning (Poquet & De Laat, 2021). However, unique motivations such as financial sustainability in aging societies emerged. Ethical awareness is inconsistent, with gaps between concern and actionable knowledge. This disconnection mirrors broader patterns of limited ethical literacy noted in AI-enabled education research (Chounta et al., 2022). Persistent concerns over bias, data privacy, and manipulative algorithms highlight the urgency for digital literacy initiatives and systemic transparency. The emerging themes from qualitative data analysis represent how users

perceive or fail to perceive ethical issues in lifelong learning technologies. Based on our results, we can summarise the final themes as follows:

5.1 Awareness vs. Perceived Ethical Violations

Some respondents expressed concerns about privacy, bias, and manipulative practices, while others were unaware of these issues. Awareness levels varied, with some lacking knowledge or technical understanding of ethical considerations. Those who were aware linked ethical concerns to data privacy, misinformation, and bias in AI-driven learning tools. Despite these concerns, many could not recall specific violations, indicating a lack of transparency or personal experience with unethical practices. These findings are discussed below.

1. Lack of Awareness and Indifference Many respondents had never considered the ethical implications of lifelong learning technologies or viewed them as irrelevant to their experiences. Some did not actively seek information on ethical policies, indicating a low priority for these considerations when selecting platforms.
2. Partial Awareness and Uncertainty Some respondents acknowledged ethical concerns but lacked the technical knowledge to understand them fully. Others recognised the presence of ethical policies but were unsure of their effectiveness, highlighting the need for greater transparency.
3. Full Awareness and Concerns Respondents with full awareness focused on privacy and data protection. While some mentioned encryption, transparency, and security policies, they remained sceptical about platforms' commitment to protecting user data. Ethical concerns extended beyond privacy to include bias and fairness in AI-driven learning. Some respondents noted ongoing challenges and expressed concerns about the potential for manipulative AI use.

The distinction between awareness of ethical considerations and recognition of ethical violations remains blurred due to individual priorities, knowledge, and experiences. Chounta et al (2022) found that Estonian K-12 teachers had a limited understanding of AI and its potential applications in their work. Similarly, Hsiao and Tang (2024) emphasised the need for continuous ethical reflection when using Generative AI tools, particularly concerning plagiarism and intellectual property rights. Educators play a key role in fostering discussions on these issues, establishing responsible use guidelines, and encouraging ethical behaviour.

5.2 Caring About Ethics vs. Reported Violations

Some respondents accepted unethical practices as inevitable, prioritising functionality and convenience over ethical considerations as discussed below.

1. Addictive or Influential Content: Algorithm-driven platforms, such as YouTube or Kindle, may promote prolonged engagement, raising concerns about exposure to harmful content. Monetisation strategies, including excessive AI driven promotions, may further exacerbate these issues.
2. Data Privacy, Well-being, and Security Many respondents reported unauthorised data collection and sharing. Ethical concerns included privacy, data security, AI bias, and transparency. Despite recognising these risks, many assumed platforms adhered to ethical standards without verification. Some also raised concerns about misinformation and exposure to harmful content. In particular, there exists a gap between awareness and action, as many users assume that platforms adhere to ethical considerations without verification.

Chowdhary et al (2023) found that power dynamics in workplace wellbeing technologies led to "meaningless" consent, highlighting the need for structural changes to ensure meaningful user agreement.

3. Algorithmic Bias and Misinformation Participants also recognised that ethical concerns extend beyond privacy to include bias and fairness issues in AI-driven learning. Although respondents acknowledged efforts to mitigate bias, they identified ongoing challenges and expressed concern over the potential for manipulative use of AI. This theme reflects heightened apprehension regarding digital privacy, the ethical use of personal data, and the ethical complexities of AI in education, particularly concerning fairness and bias.
4. Personal Responsibility: A subset of participants felt that the onus of ethical responsibility rested with them as users, while others asserted that platforms should bear this responsibility. This divergence highlights contrasting perspectives: Some believe users should verify the ethical implications of their choices, whereas others argue that platforms are obligated to uphold ethical standards proactively. Other studies such as Curran et al (2019) also indicated that individuals assume "ownership of their

own thoughts and actions". Thus, there are many personal responsibilities demand from those engaging in lifelong learning to be aware of the process, tools, and actions enshrined in lifelong learning.

5.3 Ethical Violations vs. Systemic Issues

Respondents identified ethical violations, including data privacy breaches, bias in learning content, and exploitative monetisation tactics. Some noted that ethical concerns were not always explicit, but industry-wide practices, such as misinformation amplification on social media, raised doubts about technology providers' accountability. The findings are discussed below.

1. Bias in learning content Bias in lifelong learning technologies remains a significant yet overlooked issue. AI-driven platforms often prioritise popular content, reinforcing Western perspectives while neglecting diverse cultural view-points.

Algorithmic bias can favour specific groups, limiting equitable access to knowledge. Social media-based learning platforms risk amplifying biased or misleading content, raising concerns about information accuracy.

2. Lack of Transparency Concerns persist regarding transparency in user data handling, content recommendations, and AI-driven decision-making. Unclear privacy policies and a lack of explicit consent contribute to these concerns. Opaque AI algorithms fuel suspicions of bias in learning content.
3. Exploitative Monetization Tactics Hidden monetization strategies, including manipulative advertising and profiling, raise ethical concerns. Some platforms prioritize trending topics for profit rather than learning value, while data sharing practices often lack clear disclosure.

Ala-Mutka, Punie, and Redecker (2008) emphasised the importance of digital literacy, particularly among young users, to enhance awareness of security, privacy, and ethical content creation. Similarly, Marín and Tur (2024) noted that ethical considerations in educational technology remain underexplored.

5.4 Limitations

While this study offers valuable insights into the ethical concerns surrounding lifelong learning technologies, it is important to interpret its findings with caution due to potential biases. For instance, although the qualitative responses provide valuable perspectives, some are vague or lack sufficient detail, making it challenging to draw nuanced conclusions. Also, methodological limitations, such as sample size and possible contextual constraints, should be considered. Future studies could address these gaps by including larger and more diverse samples, employing mixed-method strategies, and performing comparative analyses across various technological and regulatory contexts.

6. Conclusion and Implications

The COVID-19 pandemic has expanded the role of digital technologies in lifelong learning, making ethical considerations increasingly critical. Our findings highlight gaps between ethical awareness, concern, and action. While many users value ethics, their ability to recognise or respond to violations is inconsistent. Addressing these gaps requires a comprehensive approach (Pammer-Schindler & Rosé, 2022), including targeted support to help stakeholders understand and manage ethical issues. Similarly, Mouta et al. (2024) emphasize that educators must assess the risks and benefits of AI in education and define clear purposes for its use.

Concerns about privacy, security, and bias vary widely, indicating the need for greater platform transparency and ethically grounded design. Digital literacy initiatives are vital to raise awareness and foster accountability. Stronger platform responsibility, reinforced by data protection laws like GDPR, algorithm audits, and ethical certifications, is essential to ensure innovation balances with fairness, safety, and equitable learning opportunities. In light of the findings it is recommended that organisations i) increase awareness and training on digital ethics for employees and employers, , and ii) structures to monitor ethical breaches and accountability are needed at the workplaces.

Ethics Declaration

Ethical clearance for this study was not needed.

AI Declaration

The authors confirm all major contributions—study design, data preparation, analysis, and writing—were made by humans. ChatGPT assisted with data analysis only. No conclusions or decisions were delegated to AI. The authors independently reviewed and approved all work, adhering to ethical guidelines for the responsible use of AI in academic research.

Authors' Contributions Principal Author

The first author was responsible for instrument design, data collection and analysis, and text composition. Co-author 1: Instrument design, data collection, text composition, proofreading responding to reviewers' queries. Co-author 2: Instrument design in Estonian Language, data collection reviewing and responding to reviewers' queries

References

Pandey, S. and Rathee, G. (2020) Lido Learning (Industrial project carried out at Quality Tutorials Pvt. Ltd.). Solan, HP: Jaypee University of Information Technology.

Jacobs, R.L. and Park, Y. (2009) 'A proposed conceptual framework of workplace learning: Implications for theory development and research in human resource development', Human Resource Development Review, 8(2), pp. 133–150.

Pammer-Schindler, V. and Rosé, C. (2022) 'Data-related ethics issues in technologies for informal professional learning', International Journal of Artificial Intelligence in Education, 32(3), pp. 609–635.

Tam, S. and Gray, D.E. (2016) 'What can we learn from the organizational life cycle theory? A conceptualization for the practice of workplace learning', Journal of Management Research, 8(2), pp. 18–29.

Hsiao, C.-H. and Tang, K.-Y. (2024) 'Beyond acceptance: an empirical investigation of technological, ethical, social, and individual determinants of GenAI-supported learning in higher education', Education and Information Technologies, pp. 1–26.

Rawas, S. (2024) 'ChatGPT: Empowering lifelong learning in the digital age of higher education', Education and Information Technologies, 29(6), pp. 6895–6908.

Mouta, A., Torrecilla-Sánchez, E.M. and Pinto-Llorente, A.M. (2024) 'Design of a future scenarios toolkit for an ethical implementation of artificial intelligence in education', Education and Information Technologies, 29(9), pp. 10473–10498.

Braun, V. and Clarke, V. (2012) Thematic analysis.

Chowdhary, S., Kawakami, A., Gray, M.L., Suh, J., Olteanu, A. and Saha, K. (2023) 'Can workers meaningfully consent to workplace wellbeing technologies?', in Proceedings of the 2023 ACM Conference on Fairness, Accountability, and Transparency. New York: ACM, pp. 569–582.

Poquet, O. and De Laat, M. (2021) 'Developing capabilities: Lifelong learning in the age of AI', British Journal of Educational Technology, 52(4), pp. 1695–1708.

Singh, S., Schmidt-Lauff, S. and Ehlers, S. (2022) 'Transitions from adult education sectors to lifelong learning systems: A comparative study from Denmark, Switzerland, Germany and the European Education Area', in Erwachsenenbildung in internationalen Perspektiven: Grenzen und Chancen. pp. 97–112.

Gaskins, N. (2023) 'Interrogating algorithmic bias: From speculative fiction to liberatory design', TechTrends, 67(3), pp. 417–425.

Van de Poel, I. (2020) 'Embedding values in artificial intelligence (AI) systems', Minds and Machines, 30(3), pp. 385–409.

Zirar, A., Ali, S.I. and Islam, N. (2023) 'Worker and workplace artificial intelligence (AI) co-existence: Emerging themes and research agenda', Technovation, 124, 102747.

Charungkaittikul, S., Pathumcharoenwattana, W. and Kovitya, M. (2022) 'A study on the required work competencies of graduates in the non-formal education program', Kasetsart Journal of Social Sciences, 43(4), pp. 825–832.

Ala-Mutka, K., Punie, Y. and Redecker, C. (2008) Digital competence for lifelong learning. Institute for Prospective Technological Studies (IPTS), European Commission, Joint Research Centre. Technical Note: JRC 48708, pp. 271–282.

Marín, V.I. and Tur, G. (2024) 'Ethical issues in the use of technologies in education settings: A scoping review', Education in the Knowledge Society (EKS), 25, e31301.

Chounta, I.-A., Bardone, E., Raudsep, A. and Pedaste, M. (2022) 'Exploring teachers' perceptions of artificial intelligence as a tool to support their practice in Estonian K-12 education', International Journal of Artificial Intelligence in Education, 32(3), pp. 725–755.

Shifa, S., Javaid, H.A., Khalid, S. and Shafiq, F. (2025) 'How AI can facilitate continuous education and skills development for adults throughout their careers', The Critical Review of Social Sciences Studies, 3(1), pp. 3252–3267.

Cachioni, M., Ordonez, T.N., da Silva, T.B.L., Batistoni, S.S.T., Yassuda, M.S., Melo, R.C., Domingues, M.A.R.C. and Lopes, A. (2014) 'Motivational factors and predictors for attending a continuing education program for older adults', Educational Gerontology, 40(8), pp. 584–596.

Bjursell, C. (2019) 'Growth through education: The narratives of older adults', Frontiers in Sociology, 4, 11.

Karhapää, A., Hämäläinen, R. and Pöysä-Tarhonen, J. (2025) 'Digital work practices that promote informal workplace learning: Digital ethnography in a knowledge work context', Studies in Continuing Education, 47(1), pp. 1–18.
Merriam, S.B. and Kee, Y. (2014) 'Promoting community wellbeing: The case for lifelong learning for older adults', Adult Education Quarterly, 64(2), pp. 128–144.

The Changing Trends in Higher Education: Lecturertainers' Pedagogy and Personality Blending

Sky L. Mkuti[1] and Wiza Munyeka[2]
[1]The Independent Institute of Education (Emeris, Faculty of Humanities), South Africa
[2]Durban University of Technology (DUT), South Africa

smkuti@yahoo.com
wizam@dut.ac.za

Abstract: In the era of the 'New Normal,' marked by rapid digital transformation and evolving student expectations, traditional approaches to teaching face unprecedented challenges. To avoid being redundant, Teaching and Learning (T&L) teams are tasked to upskill their T&L roles in the classrooms and practice in the institutions of Higher Learning. To better serve the needs of the millennials and to advance academic excellence, lecturers and the education system must adapt to new and innovative approaches to T&L. Only then can Higher Education systems enable a *Lecturertainer* to supplement the existing traditional learning interventions. A *lecturertainer* is a new concept which compliments the contemporary T&L approaches in contemporary Higher Education.Whilst these must respond effectively to the hyper-transformative and highly-personalised solutions to match the evolving digital academic environment, this new concept enables lecturers to proactively shape students' learning experiences. This paper addresses the changing trends and trajectories in Higher Education which influence Lecturer's pedagogy and personality blending in the post-COVID-19 era. A *lecturertainer's* goal is to ensure adaptability to the digitalization in the classroom environment by utilising multimedia tools and enhance interactive pedagogy to captivate students, bridge digital divides, and foster academic excellence in both virtual and hybrid settings. This study's theoretical background conceptualises the term *lecturertainer* drawing on empirical studies and practical examples to uncover how lecturertainers navigate the demands of digital fluency, student engagement, and curriculum relevance in an increasingly diverse academic environment. The proposed *lecturertainer* model suggests that university educators must tap into *lecturertaining* transformational practices to enhance learning outcomes and enrich educational experiences. Thus, redefining pedagogical excellence in contemporary higher education.

Keywords: Artificial Intelligence, Digitalisation, Higher Education, *Lecturertainer,* Teaching and Learning.

1. Introduction

The changing roles and identities of lecturers are heavily shaped by the higher education market. To ensure teaching remains interesting for students, lecturers have signaled the importance of having fun, especially for students but also for staff. It is, of course, to the credit of tutors that they design and deliver lessons that are enjoyable for their students. Although this study also questions the extent to which lecturers now consider entertainment to be a part of their teaching role. For educators, it is usually self-satisfying to observe student enjoyment in their teaching (Wong & Chiu, 2019). In exploring the question, "What is a lecturer?" Blair (2019) suggests that simply listing tasks offers only a superficial understanding of the role. While it's easy to assume the researchers fully grasp what it means to be a lecturer, a deeper inquiry reveals that this role is shaped by personal journeys and diverse perspectives within Higher Education. The complex and evolving nature of academia means that being a lecturer is not a fixed state; rather, it is an ongoing process of 'becoming' an actor of academic excellence in any education setting. This process is influenced by individual understanding and the expectations of others. Instead of searching for a single, universal definition, we should first take time to reflect on and explore our own interpretations of what it truly means to be a lecturer.

Education in the 21st century requires that its educators become adaptable to the new technological era where T&L skills are substantially diversified from past centuries. In a technologically-driven era, lecturers are expected to be vested with digital skills to better engage with digitally-bound students, making it imperative to enhance classroom creativity to better advance students' competencies and academic success (Söylemez, 2023).

With the closure of educational institutions worldwide, during COVID-19, a rapid shift to emergency remote education (ERE) occurred (Bozkurt & Sharma, 2020; Hodges, Moore, Lockee, Trust & Bond 2020). Consequently, this periodic shift was dubbed the "great online learning experiment" (Zimmerman, 2020). This experiential period is still helping us understand what works and what does not. Though ERE and distance education may seem similar, they differ fundamentally. Distance education is a planned, optional approach rooted in theory, while ERE is an unplanned response to a crisis (Bozkurt & Sharma, 2020). While ERE and distance education are critical in maintaining learning continuity, they should not be misinterpreted to avoid widespread educational missteps, often by attempting to simply replicate face-to-face learning online. Hence, adaptability to online-specific methods is critical in mitigating a "copy-paste" approach, which has proven ineffective.

The rapid shift has also triggered "digital burnout" and fatigue, emerging as widespread issues in the post-COVID world, augmented by desensitisation coupled with physical stress and mental exhaustion (Degges-White, 2020; Nadler, 2020; Erten & Özdemir, 2020). In most cases, burnout affects both teachers and learners due to constant screen time, hyper-focus, and the lack of natural interaction. Preventing digital fatigue requires a strategic implementation of best practices and mindful approaches tailored to online sessions. However, with the normalisation of the post-COVID education, classrooms had to keep the tech-momentum by bringing technology into the T&L environment. The evolving nature of education in a fast-paced world suggests that "there is no running away from the use of technology in higher education" (Essop, 2021, p.33). Essentially, whilst incorporating technology in the teaching processes, lecturers have to continually upscale their teaching skills to retain relevance. Thus, being lectures with 'entertaining' skills – the new age *lecturetainers* who can adapt, communicate, learn new skills, are visionary leaders, collaborate, and take risks sensibly (Söylemez, 2023). This qualitative study employs a content analysis to explore *lecturertainers* role in Higher Education. It starts by conceptualizing the evolution of the 'new normal' in Higher Education. Thereafter, it discusses the rise of *lecturertainers* to uncover how they navigate the demands of digital fluency, student engagement, and curriculum relevance in an increasingly diverse academic environment.

2. The '*New Normal*' in Higher Education

The COVID-19 pandemic prompted a critical re-evaluation of educational assumptions, particularly within higher education, as outlined by Rapanta, Botturi, Goodyear, Guàrdia, and Koole (2021). Amid the widespread challenges, especially with emergency remote teaching (ERT), educators across levels reassessed their roles, approaches to supporting student learning, and the conceptualisation of students as self-directed learners, active citizens, and autonomous social agents (Rapanta et al., 2021). Bozkurt and Sharma (2020) highlight that the COVID-19 pandemic has been more than a crisis; it has prompted a global shift in how we view the world and our everyday lives. The idea of "normal" has become fluid, evolving into terms like "new normal" and "next normal." These variations highlight that what may be normal for one person can be new or future-facing for another, especially in areas like education, which is undergoing significant transformation in teaching and learning. This unprecedented period urges us to reflect on what was, what is, and what lies ahead.

3. The Rise of the *Lecturertainer*: Adapting to a New Pedagogical Persona

In this section, we introduce the term *Lecturertainer* which describes an adaptable educator who combines lecturing with entertainment to engage students through technology in a dynamic and interactive learning experience. It draws from the idea of "edutainment" which refers to a student-centred approach in a tech-bound learning environment where teaching and learning processes rely on Web 2.0 tools. The use of tech-tools such as mind mapping, infographics, cartoon creation and interactive video development, pins, YouTube videos etc. have become irreplaceable in T&L practices (Zorica, 2014). Apart from enhancing students' academic experiences and increasing interest as well as active classroom interaction, the lecturer needs to keep the students 'entertained' by capturing their attention. Since the concept of a *lecturer*, lacks a universal definition, its definition can be blurred by the roles involved in academic practice. For the purpose of this chapter, a *lecturer* is an evolving term exhibited in the role that one plays during an instructional knowledge delivery. As such, through their "own understanding of the world" lecturers impart knowledge during interactions meant to satisfy others' expectations (Blair, 2019:42). The *lecturetainer*, therefore, adopts entertainment skillfully to impart knowledge effectivelly (Zasrianita, Susanto & Revola, 2023). Thus, acting, speaking, or promoting interesting features or content about the lesson in a manner in which *Lecturertainers* comprehend the play role activities to ensure that student's academic expectations are met.

The *lecturertainer* approach which refers to a blended T&L approach incorporates diverse modes of learning instruction. That is, a combination of face-to-face classroom teaching, online learning and the adoption of other digital technologies, which to an extent has become a major feature in the new normal amongst most South African HEIs (Mukhari & Sanders, 2025). This approach emphasises creativity, use of digital tools, and flexible teaching strategies to enhance engagement, not only in virtual settings but also in the classrooms. This lecturing style helps maintain student interest and enhance class participation. It makes learning both informative and enjoyable. This paper proposes the term '*Lecturertainer*' and figure 1 illustrates this concept.

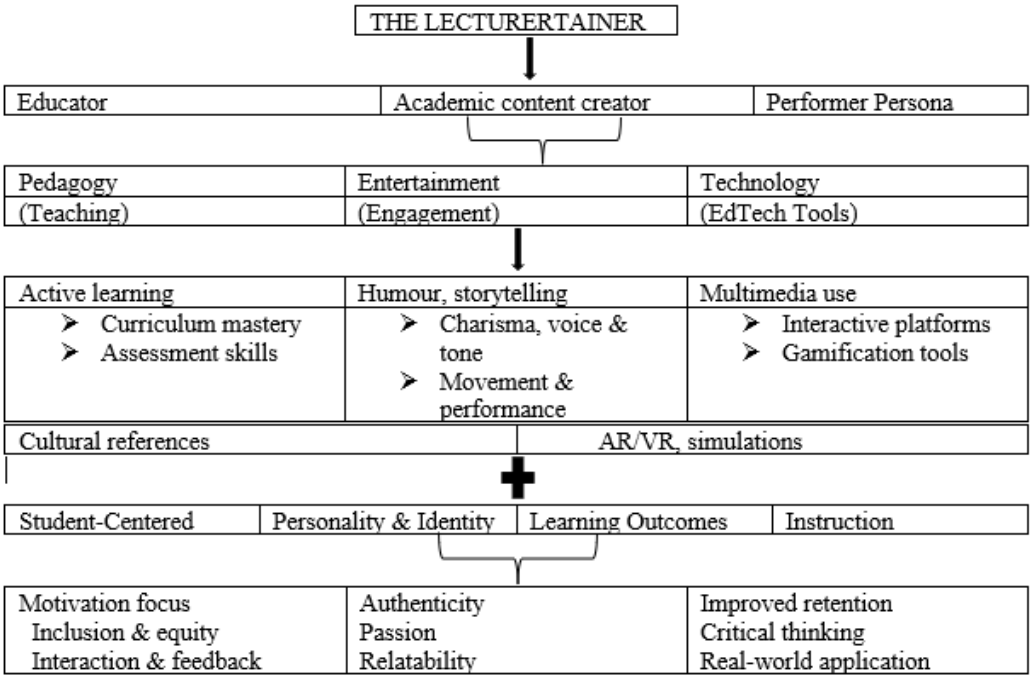


Figure 1: Proposed Lecturertainer model

The proposed *Lecturertainer* is a hybrid educational model that merges the roles of a lecturer and an entertainer to create a dynamic, engaging, and effective learning environment. At its core, the *Lecturertainer* maintains strong pedagogical foundations, ensuring academic rigor and structured content delivery. However, unlike traditional lectures, this approach incorporates elements of entertainment employing technological tools that captivatestudents' attention and enhance active participation. Modern technology supports this model by enabling the use of multimedia, gamification, and interactive platforms that deepen understanding. A student-centered philosophy lies at the heart of the *Lecturertainer's* practice, focusing on inclusivity, emotional connection, and fostering critical and creative thinking. Ultimately, this approach leads to improved student motivation, knowledge retention, and overall academic success, while making education an enjoyable experience. Important concepts in this proposed model are highlighted by Sonmark, Révai, Gottschalk, Deligiannidi and Burns (2017) who mention that pedagogical knowledge was broken down into the domains of assessment, instructional processes and learning processes. However, with the rise of technology, the methods of teaching, learning experiences, and educational outcomes are continuously transforming students' competencies in addressing societal challenges (Li and Zhang, 2025).

3.1 Student Engagement and Academic Rigour

The role of a *Lecturertainer* encompasses far more than just imparting curricula outcomes to their students; they need to equip students with the necessary tools to experience social and academic success both inside the classroom and beyond it. According to Franklin and Harrington (2019), this responsibility requires a shift from traditional teaching practices to methods that foster active engagement and critical reflection. Teachers need to empower students with the means to critically analyse the world around them to develop into critical, independent thinkers capable of navigating complex societal challenges. However, with the infinite volume of information available in our rapidly changing digital landscape. This means that lecturers need to constantly reinvent themselves whilst maintaining academic rigour (Rudman, 2021). It is not enough to ensure students' proficiency in utilising tech-tools such as Artificial Intelligence (AI) and ChatGPT without promoting students' higher levels of thinking to avoid dependency to such tools. Given that education is highly driven by digital and information-saturated platforms, it is critical for both lecturers and students to continuously adapt to the challenges that come with technological innovation, specifically the ethical use of AI tools (Mulaudzi & Hamilton, 2025).

Just as teachers need to take responsibility for the various methods of teaching and learning in the classroom, students need to adhere not only to the institutional policies but also to the academic integrity by taking ownership of their academic journey whilst the lecturers guide and support their academic success.

4. Technology and Its Impact on Pedagogy

The rapid advancement of artificial intelligence (AI) technologies has significantly influenced the landscape of higher education, offering tools that enhance learning efficiency and academic performance (Cooper, 2023; Goralski & Tan, 2020; Ouyang, Zheng & Jiao 2022). As AI becomes increasingly integrated into educational practices, it has the potential to empower students by expanding their capabilities and streamlining academic tasks. However, this technological shift is not without its drawbacks. Chen, Hu, and Wei (2025) observe that the growing reliance on AI in academic settings has also contributed to heightened levels of anxiety and stress among university students, raising concerns about its psychological impact. Thus, while AI offers considerable benefits in promoting educational advancement, it also necessitates critical reflection on its effects on student's over-reliance side effects. Panakaje *et al*. (2024) highlight that numerous models and theories have been developed to explain technology integration among teachers. Building upon this foundation, their study advances discourse by examining how such integration contributes to the enhancement of teaching practices—particularly in the areas of teacher learning, pedagogical strategies, instructional performance, and student engagement. A central challenge identified is the need to adopt innovative teaching methods that align with the increasingly tech-savvy nature of students. This underscores the imperative for educators to not only adopt but also effectively integrate technology into their pedagogical approaches to remain relevant and impactful in contemporary educational settings.

AI undoubtedly enhances educational quality, making education more personalized and efficient (Jian, 2023). However, some negative impacts have also garnered scholarly attention. Chief among them the rise in generative-AI hallucinations, which mislead information and compromise academic integrity causing ethical concerns (Zhai, Wibowo and Li, 2024). Additionally, AI dependency has proven to diminish students' critical cognitive capabilities arising from persistent reliance on generative-AI systems. For instance, Ivanov (2023) identified some dark sides of AI, in higher education, citing issues such as algorithmic bias, behaviour manipulation, excessive surveillance, over-reliance, and privacy breaches. More importantly, the technological pressure and psychological anxiety induced by AI can have profound effects on students while also exerting pressure on academic institutions and lecturers (Hopcan, Türkmen & Polat, 2024; Kwak, Ahn & Seo, 2022; Corbin, *et al*., 2025).

4.1 The Gamification/use of Digital Tools in Learning

Gamification refers to the application of game design principles in non-game contexts, has emerged as a transformative strategy in higher education. It integrates academic web-based games to enhance class participation whilst actively engaging and motivating students to benefit from the module's learning outcomes. Since gamification provides "real-time feedback, leaderboards and score management," lecturers can assess students' comprehension when using web-based games such as Kahoot and Quizzes (Shumba, 2024). Gamification has been widely used to design better educational systems aiming to increase students' concentration, motivation, engagement, flow experience, and others positive experiences Mushtaq, Nazeer, Fayaz & Gulzar, 2025). Chief amongst these experiences is the cultivation of a learning environment that is essentially inclusive and positive. Furthermore, the implementation of novel gamification tactics provides an opportunity to not only create personalized educational programs that encourage students' enthusiasm in the classroom but also improve academic excellence seen in the students' progressive results.

4.2 The Digital Divide

The COVID-19 worldwide pandemic affected extensively educational institutions that relied on traditional face-to-face teaching strategies. It is, however, worth noting that, despite the remnant COVID-19 challenges, other structural challenges persist in the context of South African HEIs. To the most part, South African higher education institutions are still battling with historical inequalities (Tunjera & Chigona, 2021; Mkuti & Aucamp, 2024). And even though, to an extent, virtual learning has diminished amongst non-distance learning HEIs, in post-COVID-19, the absence of a formal digital learning management system (DLMS) in public universities in many countries meant that social network sites (SNSs) were adopted. These include sites such as WhatsApp, and/or other digital communication platforms, particularly Microsoft (MS) Teams and Zoom which have been highly utilised to support T&L and sustain active academic interactions.

The benefits of SNS for academic purposes, including instructional delivery and collaborative have been evident (Sobaih, Hasanein, & Abu Elnasr, 2020; Deng & Tavares, 2013; Jong, Lai, Hsia, Lin, & Liao, 2014; Awidi, Paynter, & Vujosevic, 2019). In most instances, learning through digital networks have enhanced academic performance,

foster informal scholarly exchange, support community building, promote trust and user satisfaction, improve connectivity, and enrich students' overall learning experience (Valenzuela, Park, and Kee, 2009, Lambić, 2016 & Yildiz Durak, 2019).

The previously described studies underscore the evolving role of the *lecturertainer* a term introduced in this paper which describes an educator who effectively integrates social networking sites to engage students, enhance communication, and enrich the learning experience in dynamic and interactive ways.

4.3 The Risks of Digital Distraction

Today's traditional-aged college students are avid recreational users of mobile technology (Flanigan & Babchuk, 2022). Technology enables a more sustainable and universally accessible educational model. However, despite the benefits which technology presents, there are a few challenges that can also present a paradox in students' academic lives. For instance, while technology facilitates engagement in learning activities, to some extent, it can also serve as a significant source of distraction (Pérez-Juárez, González-Ortega, & Aguiar-Pérez, 2023). As such, continuous class monitoring is required to ensure that students are actively engaged in the class activities. Social media, in particular, has become deeply embedded in the daily routines of university students. Often referred to as the Net Generation comprising students who are accustomed to constant connectivity and the pervasive use of digital tools (Tapscott, 1998, Flanigan & Kiewra, 2018). While these technologies offer innovative opportunities for learning, research shows that university students frequently use their devices—such as smartphones, tablets, and laptops—for non-academic, off-task activities (Pérez-Juárez et al., 2023). This dual nature of technology in higher education highlights the ongoing challenge of balancing its educational potential with its distracting tendencies.

The major concern accentuated in Flanigan and Babchuk (2022) is that, despite being essential for learning, digital devices are simultaneously posing a threat to students' concentration and creativity. Often times diminishing students' learning and achievement as a result of unwarranted distractions. In response, the implementation of explicit classroom technology-use for class activities only may curb distractions and foster a more focused learning environment. Nonetheless, maintaining student attentiveness in a technologically enriched classroom may become a daunting task.

In light of the techno-developments aiding T&L, *Lecturertainers* still need to strike a balance between entertainment and being rigorous to ensure their relevance particularly in a techno-revolutionised world. The use of AI and gamification as shown in this paper signals that teaching remains interesting for students. However, as Arthur (2009) indicated, lecturers have also signaled the importance of having fun, not only for students but also for staff. The reality which still remains applicable, and may go beyond 2025.

5. Limitations and Recommendations

The concept of the *lecturertainer* represents an innovative evolution in higher education as introduced by the authors. It blends the traditional role of a lecturer with the engaging qualities of an entertainer to foster deeper student engagement and improve learning outcomes. This hybrid approach responds to the modern classroom's demand for creativity, interactivity, and learner-centered techniques. The *lecturertainer* employs storytelling, humor, multimedia tools, and performance-based strategies to present content in an accessible, memorable, and stimulating manner, while still upholding academic rigour. As attention spans decline and students increasingly respond to dynamic content, this approach aims to bridge the gap between pedagogy and performance.

To successfully implement the *lecturertainer* model, several recommendations are worth considering. Institutions should invest in professional development workshops to equip educators with skills in communication, storytelling, and digital tool use. Blended learning techniques enhance the learning experience. It is critical, however, that all entertaining elements align closely with the learning objectives to maintain content integrity. Thus, encouraging continuous feedback from students can help to fine-tune delivery methods, while adapting the approach to the cultural and disciplinary context for relevance. Additionally, academic performance reviews should recognise and reward innovative teaching approaches, thereby legitimising the *lecturertainer* within formal structures.

Despite its promise, the newly introduced *lecturertainer* model is not without limitations. An overemphasis on entertainment risks diluting the seriousness of academic content and may lead to perceptions of superficiality. The high levels of energy and creativity required to perform consistently can result in educator burnout. For

instance, other HEIs across the globe, such as in Thailand also indicate growing cases in educator burnout which require the adoption of a balanced workload and mental health support systems (Pakdee, *et al*. 2025). Furthermore, not all lecturers possess the personality traits, training, or institutional support necessary to adopt this model effectively, which may lead to disparities in student experience. Students themselves may begin to expect constant stimulation, potentially diminishing their engagement with more traditional academic tasks. In certain disciplines or cultural contexts, the performative nature of the *lecturertainer* may clash with established norms or expectations of academic professionalism. Lastly, assessing the effectiveness of this approach remains a challenge, particularly if evaluations focus solely on student satisfaction rather than measurable academic achievement. While the *lecturertainer* introduces exciting possibilities, its success depends on careful, context-sensitive implementation and ongoing evaluation.

6. Conclusion

In closing, this paper introduced the concept of the *lecturertainer* to capture the evolving, and often precarious, identity of modern educators navigating between pedagogy and performance. As Wong and Chiu (2019) aptly argue, the expanding expectations placed on lecturers demand urgent institutional and national dialogue to redefine their roles with greater clarity and support. Until such boundaries are meaningfully addressed, the university lecturer will continue to juggle multiple personas—mentor, content expert, service provider, and entertainer—balancing academic rigor with the need to captivate a digitally distracted generation in need of instant achievements. Thinking forward, we believe that the expanding role of lecturers merits an urgent review at the institutional and national level. This broader consideration will enable HE policy-makers to promote and ensure clarity of the boundaries and expectations of teaching staff. Until then, we also agree with Wong & Chiu (2019) observations that the identities of lecturers remain precarious. They are supportive tutors, service providers and in some cases, *Lecturertainers* who need to ensure that pedagogy motivates and promotes students' active learning and critical thinking.

Ethics and AI Declarations

We declare that we are fully aware of the stance taken by the Research Ethics Committee, Faculty of Humanities, regarding the importance of obtaining informed consent from all research participants. This study is devoid of Human participants. We, therefore, deem it impossible to obtain such consent in the current research project. An Ethics Waiver for Qualitative Study has been submitted to the IIE Research Ethics Committee (IIE REC). We declare that, during this research, we have observed all academic integrity criteria by taking due care to protect and safeguard the intellectual autonomy of all academic resources supporting this research project. We declare that this project is an original work of the authors, and no AI tools were used in its creation.

References

Arthur, L. (2009). From performativity to professionalism: Lecturers' responses to student feedback. Teaching in higher education, 14(4), pp.441-454. https://doi.org/10.1080/13562510903050228.

Awidi, I. T., Paynter, M., and Vujosevic, T. (2019). Facebook group in the learning design of a higher education course: An analysis of factors influencing positive learning experience for students. *Computers & Education*, *129*, pp.106-121.

Bozkurt, A., and Sharma, R. C. (2020). Education in normal, new normal, and next normal: Observations from the past, insights from the present and projections for the future. Asian Journal of Distance Education, 15(2), pp.i-x. Retrieved from: http://www.asianjde.com/ojs/index.php/AsianJDE/article/view/512.

Blair, E. (2019). What is a lecturer?. *New Vistas*, *5*(1).pp.38-42. doi: https://doi.org//uwl.81.

Chen, C., Hu, W., and Wei, X. (2025). From anxiety to action: Exploring the impact of artificial intelligence anxiety and artificial intelligence self-efficacy on motivated learning of undergraduate students. *Interactive Learning Environments*, *33*(4), pp.3162-3177. https://doi.org/10.1080/10494820.2024.2440877.

Cooper, G. (2023). "Examining science education in ChatGPT: An exploratory study of generative artificial intelligence". *Journal of Science Education and Technology*, 32(3), pp.444–452. https://doi.org/10.1007/s10956-023-10039-y

Corbin, T. Boud, D. Bearman, M. and Dawson, P. (2020). Our new study found AI is wreaking havoc on uni assessments. Here's how we should respond. *The Conversation*, 16 September. Retrieved from https://theconversation.com/our-new-study-found-ai-is-wreaking-havoc-on-uni-assessments-heres-how-we-should-respond-264787

Degges-White, S. (2020). Zoom Fatigue: Don't Let Video Meetings Zap Your Energy. Some 'cheats' to help you beat Zoom fatigue before it beats you. Psychology Today. https://www.psychologytoday.com/us/blog/lifetime-connections/202004/zoom-fatigue-dont-let-video-meetings-zap-your-energ

Deng, L., and Tavares, N. J. (2013). From Moodle to Facebook: Exploring students' motivation and experiences in online communities. *Computers and Education*, *68*, pp.167-176. https://doi.org/10.1016/j.compedu.2013.04.028.

Erten, P., and Özdemir, O. (2020). The Digital Burnout Scale Development Study. *Inonu University Journal of the Faculty of Education*, 21(2), 668-683. https://doi.org/10.17679/inuefd.597890.

Essop, A. (2021). COVID-19: the "New Normal" and the Future of Higher Education. *University of Johannesburg*. Retrieved from: https://www.uj.ac.za/wp-content/uploads/2021/09/covid-19-and-the-future-of-higher-education.pdf

Flanigan, A. E., and Babchuk, W. A. (2022). Digital distraction in the classroom: exploring instructor perceptions and reactions. *Teaching in Higher Education*, 27(3), pp.352-370. https://doi.org/10.1080/13562517.2020.1724937.

Flanigan, A. E., and Kiewra, K. A. (2018). What college instructors can do about student cyber-slacking. *Educational Psychology Review*, *30*, pp.585-597. https://doi.org/10.1007/s10648-017-9418-2.

Franklin, H., and Harrington, I. (2019). A review into effective classroom management and strategies for student engagement: Teacher and student roles in today's classrooms. *Journal of Education and Training Studies.* https://doi.org/10.11114/jets.v7i12.4491.

Goralski, M. A., & Tan, T. K. (2020). Artificial intelligence and sustainable development. *The International Journal of Management Education,* 18(1), pp.100330. https://doi.org/10.1016/j.ijme.2019.100330.

Hodges, C., Moore, S., Lockee, B., Trust, T., and Bond, A. (2020). The difference between emergency remote teaching and online learning. *Educause review*, *27*(1), pp.1-9. https://doi.org/10.1163/9789004702813_021.

Hopcan, S., Türkmen, G., and Polat, E. (2024). Exploring the artificial intelligence anxiety and machine learning attitudes of teacher candidates. *Education and Information Technologies,* 29(6), 7281–7301. https://doi.org/10.1007/s10639-023-12086-9.

Ivanov, S. (2023). The dark side of artificial intelligence in higher education. *The Service Industries Journal,* 43(15–16), pp.1055–1082. https://doi.org/10.1080/02642069.2023.2258799.

Jian, M.J.K.O. 2023. Personalized learning through AI. *Advances in Engineering Innovation (AEI)*, Vol. 5. pp.1-4. https://doi.org/10.54254/2977-3903/5/2023039.

Jong, B. S., Lai, C. H., Hsia, Y. T., Lin, T. W., and Liao, Y. S. (2014). An exploration of the potential educational value of Facebook. *Computers in Human Behavior*, *32*, pp.201-211. https://doi.org/10.1016/j.chb.2013.12.007Get rights and content.

Kwak, Y., Ahn, J.-W., and Seo, Y. H. (2022). Influence of AI ethics awareness, attitude, anxiety, and self-efficacy on nursing students' behavioral intentions. BMC Nursing, 21(1), p.267. https://doi.org/10.1186/s12912-022-01048-0.

Lambić, D. (2016). Correlation between Facebook use for educational purposes and academic performance of students. *Computers in Human Behavior,* 61, pp.313-320*.* https://doi.org/10.1016/j.chb.2016.03.052Get rights and content

Li, Z., and Zhang, W. (2025). Technology in education: Addressing legal and governance challenges in the digital era. *Education and Information Technologies*, *30*(7), pp.8413-8443.

Mkuti, S. & Aucamp, E. (J.I.). (2024). Contextualising the South African Higher Education Academic Interventions for Student Success: Challenges and Opportunities. Proceedings of the 1st International Conference on Education Research (ICER),Vol. 1 No. 1, pp.194-201. https://doi.org/10.34190/icer.1.1.3108.

Mulaudzi, L.V. and Hamilton, J. (2025). Lecturer's Perspective on the Role of AI in Personalized Learning: Benefits, Challenges, and Ethical Considerations in Higher Education. Journal of Academic Ethics, pp.1-21. https://doi.org/10.1007/s10805-025-09615-1.

Mukhari, S.S. and Sanders, D.A. (2025). Exploring Student Perceptions of Blended Learning in a Higher Education Institution in South Africa. *Unisa Press*, pp.1-19. https://doi.org/10.25159/2663-5895/17469.

Mushtaq, N., Nazeer, N., Fayaz, I., & Gulzar, F. (2025). Next-Gen Learning: Gamifications impact on higher education. *Education and Information Technologies*, pp.1-27. https://doi.org/10.1007/s10639-025-13431-w.

Nadler, R. (2020). Understanding "Zoom fatigue": Theorizing spatial dynamics as third skins in computer-mediated communication. *Computers and Composition,* 58, 102613. https://doi.org/10.1016/j.compcom.2020.102613.

Ouyang, F., Zheng, L., and Jiao, P. (2022). Artificial intelligence in online higher education: A systematic review of empirical research from 2011 to 2020. *Education and Information Technologies,* 27(6), pp.7893–7925. https://doi.org/10.1007/s10639-022-10925-9.

Pakdee,S. Cheechang, P. Thammanoon, R. Krobpet, S. Piya-amornphan, N. Puangsri, P. and Gosselink, R. (2025). Burnout and well-being among higher education teachers: Influencing factors of burnout. *BMC Public Health* vol. 25, (1409), pp.1-10. https://doi.org/10.1186/s12889-025-22602-w.

Panakaje, N., Ur Rahiman, H., Parvin, S. R., P, S., K, M., Yatheen, and Irfana, S. (2024). Revolutionizing pedagogy: navigating the integration of technology in higher education for teacher learning and performance enhancement. *Cogent Education*, 11(1), pp.1-27. https://doi.org/10.1080/2331186X.2024.2308430

Pérez-Juárez, M. Á., González-Ortega, D., and Aguiar-Pérez, J. M. (2023). Digital distractions from the point of view of higher education students. *Sustainability*, *15*(7), pp.6044. https://doi.org/10.3390/su15076044.

Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., and Koole, M. (2021). Balancing technology, pedagogy and the new normal: Post-pandemic challenges for higher education. *Postdigital Science and Education*, *3*(3), pp.715-742. https://doi.org/10.1007/s42438-021-00249-1.

Rudman, R.J. 2021. Understanding the Unintended Consequences of Online Teaching. *South African Journal of Higher Education*, Vol. (35) 4, pp.1-12. https://dx.doi.org/10.20853/35-4-4717.

Shumba, T. (2024). Exploring Lecturers' Readiness and Perceptions of Gamification in Higher Education Institutions of South Africa. *Journal of Public Administration and Development Alternatives*, 9(3), pp.115-127. https://doi.org/10.55190/JPADA.2024.346.

Sobaih, A. E. E., Salem, A. E., Hasanein, A. M., and Elnasr, A. E. A. (2021). Responses to Covid-19 in higher education: Students' learning experience using microsoft teams versus social network sites. *Sustainability*, *13*(18), p.10036. https://doi.org/10.3390/su131810036.

Sobaih, A. E. E., Hasanein, A. M., and Abu Elnasr, A. E. (2020). Responses to COVID-19 in higher education: Social media usage for sustaining formal academic communication in developing countries. *Sustainability*, *12*(16), p. 6520. https://doi.org/10.3390/su12166520.

Sonmark, K., Révai, N., Gottschalk, F., Deligiannidi, K., and Burns, T. (2017). Understanding teachers' pedagogical knowledge: report on an international pilot study.

Soylemez, N. H. (2023). Teacher and Student in the 21st Century: A Mixed Design Research. *International Journal of Psychology and Educational Studies*, *10*(3), pp. 758-772. https://doi.org/10.52380/ijpes.2023.10.3.1128.

Tapscott, D. (1998). *Growing up digital* (Vol. 302). San Francisco: McGraw-Hill Companies.

Tunjera, N. and Chigona, A. (2021). Teaching virtually using multi-application to overcome digital divide during the COVID-19 pandemic. In E. Langran and D. Rutledge (Eds.), *Proceedings of SITE Interactive Conference* (pp. 65-78). Online, United States: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org/p/220168.

Valenzuela, S., Park, N., and Kee, K. F. (2009). Is there social capital in a social network site?: Facebook use and college students' life satisfaction, trust, and participation. *Journal of computer-mediated communication,* 14(4), 875-901. https://doi.org/10.1111/j.1083-6101.2009.01474.x.

Wong, B., and Chiu, Y. L. T. (2019). Let me entertain you: The ambivalent role of university lecturers as educators and performers. *Educational review*, *71*(2), pp.218-233. https://doi.org/10.1080/00131911.2017.1363718.

Yildiz Durak, H. (2019). Examining the acceptance and use of online social networks by preservice teachers within the context of unified theory of acceptance and use of technology model. *Journal of Computing in Higher Education*, *31*(1), pp.173-209. https://doi.org/10.1007/s12528-018-9200-6.

Zasrianita, F., Susanto, F., and Revola, Y. (2023). The Roles Relevance Development of English Lecturer toward Harmer's Teaching Theory in Industry Revolution 5.0. In *Conference on English Language Teaching.* July, pp.1157-1181.

Zhai, C. Wiboho, S. and Li, L.D. (2024). The effects of over-reliance on AI dialogue systems on students' cognitive abilities: a systematic review. *Smart Learning Environments*, 11(28), pp.1-37. http://doi.org/10.1186/s40561-024-00316-7.

Zimmerman, J. (2020). Coronavirus and the Great Online-Learning Experiment. Chronicle of Higher Education. 20 March. https://www.chronicle.com/article/Coronavirusthe-Great/248216.

Internationalization of African Universities: South African Student-centred Transformational Agenda

Sky Lukas Mkuti
The Independent Institute of Education, Emeris, Faculty of Humanities, South Africa

smkuti@yahoo.com

Abstract: The internationalization of African Universities is not a new phenomenon, specifically because the system of higher education is considered a vital link to the attainment and dissemination of global knowledge. Over the years, internationalisation has been advanced through student exchange programmes enabling the calibration of local, national and international cooperation in African universities. However, the disruptions of COVID-19 impacted negatively on the entire institutional processes and national economies. With the emergence of COVID-19 pandemic season, several African institutions, specifically the education systems were compelled to adjust rapidly to institutional changes. In South Africa, internationalisation of Higher Education Institutions (HEIs) fosters an inclusive learning environment nationally. However, this role requires an interweaved approach that incorporates both intercultural and international dimensions. By blending the teaching curriculum, research and extracurricular activities, these activities aid students in effectively broadening their academic development. Internationalisation of Universities enable students to engage in greater international cooperation, innovation and scholarly inspiration. In post-COVID-19 era, South Africa local universities grappled with the emerging platformisation and accelerated technological innovation on teaching and learning. This reality sets a note for an urgent need to draw an understanding on how technological innovations coupled by a rapid integration of internationalisation in HEIs remain critical. These developments enriching academic excellence through a tapestry of cultural perspectives brought by a diverse student population and transformed curricula. This paper's main contribution to the internationalization of African Universities debates lies in its nuanced analysis of internationalization within the context of South Africa. The paper uncovers the tensions between internationalisation and the decolonisation rhetoric as key aspects of transformation agenda in African Universities, specifically in South African Higher Education Institutions (HEIs). The paper argues that despite the growing necessity for decolonialization of the curriculum in African universities, in South Africa, a student-centred approach to internationalization remains critical to enhance transformation, in its broader sense.

Keywords: COVID-19, HEIs, Internationalization, South Africa, Transformation, Teaching and Learning

1. Introduction

For the past decades, African Universities have been vital instruments of development and the fabricators of agents of change. Generally, the African system of Higher Education existed through the establishment of ancient Museum and Library, centres of Christianity specifically monasteries and Islamic mosques such as the Cairo Al-Azhar Mosque University of 969 years (Abdelmassieh, 2020, p.27). For instance, the Alexandria Museum and Library established in third century B.C., in Egypt is known to have "left a rich legacy of scholarship covering a wide range of fields from mathematics and the sciences to philosophy and religion" (Zeleza, 2006). In South Africa as in most African Universities, the offered education to African students have not been equitable given the heavy reliance on Westernised curriculum which "glorifies Western culture," and alienates African cultural traditions (Tella, 2021, p.249). This study intends to uncover the role of internationalisation in the transformation and decolonisation of African Universities. Over the years, the decolonization of African Universities has taken centre stage in academic circles, specifically in South Africa. However, the complexity of the challenges faced by African Universities in the 21st Century, presents an urgent need to transform itself through internationalization process. A process which does not only decolonize the curricula and the teaching modes but infuses African traditions to balance the Western epistemologies in the production of pan-African scholarship. This has become a major focal point of transformation for African Universities as this demystifies the rhetoric framing Euro-civilizational superiority in the past centuries.

2. Methodology

This paper is qualitative in nature and employs a Purposive literature review. The objective of the study is to generate empirical knowledge and insightful understanding of the dynamics of internationalisation of African Universities with specific focus to South Africa. As such, the study uses reviewed literature for a specific purpose (Ahmad & Wilkins, 2024). The purpose is to not only demystify the misleading rhetoric regarding Euro-civilisational superiority in African Universities, but to also allow the study to reflect broadly upon internationalisation and provide insights on its educational transformative role. To achieve

this research goal, the study has established an inclusive criterion where peer reviewed journals drawn from scholarly databases such as JSTOR, Science Direct, Google Scholar and institutional repositories were purposively selected. Key terminologies such as "internationalisation" and "transformation" in Higher Education have been instrumental in drawing a systematic review of "research, frameworks, and philosophy" used in South African education (Cook, 2019:56). The benefits of a purposive literature review lie in its ability to concisely address social phenomena through far-reaching research questions to produce novel insights on the complexities surrounding African universities.

Research questions uncovering why internationalisation remains a significant tool for transformation in African Universities, and how African Universities in the post-colonial era calibrated the internationalization of its curriculum are significant in shaping the realities and complexities in African Universities. Essentially, this study zooms into South African as a case study to interrogate how the evolving transformation agenda influenced internationalisation and the decolonisation in HEIs. The South African case study contextualises the dynamics associated with internationalization of African Universities, and the opportunities that this phenomenon presents for an accelerated transformation agenda through a student-centred analytical approach.

The conceptualisation of key concepts will follow to detangle the tensions between internationalisation and the decolonisation rhetoric found in literature related to transformation agenda in African Universities. The South African case study provides a better understanding in the evolving dynamics associated with the internationalization of African Universities and the opportunities that present an accelerated transformation agenda through a student-centred approach.

3. Conceptualising the Transformation Agenda in South Africa: a Student-centred Approach

Generally, transformation in Higher Education (HE) is a vital process of structural changes in the nature of policies adopted by institutional leadership (Masinde and Roux, 2020). In the context of South Africa, the Transformation of Higher Education took a significant turn in post-apartheid era. The 1994 democratic government sought to accelerate a transformation agenda which was inherently disproportional. The laws and policies governing South African the Higher Education Institutions (HEIs) prior to 1994 did not reflect the constitutional principles of "human dignity, equality, freedom, non-racialism and non-sexism" (Majola, 2022).

Instead, the education system of the past was rooted in racial, socio-economic, and cultural discrimination. Thus, becoming imperative to accelerate a transformation agenda that creates and sustains an education system that is inclusive. To this end, the transformation of South African HEIs institutionalises equitable representation where access to higher education aligns with the promotion of democratic constitutional and legislative values that underpin a free and democratic society mentioned earlier. A student-centred approach is one in which the students at the HEIs shape the "interactions, structures and operations" from within (Wahl, 2022, p.12). The interactions, structures and operations within the HEIs reflect the critical values advancing the academic development of students. For example, values such as belonging, human dignity, agency, integrity, plurality/diversity, have ranked higher amongst the identified core-values associated with a student-centred approach as seen in figure 1 below:

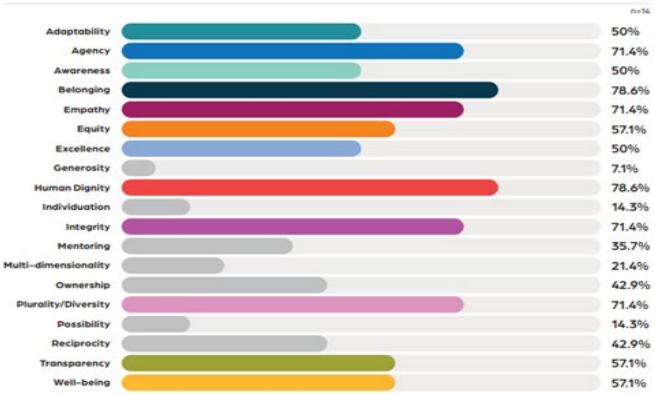


Figure 1: Core-values associated with a student-centrism in South African HEIs

Source: Wahl (2022, p.13).

The above figure 1 depicts all the essential values associated with the transformative agenda imperative of a student-centred approach in South African higher education system. Only the values that ranked 50% and above have been selected as vital indicators of an ultimate student-centred value through which South African HEIs advance their teaching and learning mandates in line with the broader transformative agenda (Wahl, 2022).

3.1 The Significance of a Student-centred Approach as a Transformational Agenda in HEIs

A student-centred approach entails the implementation of teaching and learning practices that advance students' academic interests, optimises students learning processes. The optimisation of students' academic development is attained through collaborations, theory testing, creation of progressive knowledge that directs students' knowledge-building enhancing greater global impact (Trinidad, 2019). Internationalisation in institutions of Higher Learning, therefore, revitalises interconnections through student's active involvement in knowledge production not only through mobility but also in the content they learn. In advancing a student-centred approach education systems in HEIs embody a wide "range of educational outcomes, not limited to attaining a qualification but including other aspects such as moral development" (Xulu-Gama, Nhari, Alcock and Cavanagh, 2018 p8). In the context of South African HEIs, a moral development encompasses practices of internationalisation which underpins a transformational agenda. To cultivate knowledge-sharing at a global scale, internationalisation enhances inter-connectedness, and to an extent creates conditions to reform the historically immoral institutional practices that suppress and undermine African ontological experiences as inferior epistemologies (Hlatshwayo, 2020).

4. Understanding the Influence of Globalisation, Internationalisation and Decolonization of Curriculum in Sub-Saharan Africa HEIs

Globalisation is a global phenomenon that fuelled socio-economic and political pressures and introduced internationalization of education systems as a result of the longevity of Westernised influences in Africa, (Dzvimbo and Moloi 2013). Globalisation and internationalisation are, therefore, interconnected, as one cannot exist without the other. However, although both globalisation and internationalisation can transform institutional structures and practices at a global and international scale, to an extent, these two terms are slightly distinct. On the one hand, globalisation capacitates economic development and enhances the image of educational institutions by attracting international students and expanding research through collaborations as well as innovations driven by the 4th Industrial Revolution (4IR), (Rensburg, Motala, David, 2015; Masinde and Roux, 2020; Tight, 2022). On the other hand, internationalisation has become a dynamic process in HEIs serving as a strategic response to globalisation. Internationalisation has, thus, become instrumental in shaping HEIs by enhancing an international context in its educational environment (Strielkowski, Grebennikova, Razinkina and Rudenko, 2021, p.5).

Similarly, in a globalised society, the internationalisation of African Universities and decolonization of curriculum have driven and shaped the essence of African education systems, specifically in Sub-Saharan Africa (SSA) region. In South Africa, for instance, with the adoption of the Transformation Strategy Group (TSG), in 2020, as designed by the Universities South Africa (USAf) commits to advancing knowledge that contributes towards redressing historically inherited inequities and improve social cohesion and to enhance the societal relevance of the science. Similarly, the Academy of Science of South Africa (ASSAf) holds a transformation Strategy which serves as a framework advancing a Student-centred approach in Higher Education System (Soodyall, 2025). The adoption of transformative strategies in HEIs demonstrate that the educational system recognises the existing need for a dynamic change in education through an emancipation and decolonisation of the curriculum to reshape African universities (Green, 2023; Luescher and Holtzhausen, 2023). In essence, internationalisation of HEIs is measured by the extent it facilitates exchange of student collaboration locally, regionally and globally through an "intentional integration of international and intercultural dimensions" of students at home or abroad (DHET, 2019, p.45).

In the context of South Africa, the internationalisation process in HEIs as well as the transformed content of curriculum are both significant. Through the internationalisation of the curricula, South African HEIs

have been able to foster curriculum transformation imperatives. As such, beyond fostering global mindsets and inclusive skills, internationalisation of the curriculum promotes the adoption of innovative teaching and learning methods that can generate relevant knowledge. A transformative knowledge that is not only responsive to the evolving socio-economic demands through community engagement but also advances output on research publications (Fakunle, Lock & Johnson, 2020, Luescher, *et al*., 2023). Output on research publications has become one of the main indicators of institutional academic worth that provide measures for national and global rankings. Despite having been implemented as a national policy, in 2005, by the Department of Higher Education and Training (DHET), the adoption of the Research Output Policy showed a gradual improvement with an average growth rate of 8.06% (Mouton, *et al.,* 2019p.28). However, despite this slight progress, a growing criticism emerged, labelling the overall research output as a "meagre rise" in publication outputs (Sebola, 2023, p.222).

In spite of the pessimist outlook on internationalisation as observed in Sebola (2023), such views did not hinder South African HEIs from continuing to produce relevant research with a strong pan-African perspective (Tight, 2022). In fact, other African states such as Nigeria, Ghana, and across East Africa have also been generating research that examines the transformation agenda of African HEIs. Additionally, the Diaspora has also made significant contributions with scholars based in the United States of America (USA), the United Kingdom (UK) and other Western countries producing academic works engaging with the transformational agenda of African HEIs (Zavale & Schneijderberg, 2022). These developments demonstrate that not only does Internationalisation inspire knowledge production through practical multidisciplinary engagements but also fosters inclusion of intercultural curriculum in HEIs across the world. In fact, internationalisation in HEIs advances a global agenda connecting the Global North and the Global South through the International Education Agenda 2030. This agenda synchronises educational policies across borders in response to the demands of globalised economies (Rensburg, *et al*., 2015 p.101; Fakunle, *et al*., 2020; Lourenço & Paiva, 2024).

In African context, Internationalisation has also been a driving force for transformation taking a decolonial approach to correct the dehumanising narratives that suppress African traditions and epistemologies (Davids, 2024). This decolonial approach remains in motion as it aims to promote democratic practices that benefit all individuals regardless of gender, race or historical background (Rensburg, *et al*., 2015 and Tight, 2022).

As Soodyall (2025) observes, in South African Society, the transformation of knowledge "will always be shortchanged unless it seeks active engagement and collaboration with knowledge and knowledge producers in the region and across the continent". This assertion suggests that, inasmuch as Western influences have challenged the general composition of African educational systems, it is critical that African Universities retain their regional and continental sources of knowledge as well. For instance, while the educational systems of SSA Universities and Africa more broadly, have to some extent yielded to unavoidable and irreversible neo-liberal market economic pressures. To the most part, neo-liberal pressures have shaped the fabric of African educational systems, which have also led to the adoption of Eurocentric curriculum in HEIs. For instance, in South Africa, the Apartheid regime supported an exclusively Westernised Education model which accentuated the exclusion of minority groups in the knowledge development processes of teaching and learning (Mashilo, 2023 & Chawaremera, 2024).

The idea of internationalisation in African universities is not a new phenomenon. Internationalisation through education has been advanced globally even before the expansion of the notion of global citizenship. This notion was advanced in education through the 1974 Recommendation by the United Nations Educational, Scientific and Cultural Organization (UNESCO), (UNESCO, 2022). UNESCO's approach to internationalization brings to light a multi-faceted dimension of the education system worldwide. Since globalisation has catalysed internationalization, specifically of higher education, this trend has become "irreversible" (Tsiligiris, 2014).

internationalization in HEIs serves as a global strategy that standardizes teaching and learning norms that states apply in their national education systems. In essence, internationalisation strengthens international cooperation as well as peaceful relations, Gultekin (2021). One can pose and ask, in what ways has the internationalization of universities created opportunities to advance the transformation agenda in Africa?

Over the years, internationalisation in HEIs has taken many forms, from cross-border activities such as conferences to student exchange programmes, research collaborations, and to some extent the

replication of curriculum in universities. Thus, enabling African Universities to bring into the global stage their Africanised worldviews and epistemologies. A process through which a nation's HEIs, their regulatory bodies, government departments, research institutions, and international organisations engage in educational activities to foster a multicultural and interdisciplinary connection. Tsiligiris (2014) points out that these connections, have in part, been a response to the transformative effects of globalisation that continue to shape African HEIs despite a multitude of complex challenges. For instance, in the institutional environment of South Africa and Africa in general, challenges associated with post-colonial transformation which have been ongoing for decades impact the manner in which the systemic teaching and learning methods and curricula are implemented. For these reasons, despite existing challenges integrating intercultural and international into the curriculum can expand the intellectual capacity of African Universities. It also presents progressive opportunities that reshaped positively institutional cultures, specifically in South Africa where decolonial rhetoric has opened old wounds accentuated calls for a curriculum revolution in HEIs (Green, 2023).

For the most part, the push for a curriculum revolution challenges the persistence of alienated opportunities in education and knowledge production which the post-1994 democratic transition sought to institute by pursuing a non-discriminatory educational system for all. However, as it turned out Students across public South African universities refuted the manner in which the teaching and learning methods and the curriculum has been taught. With the #Rhodes must fall campaign that took place, in 2015. Students across the country called for an urgent shift in the adoption of Westernised paradigms in the educational systems and the strengthening of pedagogies that drift towards a decolonial contextual lens (de Wit and Altbach, 2020).

The above incident demonstrated the significance of incorporating pan-African knowledge in the African University curriculum. The need for the adoption of Afro-centric teaching and learning methods in African HEIs cannot be compromised as the suppression thereof has shown to potentially lead to radical expression of discontentment and violent revolutions. Kasibe (2021) maintains that the manifestation of the #Rhodesmustfall campaign suggests that revolutions or any required transformation to the status quo, be it in an educational system or otherwise, requires a certain degree of sacrificial boldness. However, this does not in any form call for the complete eradication of the Western content in the education curriculum of African Universities as these westernised educational values also form part of African historical knowledge.

Ntloedibe (2019) asserts that, instead of destroying the Western perspectives or the pathogenic colonial knowledge, African HEIs should integrate relevant Western perspectives to advance African epistemologies. In this way, decentralising Eurocentric knowledge in practice allows educational programmes to critically examine colonial perspective to knowledge acquisition rather than eliminating them, specifically those with non-discriminatory inclination (Ndaipa, *et al*., 2023). However, it is worth noting that, the resistance to exclusively adopting European epistemologies stems from the fact that, some Eurocentric curricula have historically been laced with distorted views regarding Africa and its descendants, thus, necessitating critical analysis and to an extent a drastic change to their adoption (Nyoni, 2019).

Despite these complexities, the adoption both Eurocentric and African-centred epistemologies in African universities would enable the validation of African knowledge patterns which are to the most part "grounded in the principle of interconnectedness that defines the communitarian traditional African thought" (Adeate and Sewchurran, 2023, p.2). For instance, in Cape Peninsula University of Technology students' responses to African infused epistemologies have been rather positive. Waghid (2022) maintains that the student-centred approach to decolonisation of the curriculum in South African universities has not only enabled the humanisation of education in institutions of higher learning but have also contributed to enhance students' socio-cultural worth in knowledge acquisition rather than seeing students from a human capitalist lens. The contribution this paper makes to this highly contested discourse, is that Eurocentric epistemologies can still be used for comparative analysis and development when integrated and adopted together with Afrocentric curriculum in African Universities. Below are a few opportunities that internationalisation offers for advancing a transformational agenda in HEIs:

5. Opportunities of Internationalisation for an Accelerated Transformation Agenda

South Africa experienced numerous educational reforms that impacted its internationalisation and transformational acceleration agenda. For instance, at the height of the COVID-19 pandemic season, African universities had to use the emerged challenges to accelerate a transformational agenda through improvement of technological infrastructure (Mkuti & Aucamp, 2024). Arguably, the events of COVID-19 propelled the enhancement of information technology (IT) which became pivotal to meet the evolving pedagogical and curricula demands of students (Zeleza, 2021). Face-to-face class interactions had to be restructured into online platforms such as Blackboard. Students and educators had to enhance their digital literacy skills. However, the lack of international mobility resulting from COVID-19 restrictions also meant that African HEIs had to be innovative. The adoption of internationalisation plans and policies were accelerated with the goal of strengthening collaborations at home and abroad despite the mobility restrictions of that particular time (Quinlan and Singh, 2022).

In response, digital student-centred initiatives such as Thuso Resources and Thuso Connect were created, in South Africa to expand research and mentorship to emerging scholars (USAf, 2023). This emancipated trajectory increases the engagement of South African universities in global research activity as a strategic internationalisation integration initiative. By incorporating student-centred transformational practices in HEIs, students tend to embrace their own socio-cultural contexts into their studies. This approach enables them to draw strengths from socio-cultural engagements that aid the development of critical perspectives when addressing intricate pedagogic aspects.

6. Findings and Recommendations

This study's findings present clear evidence that eradicating the vestiges of colonial influence from African Universities' educational system, in its totality, is not the primary driver of internationalization or educational transformation. These findings are consistent with Ntloedibe (2019), who emphasises that while internationalisation plays a critical role in advancing an inclusive educational strategy a decolonialised curricula is critical. To a larger extent, a decolonised curricula boosts Africanisation when the syllabus is African-oriented (Mashilo, 2023). This study found that despite the existence of progressive educational opportunities, an effective transformational agenda in South African Universities requires refinement. Only then, can the achievement of transformational education be fully achieved, specifically when students' educational interests are prioritised. The study also found that students that are encouraged to use their African language or express their views from an African perspective tend to gain confidence about themselves and their cultural affinities. Sadly, not all institutions of Higher Learning in South Africa have adopted an Africanised curriculum.

In light of these findings, the study recommends African Universities to prioritise the inclusion of Africanised curricula in its efforts to strengthen internationalisation. By integrating African epistemologies into the educational system, it leverages a meaningful educational transformation approach. While this study recognises the continued relevance of Eurocentric knowledge, it also highlights progressive historical educational systems that shape the much-needed transformation agenda in African universities. The study argues that, this in turn, fosters impactful student-centred competencies that contribute to local, regional, and international educational contexts.

7. Conclusion

The analysis of internationalization in African Universities conducted in this study highlights the significance of adopting diverse epistemological orientations beyond the deficiencies compounded by legacies of colonial educational systems. While the study acknowledges the limitations that colonial educational systems have had in largely suppressing African values in shaping students' experiences, internationalisation and decolonialisation of the curricula in African Universities present opportunities intended to strengthen the integration of Africanised content in educational systems. In this regard, by prioritising students' educational needs in African Universities, specifically within the South African context, this study argues for a balanced educational system. More studies need to be conducted to critically examine the dynamics of the internationalisation process in accelerating a balanced educational transformation agenda, more so, in South African Universities where there are still noticeable imbalances between historically white institutions from the previously disadvantaged black universities.

Ethics and AI Declarations

I declare that an Ethics Waiver for Qualitative Study has been submitted to the IIE Research Ethics Committee (IIE REC). The research study is purely qualitative and devoid of human participants. I also declare that this project is an original work of the author, and no AI tools were used for its development.

References

Abdelmassieh, F. (2020). Egyptian-Islamic Views on the Comparison of Religions: Positions of Al-Azhar Scholars on Muslim-Christian Relations. Münster: LIT Verlag Fresnostr.

Adeate, T. and Sewchurran, A. (2023). African epistemologies and the decolonial curriculum. Acta Academica, Vol. No. 55, Issue No. 1, pp. 1-19.

Ahmad, M. And Wilkins, S. (2024). Purposive sampling in qualitative research: a framework for the entire journey. Quality & Quantity, 59, pp. 1461–1479. https://doi.org/10.1007/s11135-024-02022-5.

Chawaremera, M. (2024). Exploring Opportunities and Obstacles in the Decolonisation of South African Higher Education Curriculum. International Conference on Education Research (ICER), Vol. 1 (1), pp.36-41. https://doi.org/10.34190/icer.1.1.2778.

Cook, D.A. (2019). Systematic and Nonsystematic Reviews: Choosing an Approach. In Nestel, D. Hui, J. Kunkler, K. Scerbo, M. W. and Calhoun, A. (eds) Healthcare Simulation Research. Springer: Cham, pp.50-60. https://doi.org/10.1007/978-3-030-26837-4_8.

Davids, N. (2024). Decolonization in South African universities: storytelling as subversion and reclamation. *Journal of Philosophy of Education*, Vol.58, pp. 189–208. https://doi.org/10.1093/jopedu/qhae029.

Department of Higher Education and Training (RSA). (2019). Policy Framework for Internationalisation of Higher Education in South Africa. *University Education Policy and Support,* pp.1-65. Available at: https://www.dhet.gov.za/Policy%20and%20Development%20Support/Policy%20Framework%20for%20Internationalisation%20of%20Higher%20Education%20in%20South%20Africa.pdf [Accessed on 26 May 2025].

Dzvimbo, K.P. and Moloi, K.C. (2013). Globalisation and the internationalisation of higher education in Sub-Saharan Africa, *South African Journal of Education*, 33(3), pp.1-16.

Fakunle, O. Lock, J. and Johnson, C. (2020). Is Internationalization Intentionally Integrated in Online Learning Environments? Exploring The Challenges and Possibilities. *International Journal on Innovations in Online Education*, 4(3), pp.1-20.

Green, M. (2023). A Transformation Strategy Group study has produced a Framework for a Student-centred Higher Education System in South Africa. *USAf*. Available at: https://www.usaf.ac.za/a-transformation-strategy-group-study-has-produced-a-framework-for-a-student-centred-higher-education-system-in-south-africa/ [Accessed on 26 May 2025].

Hlatshwayo, M.N. (2020). Being Black in South African higher education: An intersectional insight. *Acta Academica*, Vol. 52, No 2, pp. 163-180. DOI: http://dx.doi.org/10.18820/24150479/aa52i2/9.

Kasibe, W. (2021). Rhodes Must Fall a defining moment in SA history. IOL Opinion. Available at: https://www.iol.co.za/news/opinion/rhodes-must-fall-a-defining-moment-in-sa-history-f27fa61d-733b-44c9-8f8e-0310ed7a9322 [Accessed on 26 May 2025].

Lourenço, A. and Paiva, M.O. (2024). Globalization of Higher Education: The Internationalization From a Multifactorial Perspective. In Kayyali, M.(Ed.) *Building Resiliency in Higher Education: Globalization, Digital Skills, and Student Wellness*. Hershey, PA: IGI Global, pp.285-305. https://doi.org/10.4018/979-8-3693-5483-4.

Luescher, H.M. and Holtzhausen, S.M. (2023). Transdisciplinarity and ubuntu ethics as principles for responsive, engaged, and student-centred African universities. *Journal of Student Affairs in Africa*, Vol. 11 No. 2, pp. vii–xv. DOI: 10.24085/jsaa.v11i2.4910

Luescher, T.M.; Mncwango, B.; Fongwa, S. N.; Oppelt, T.; Mthombeni, Z.; and Paterson, M. (2023). The State of Transformation in South Africa's Public Universities. *Research Report of the Ministerial Oversight Committee on Transformation in the South African Public Universities* (TOC). Pretoria: TOC/Department of Higher Education and Training (DHET).

Majola, B. (2022). Transformation in higher education - perspective of the SAHRC. South African Human Rights Commission. Available at: https://www.sahrc.org.za/index.php/sahrc-media/news/item/602-transformation-in-higher-education-perspective-of-the-sahrc#:~:text=Transformation%20in%20South%20Africa%20Universities,teaching%20and%20learning%2C%20research%20and [Accessed on 26 May 2025].

Mashilo, P.P. (2023). African identity and curriculum transformation at universities in South Africa. African Journal of Teacher Education, Vol. 12 (2), pp.119-143.

Masinde, M. and Roux, P.A. (2020). Transforming South Africa's Universities of Technology: a Roadmap Through 4IR Lenses. *Journal of Construction Project Management and Innovation*, Vol.10 (2), pp. 30-50.

Mouton, J. Redelinghuys, H. Spies, J. Blanckenberg, J. Lorenzen, L. Ford, K. Visagie, A. and van Niekerk, M. (2019). The Quality of South Africa's Research Publications. *CREST Final Report to the DHET*, pp. 1-192. Available at:

https://www.dhet.gov.za/Policy%20and%20Development%20Support/REPORT%20ON%20THE%20QUALITY%20OF%20SOUTH%20AFRICA%E2%80%99S%20RESEARCH%20PUBLICATIONS.pdf.

Mkuti, S. and Aucamp, E. (2024). Contextualising the South African Higher Education Academic Interventions for Student Success: Challenges and Opportunities. ICER, Vol. 1 (1), pp.194-201. DOI: https://doi.org/10.34190/icer.1.1.3108

Ndaipa, C.J. Edström, K. Langa, P. and Geschwind, L. (2023). Internationalisation of the curriculum in higher education: A case from a Mozambican university. *congent education*, pp.1-16. https://doi.org/10.1080/2331186X.2023.2188773 [Accessed on 26 May 2025].

Ntloedibe, F.N. (2019). Where are our heroes and ancestors? The spectre of Steve Biko's ideas in Rhodes must fall and the transformation of South African Universities, African Identities. *Routledge*, 17(1),64-79.

Nyoni, J. (2019). Decolonising the higher education curriculum: Analysis of African Intellectual readiness to break the chains of a colonial caged mentality. *Aosis*, pp.1-10.

Sebola, M.P. (2023). South Africa's public higher education institutions, university research outputs, and contribution to national human capital. Human Resource Development International, Vol. 26, No. 2, pp.217–231. https://doi.org/10.1080/13678868.2022.2047147.

Soodyall, H. (2025). Conceptualising transformation within ASSAf. ASSAf Newsletter June. https://mailchi.mp/assaf/assaf-newsletter-december-5046296 [Accessed on 30 June 2025].

Strielkowski, W. Grebennikova,V. Razinkina, E. and Rudenko, E. (2021). Relationship between globalization and internationalization of higher education. *E3S Web of Conferences 301*, 03006, pp. 1-9. Available at: https://www.e3sconferences.org/articles/e3sconf/pdf/2021/77/e3sconf_rec2021_03006.pdf. [Accessed on 26 May 2025].

Rensburg, I. Motala, S. David, S.A. (2015). Internationalization of Higher Education: A South African Perspective. Frontiers of Education in China 2015, 10(1): 91–109

DOI 10. 3868/s110-004-015-0006-8.

Tella, O. (2021). South Africa's Curriculum Transformation: Insights from Post-Independence Africa and Post-Civil Rights Movement in the United States. *Strategic Review for Southern Africa*, Vol 43, No 2. pp. 235-259.

Tight, M. (2022). Internationalisation of higher education beyond the West: challenges and opportunities – the research evidence. *Educational Research and Evaluation*, Vol. 27, Nos 3-4, pp. 239-259, DOI: 10.1080/13803611.2022.2041853

Tsiligiris, V. (2014). Internationalisation – A student-centred approach is key. *University World News*. Available at: https://www.universityworldnews.com/post.php?story=20140416075647276 [Accessed on 26 May 2025].

Trinidad, J.E. (2019). Understanding student-centred learning in higher education:

students' and teachers' perceptions, challenges, and cognitive gaps. *Journal of Further and Higher Education*, Vol 44, No 8, pp.1013–1023. https://doi.org/10.1080/0309877X.2019.1636214.

Quinlan, O. and Singh,T. (2022). How can internationalization regain momentum in South Africa? *University World News*, Africa Edition. Available at: https://www.universityworldnews.com/post.php?story=20220509145739708 [Accessed on 26 May 2025].

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2022, December, 06). Mobilizing the global community to advance peace through education. Available at: https://www.unesco.org/en/articles/mobilizing-global-community-advance-peace-through-education [Accessed on 26 May 2025].

Universities South Africa (USAf). (2023). Universities South Africa celebrates the launch of two digital platforms for emerging scholars. Available at: https://www.usaf.ac.za/universities-south-africa-celebrates-the-launch-of-two-digital-platforms-for-emerging-scholars/ [Accessed on 26 May 2025].

~~Waghid, Z. (~~2020). Decolonising education in South Africa – a reflection on a learning-teaching approach, *The Conversation*. Available at: https://theconversation.com/decolonising-education-in-south-africa-a-reflection-on-a-learning-teaching-approach-192190#:~:text=Decolonisation%20in%20the%20university%20context,what%20students%20learn% 20and%20how [~~Accessed on~~ 26 May 2025].

Wahl, W.P. 2022. Reshaping Universities to create a Student-Centred Higher Education

System in South Africa: A research study by the Transformation Strategy Group of Universities South Africa. *Research Report,* September. Available at: https://helm.ac.za/wp-content/uploads/USAf_ResearchReport_StudentCentredUniversities.pdf [Accessed on 30 June 2025].

Xulu-Gama, N., Nhari, S. R., Alcock, A., and Cavanagh, M. (2018). A student-centred approach: a qualitative exploration of how students experience access and success in a South African University of Technology, *Higher Education Research & Development*, Vol. 37, No 6, pp. 1302–1314. doi: 10.1080/07294360.2018.1473844.

Zeleza, P. (2021). Quality higher education 'indispensable' for Africa's future. *University World News*, Africa Edition. Available at: https://www.universityworldnews.com/post.php?story=202107051145016 [Accessed on 26 May 2025].

Zeleza, P.T. (2006). Beyond Afropessimism: Historical accounting of African Universities. *Pambazuka News*. Available at: https://www.pambazuka.org/governance/beyond-afropessimism-historical-accounting-african-universities [Accessed on 26 May 2025].

The Importance and the Role of Technology in the Education of Generation Z

Igor Piatrov and Peter Krajčovič
Faculty of Mass Media Communication, University of Ss Cyril and Methodius, Trnava, Slovak Republic

peter.krajcovic@ucm.sk
igor.piatrov@ucm.sk

Abstract: The paper focuses on the importance and the role of digital technologies in the education of Generation Z, which is growing up in an environment heavily influenced by technological advances. The aim of this paper is to identify the most commonly used digital devices in higher education and to explore the attitudes of Generation Z university students towards electronic study materials. Particular emphasis is placed on the perceived role of modern devices - computers, laptops, tablets and smartphones - in the learning process of this generation referred to as the 'digital generation'. The research was carried out at the Faculty of Mass Media Communication at the University of Ss Cyril and Methodius in Trnava. The sample consisted of 863 respondents - full-time students of bachelor's and master's degrees. The research set was non-probabilistic, purposive, and the criterion for inclusion in the research was belonging to Generation Z and active study at the faculty. The research focused on three main areas: (1) Devices used to study materials in electronic form. (2) Perceptions of the role of technology in education. (3) Preference regarding the study of electronic materials. The research was guided by an attempt to answer the following research questions: What digital devices do Generation Z university students use most often in their studies? How do Generation Z students perceive the role of modern digital devices (computers, laptops, tablets, smartphones) in the learning process? What are the preferences of university students regarding the use of electronic learning materials? Are there differences in preferences across years of undergraduate study? The results show that that digital technologies are an integral part of Generation Z education. The most prominent position is occupied by the laptop as the primary tool for working with electronic learning materials. Smartphones also play an important role, and particularly for quick access to more concise study materials such as worked-out questions. Conversely, the use of desktop computers and tablets remains rather marginal, reflecting the continuing trend towards a preference for smaller screens on mobile devices such as smartphones.

Keywords: Devices, Education, Electronic Study Materials, Generation Z, Technologies.

1. Introduction

The integration of digital technologies into education represents a complex and dynamic area of research that is particularly relevant in the context of Generation Z - a cohort born into an environment of rapid technological advancement. This generation, often referred to as "digital natives", exhibit specific learning preferences and behaviours that require a rethinking of traditional pedagogical approaches. As pointed out by older or more recent research (e.g., Cilliers, 2017 or Yu, 2020), Generation Z's high affinity for technology not only influences their learning styles but also brings new challenges and opportunities for educators in effectively engaging them in the classroom.

Traditional teaching methods often fail to meet the needs of this generation, who prefer fast-paced, visually stimulating and interactive content (Čekrlija, 2024). At the same time, research suggests that technologies such as generative artificial intelligence, virtual reality, and adaptive learning systems are transforming the way learners acquire and process information (Hernandez-de-Menendez et al., 2020; Ameen et al., 2023). However, despite the potential benefits, experts also warn of risks, such as over-reliance on technology and related ethical issues (Chan & Lee, 2023).

An essential part of the successful integration of technology into the educational process is the role of educators, who often face obstacles such as a lack of digital competences or resistance to change. Targeted professional development and systematic support in digital literacy are key to increasing their readiness to use technology in education (Islawati et al., 2025).

While digital technologies can significantly enrich education and the learning process of Generation Z through personalising content, increasing engagement and supporting skills development, their effective use requires a balanced approach. Indeed, overloading with information, complex tools or uncritical adoption of AI outputs can lead to cognitive overload and weaken independent thinking skills, as pointed out by several authors (e.g. Onjewu et al., 2024 or Chardonnens, 2025).

Last but not least, the availability of technology plays an important role. In environments outside of formal learning, especially in the home, students often do not have access to advanced digital tools. This raises

questions about which devices they use for self-study and whether the smartphone, as a ubiquitous and easily accessible device, also plays a dominant role when working with electronic learning materials.

The aim of this paper is to identify the most used digital devices during university study and to explore the attitudes of Generation Z undergraduate students towards electronic study materials. Emphasis is placed on the perceived role of modern devices - computers, laptops, tablets and smartphones - in the learning process.

2. Literature Review

Generation Z represents the first truly digitally native cohort that grew up with smartphones, social media and constant access to information. This technological context has fundamentally influenced their behaviour, cognitive processes and expectations in the learning environment. In the literature, we can find several studies that address the importance, role and position of technology in the education of this generation.

Older and more recent studies indicate that Generation Z students show a strong preference for the incorporation of technology into formal education (Cilliers, 2017; Vinh, 2020). The use of technology not only promotes academic performance but also the development of soft skills such as autonomy, collaboration or digital literacy (Hernandez-de-Menendez et al., 2020; Marzuki et al., 2024). Research shows that students of this generation prefer independent and personalized learning using technology over traditional teaching formats (Vinh, 2020; Robertson, 2019).

A key feature of Generation Z is also a strong affinity for visual, multimedia and interactive content. This is highlighted by Miller, Murphrey and Alvis (2012), for example, who point to the effectiveness of interactive technologies in holding students' attention. Similarly, Andheska and Sari (2022) point out that digital forms of learning increase interest in learning literature with visual elements. However, the effectiveness of these forms is significantly influenced by the quality of the design - Mandau and Lakulu (2022) point out the need for optimising the user interface (UI) in m-learning applications.

Several studies have looked at the specific information-seeking habits of Generation Z and their preferred digital platforms. Tick (2018) noted a shift in the behaviour of early Generation Z, who no longer rely primarily on traditional sources but seek information online, often favouring a blended learning model. Nasution (2020) highlights the importance of social media as tools to increase student engagement - platforms such as Facebook, WhatsApp, Twitter and Instagram can be transformed into digital classrooms or discussion forums.

However, this trend requires new communication approaches. Wulandari et al. (2023) highlight the need to adapt communication styles to the preferences of Generation Z, who tend towards short, visual and dynamic forms of communication, while maintaining an emphasis on security and privacy.

Despite the general enthusiasm for technology, there are also challenges that need to be taken into account. Yu (2020) points out that universal access to online education is ineffective due to varying levels of digital literacy. Interactive and multimodal formats are needed that enable real-world interactions and contribute to the development of communicative competence. Ivenz and Poláková (2024) add that technology is perceived positively, especially if it provides flexibility and the opportunity to learn at one's own pace.

Ameen, Hosany, and Taheri (2023) identified significant gaps in research on Generation Z behavior in the context of new-age technologies such as generative AI, quantum computing, and metaverse. They also propose a new research framework that incorporates interdisciplinary approaches and collaborative research strategies.

Technology can have a positive impact on students' intrinsic motivation and confidence. Robertson (2019) documents the successful use of instant feedback systems that allow students to anonymously check their knowledge and compare themselves to peers. At the same time, Wajdi et al. (2024) remind us that characteristic of Generation Z, such as multitasking, creativity and inclusivity, require innovative pedagogical strategies and greater responsiveness on the part of educational institutions.

The above overview of studies and literature provides important insights into the relationship between Generation Z and technology in education. Despite identifying significant positive aspects, such as a preference for technology, the development of soft skills, and adaptation to visual content, critical analysis reveals important gaps and contrasting perspectives that require further research.

Studies that address the need to focus on security, privacy, and digital inequality do not provide an in-depth analysis of these issues. In this context, it is essential to recognize that uncritical acceptance of technology can have significant negative consequences. For example, the use of social media and other platforms in education

raises questions about the protection of students' personal data. A critical perspective should examine the ethical implications of collecting and analysing data on student behaviour in online environments.

Furthermore, studies emphasizing the importance of technological formats over traditional ones raise the question of whether traditional forms of teaching are truly outdated or simply need to be innovatively linked to digital tools. Although multimedia and visual content can increase interest, there is a risk that it will lead to superficial processing of information. Traditional methods, such as reading textbooks, lectures, and discussions, are key to developing deep analytical thinking. In addition, excessive use of digital platforms, such as social media discussion forums, can limit the development of nonverbal communication and empathy.

Current research rightly points to a gap in the study of the impact of new technologies in education, such as generative artificial intelligence (AI), quantum computers, and the metaverse. These tools represent a radical change. Future research should focus on how Generation Z students use them and how teachers can integrate them into their teaching strategies. Such insights can bridge the gaps between different disciplines and provide a more comprehensive view of the interactions between technology, students, and teachers.

3. Methodology

The aim of this paper is to identify the most commonly used digital devices in higher education and to explore the attitudes of Generation Z university students towards electronic study materials. Particular emphasis is placed on the perceived role of modern devices - computers, laptops, tablets and smartphones - in the learning process of this generation referred to as the 'digital generation'.

The research was carried out at the Faculty of Mass Media Communication at the University of Ss Cyril and Methodius in Trnava. The sample consisted of 863 respondents - full-time students of bachelor's and master's degrees. The research set was non-probabilistic, purposive, and the criterion for inclusion in the research was belonging to Generation Z and active study at the faculty.

Data collection was conducted between September 24 and October 7, 2024, through an electronic questionnaire. The questionnaire was anonymous, and completion was voluntary. Respondents were informed of the purpose of the research and the voluntary nature of participation prior to the start of the questionnaire.

The research focused on three main areas:

1. Devices used to study materials in electronic form.
2. Perceptions of the role of technology in education.
3. Preference regarding the study of electronic materials.

The data obtained were analysed using descriptive statistics. The research was guided by an attempt to answer the following research questions (RQ):

RQ 1: What digital devices do Generation Z university students use most often in their studies?

RQ 2: How do Generation Z students perceive the role of modern digital devices (computers, laptops, tablets, smartphones) in the learning process?

RQ 3: What are the preferences of university students regarding the use of electronic learning materials?

RQ 4: Are there differences in preferences across years of undergraduate study?

4. Results and Discussion

Our research focused on what devices university students use when studying electronic materials, how they perceive the role of technology in education, and their preferences regarding the study of electronic materials.

We classified the devices used for studying electronic materials into the following groups: laptop, desktop, tablet, smartphone, while we classified the materials themselves into the following categories: books, textbooks, presentations by educators, worked-out questions, and case studies.

We classified the role of technology in education into the following groups: positive perception (technology makes learning easier), neutral perception (technology does not bring any major advantages or disadvantages in education) and negative perception (technology makes learning more difficult, more challenging and less accessible for me).

Preferences about studying electronic materials were examined by expressing the degree of agreement/disagreement with the following statements: (1) Electronic materials are more suitable for studying and preparing for exams than printed materials. (2) Electronic materials are easier to learn from than printed materials. (3) I would like all study materials to be available in one place, along with case studies and links to other resources. (4) I would like study materials to be available in a single place (for example, as a website).

A number of interesting findings emerged from the results of the investigation regarding the use of different digital devices by Generation Z university students when studying electronic study materials. The most commonly used device for studying electronic learning materials is a laptop, which students primarily use to study presentations from educators and electronic books or textbooks. There is also a significant presence of worked-out questions, but students are surprisingly more likely to use a smartphone to study them. The least used devices are the desktop computer and the smartphone. More detailed results are shown in Figure 1.

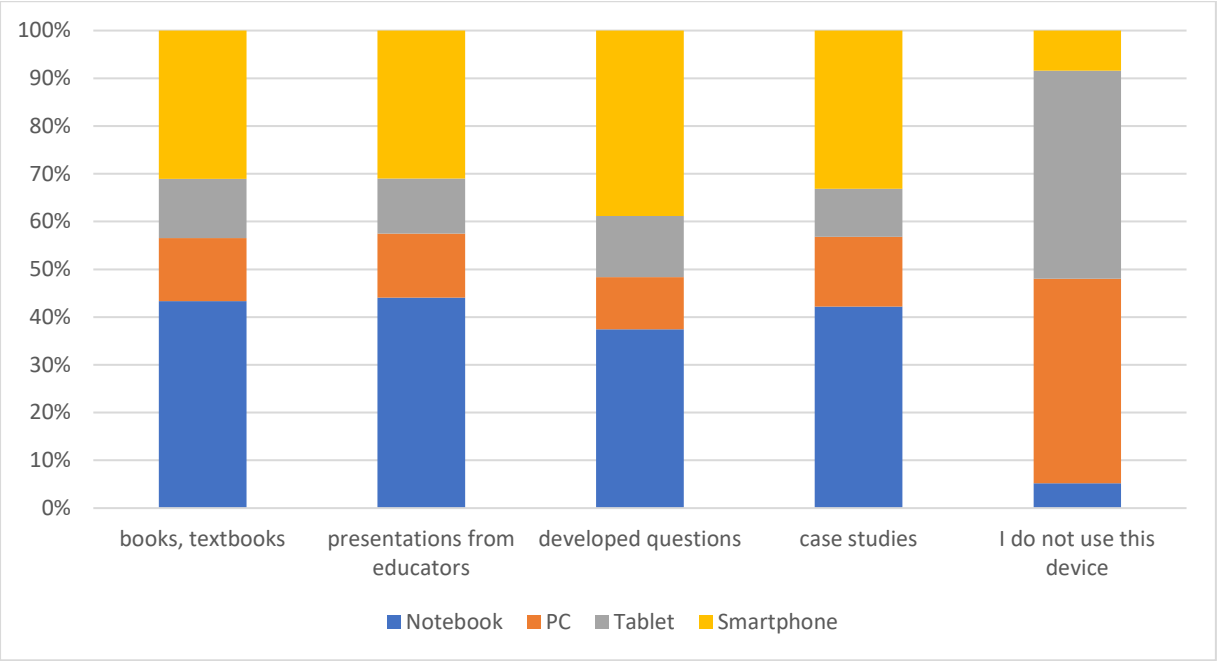


Figure 1: Devices used for studying materials in electronic form (n = 863 respondents).

Comparisons between different years of study also yielded interesting results. In the case of the laptop, although it is the most used device, we can observe a slight decrease in usage in the higher years, especially at Master level. On the contrary, desktop and tablet, although their usage is marginal, in the case of PC we can observe its most frequent usage in the 1st year of the Bachelor's degree. Tablet on the other hand has the highest usage in the 3rd year of Bachelor´s studies. In the case of the smartphone, as with laptops, there is a slight decline with higher years. Figure 2 shows the results in more detail.

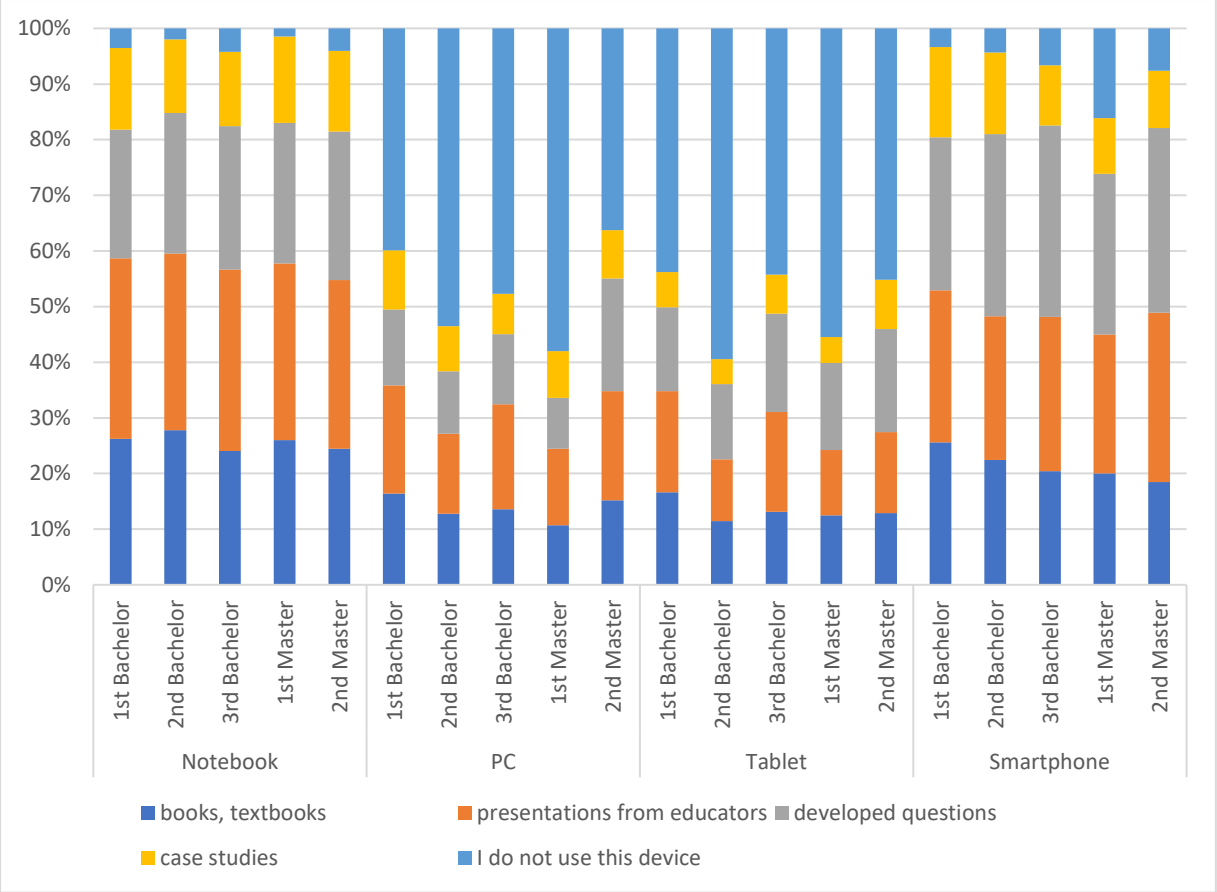


Figure 2: Devices used for studying materials in electronic form by year of study (n = 273 respondents - 1st Bachelor, 191 respondents – 2nd Bachelor, 212 respondents – 3rd Bachelor, 99 respondents – 1st Master, 88 respondents – 2nd Master).

The results of the investigation indicate the preferred facilities and the trend of development among university students, which can be summarized in Table 1.

Table 1: Type of device and trend of its usage.

Devices	1st Bachelor	3rd Bachelor	2nd Master	Notes
Notebook	Dominantly used device	Slight decrease in device usage	Slight decrease in device usage	Most used device in all years
PC	Moderately used, rather complementary	Little used device	Device minimally used	Device heavily replaced by portable devices
Tablet	Low usage rate	Relatively highest usage rate among all grades	Equipment minimally used	Complementary nature
Smartphone	Very frequent use	Consistently high use	Slight decline in device use	Quick access to questions and presentations

In terms of perceptions of the role of technology in education, a significant proportion of students perceive the role of technology positively. Thus, technology is not only accepted but actively perceived as beneficial and essential for effective higher education. However, an interesting finding is the slight trend of a decrease in the positive perception of the role of technology with increasing year and level of study. Figure 3 shows the results in more detail.

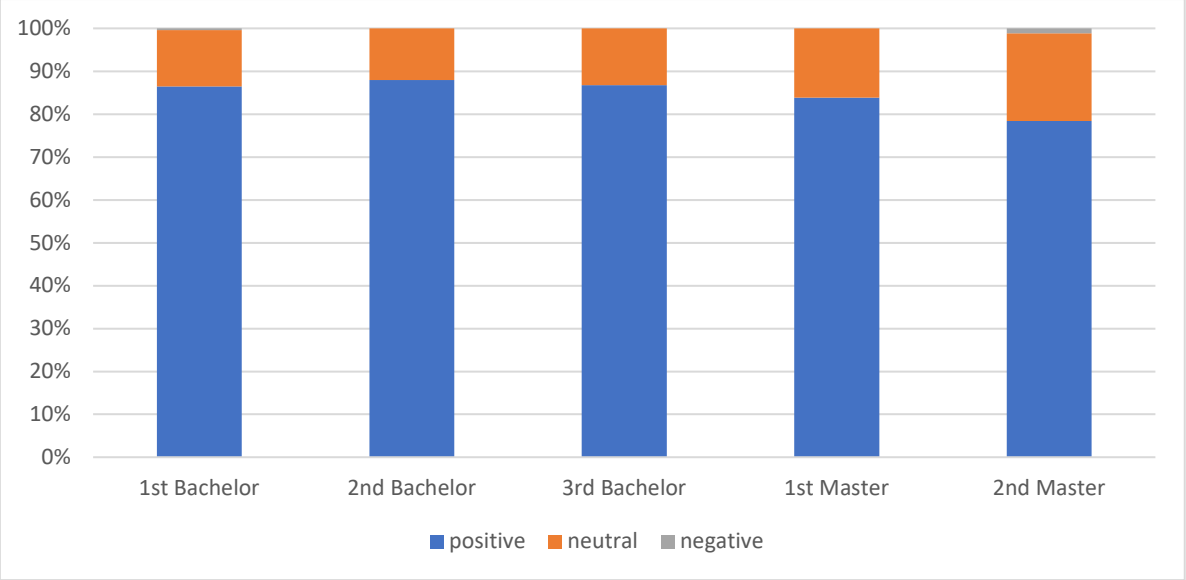


Figure 3: Perceptions of the role of technology in education by year of study (n = 273 respondents - 1st Bachelor, 191 respondents – 2nd Bachelor, 212 respondents – 3rd Bachelor, 99 respondents – 1st Master, 88 respondents – 2nd Master).

In terms of the use of electronic learning materials, the results highlighted a number of interesting findings. The majority of students only partially agree with the statement that "electronic materials are more suitable for studying and preparing for exams than printed materials", suggesting a degree of ambivalence or conditioning. Generation Z students, although they are a digital generation, still prefer printed materials to some extent, which may be related to a better ability to study the text and retain the material. This is confirmed by the respondents' answers to the second question. The majority of students disagree or only partially agree with the statement that 'it is easier to learn from electronic materials than from printed materials'. This suggests that many students still prefer or need a combination of both forms. We can assume that reading from a screen is not natural or comfortable for everyone, and some students may perceive advantages to printed text (e.g., ability to underline, better focus). Almost all students agree or partially agree with the statement 'they would like all the study materials to be available in one place, along with case studies and links to other resources'. This suggests a need to improve the organisation and accessibility of learning resources in electronic form, e.g. via e-learning platforms or university portals. This is confirmed by the agreement of almost all respondents with the statement "that they would like learning materials to be available in a single place

This is confirmed by the agreement of almost all respondents with the statement "that they would like the study materials to be available in a single place (e.g. in the form of a website)". Table 2 shows the results in more detail.

Table 2: Generation Z university students' preferences regarding studying electronic materials by year of study.

	1st Bachelor	2nd Bachelor	3rd Bachelor	1st Master	2nd Master
Electronic materials are more suitable for study and exam preparation than printed materials.					
I agree	62	40	50	15	21
I partially agree	173	113	106	49	36
I disagree	38	38	56	35	31
It is easier to learn from electronic materials than from printed materials.					
I agree	50	40	38	13	18
I partially agree	130	85	84	37	28

	1st Bachelor	2nd Bachelor	3rd Bachelor	1st Master	2nd Master
I disagree	93	66	90	49	42
It is easier to learn from electronic materials than from printed ones.					
I agree	243	170	184	79	70
I partially agree	27	19	24	19	12
I disagree	3	2	4	1	6
I would like the study materials to be available in a single place (e.g. in the form of a website).					
I agree	241	173	188	84	73
I partially agree	29	17	23	15	13
I disagree	3	1	1	0	2
SUM	273	191	212	99	88

5. Conclusion

The results of the research presented here confirm that digital technologies are an integral part of Generation Z education. These findings are confirmed by both older and more recent studies (e.g. Vinh, 2020 or Čekrlija, 2024). The most prominent position is occupied by the laptop as the primary tool for working with electronic learning materials. Smartphones also play an important role, and particularly for quick access to more concise study materials such as worked-out questions. Similar findings are reported by Poláková and Klimova (2019), whose study emphasizes that mobile technologies, including smartphones, significantly improve language learning for Generation Z students. These students, accustomed to the digital environment, benefit from interactive and multimedia content that is in line with their learning preferences. Research suggests that the use of mobile applications in the classroom has a positive effect on vocabulary retention and makes learning more enjoyable compared to traditional methods. Conversely, the use of desktop computers and tablets remains rather marginal, reflecting the continuing trend towards a preference for smaller screens on mobile devices such as smartphones.

Perceptions of the role of technology in education are overwhelmingly positive among respondents, who see digital technology as a means of making learning easier and more efficient. However, an interesting finding is a slight decline in positive perceptions of technology in the upper grades. This may be related to either increasing demands on studying or a more critical view of digital technologies in the learning process based on personal experience, for example due to potential procrastination and lack of focus. Although Generation Z is digitally proficient, the results suggest that a significant proportion of students still attribute greater effectiveness to printed materials, especially when studying for exams or learning more deeply. This implies that even among the digital generation, traditional forms of learning cannot be completely replaced, and the coexistence of both approaches is necessary for effective learning. A similar view is shared by Pikhart and Klimova (2020), who argue that blended learning approaches, which combine traditional teaching methods with digital tools, have proven effective in engaging Generation Z students. These methods allow for flexibility and accessibility, enabling students to learn at their own pace and in their preferred style.

However, the need for centralised access to digital materials became very apparent. Students are clamouring for systems that, through integration and organisation, allow easy and clear access to all the resources they need in one place. Thus, the current challenge and key task will be not only to integrate the technologies but also to strategically grasp them in a way that promotes not only efficiency but also students' own or critical thinking, focus and independence. However, it will also be important to balance technological innovation with the human dimension of learning, so that technology is not an end in itself, but a means that truly enriches the learning process in order to improve its quality and success. An interesting perspective on the different uses of technology by Generation Z members in education is provided by Bullen et al. (2011) and Lai and Hong (2015), who argue that Generation Z students tend to use a limited set of digital tools, primarily driven by factors such as knowledge

and cost. This suggests that although they are proficient in using technology, their usage patterns are not as diverse as is often assumed.

Based on the findings, it is possible to formulate several basic comprehensive recommendations for educational institutions and teachers. The most suitable approach to educating this generation may be to make all study materials available in a single centralized digital environment with a clear structure, whose design and functionality is adapted to both laptops and smaller screens such as smartphones and tablets. Another related recommendation is to prepare and provide students with study materials that are optimized for viewing on laptops, smartphones, and tablets. A suitable approach may also be to provide key text materials in printable form, which can support note-taking and concentration while eliminating digital overload. In connection with the aforementioned concentration, it is also possible to generally recommend dividing larger study topics into smaller logical parts and creating recommended time blocks for studying a given part of the topic.

Although the results of the investigation carried out provide interesting findings and highlight important aspects, the study has several limitations that need to be mentioned. This is primarily due to the focus on one group of university students, which may not reflect the preferences of all Generation Z university students. Future research in this area should therefore be extended to other groups of university students and the results compared with each other. Conducting qualitative research through individual interviews or focus groups may also be an appropriate way to better understand the results and to understand the reasons for preferences for particular technologies, the specific ways in which they are used in the learning process and, most importantly, to explore their limitations and barriers in more depth. It would also be useful to analyse the influence of the field of study on the choice of information technologies and the preference for electronic learning materials. In this respect, preferences may differ significantly. It is also important to investigate how these preferences change over time, e.g. during the transition from bachelor to master's degree or through the impact of technological innovations.

Acknowledgement

This study was written within the project supported by the Cultural and Educational Grant Agency of the Ministry of Education, Research, Development and Youth of the Slovak Republic (KEGA) No. 021UCM-4/2024 entitled “Creation of interactive multimedia study materials for the study programme Marketing Communication”.

Ethics and AI Declaration

Ethical clearance was not required for the research. No artificial intelligence tools were used in the creation of this paper.

References

Alruthaya, A., Nguyen, T. T., Lokuge, S. (2021) “The application of digital technology and the learning characteristics of Generation Z in higher education”, In *Australasian Conference on Information Systems* (pp 1–7), Sydney.

Ameen, N., Ullah, S., Hosany, S., Taheri, B. (2023) “Generation Z's psychology and new-age technologies: Implications for future research”, *Journal of Consumer Marketing,* Vol 40, No. 10, pp 2029–2040.

Andheska, H., Sari, C. M. A. (2022) “The design of literature learning innovation based on a modern digital model for Generation Z students”, In *Proceedings of the 1st International Conference on Maritime Education, ICOME 2021* (pp 1–8), Tanjungpinang, Riau Islands, Indonesia.

Basseto, C. O., Mendes, C. (2024) “A geração Z: Da universidade ao mercado de trabalho, os desafios e contradições”, *RCMOS*, Vol 1, No. 1, pp 1–10.

Bullen, M., Morgan, T., Qayyum, A. (2011) “Digital Learners in Higher Education: Generation is Not the Issue”, *Canadian Journal of Learning and Technology*, Vol 37, No. 1.

Cilliers, E. J. (2017) “The challenge of teaching Generation Z”, *PEOPLE: International Journal of Social Sciences*, Vol 3, No. 1, pp 188–198.

Čekrlija, S. (2024) “Challenges of Teaching Methods for Generation Z at Universities, Case Study China”, *SDMT 2024: International Scientific Conference - Sustainable Development: Modern Trends and Challenges* (pp 1–8), Kutaisi, Georgia.

Hernandez-de-Menendez, M., Escobar Díaz, C. A., Morales-Menendez, R. (2020) “Educational experiences with Generation Z”, *International Journal on Interactive Design and Manufacturing (IJIDeM)*, Vol 14, No. 3, pp 847–859.

Chan, C. K. Y., Lee K. K. W (2023) “The AI generation gap: Are Gen Z students more interested in adopting generative AI such as ChatGPT in teaching and learning than their Gen X and Millennial Generation teachers?”, *Smart Learning Environments*, Vol 10, No. 60, pp 1–23.

Chardonnens, S. (2025) “Adapting educational practices for Generation Z: integrating metacognitive strategies and artificial intelligence”, *Frontiers in Education*, Vol 10, pp 1–14.
Islawati, I., Samsuddin, Y. B., Sugiarti, S. (2025) “Strategi Pengembangan Profesionalisme Guru di Era Digital untuk Menghadapi Tantangan Pembelajaran Gen Z”, *Indo-MathEdu Intellectuals Journal*, Vol 6, No. 1, pp 635–645.
Ivenz, P., Poláková, P. (2024) “Gen Z students and their perceptions of technology in the process of second language acquisition based on the language proficiency level”, *Arab World English Journal*, Vol 15, No. 3, pp 3–17.
Lai, K.-W., Hong, K. S. (2015) “Technology Use and Learning Characteristics of Students in Higher Education: Do Generational Differences Exist?”, *British Journal of Educational Technology*, Vol 46, No. 4, pp 725–738.
Mandau, L. L. D., Lakulu, M. M. (2022) “A critical review on m-learning for Generation Z”, *Journal of ICT in Education*, Vol 9, No. 3, pp 111–128.
Manzanares Triquet, J. C. (2020) “Generación Z y gamificación: El dibujo pedagógico de una nueva sociedad educativa”, *Tejuelo: Didáctica de la Lengua y la Literatura*, Vol 32, pp 263–298.
Marzuki, M., Patemah, P., Parta, I. B. M. W. (2024) “Strategy for developing soft skills in Generation Z using educational technology”, *Jurnal Kajian Pendidikan dan Psikologi*, Vol 1, No. 3, pp 179–186.
Miller, K., Murphrey, T. P., Alvis, S. (2012) “Harnessing interactive technologies to serve Generation Z”, *The Agricultural Education Magazine*, Vol 85, No. 1, pp 5–7.
Nasution, A. K. P. (2020) “Integrasi media sosial dalam pembelajaran generasi Z”, *TIP*, Vol 13, No. 1, pp 80–86.
Onjewu, A. K. E., Godwin, E. S., Azizsafaei, F., Appiah, D. (2024) “The influence of technology use on learning skills among generation Z: A gender and cross-country analysis”, Industry and higher education, Vol 39, No. 2, pp 139–157.
Pikhart, M., Klimova, B. (2020) “eLearning 4.0 as a Sustainability Strategy for Generation Z Language Learners: Applied Linguistics of Second Language Acquisition in Younger Adults”, *Societies*, Vol 10, No. 2, p 38.
Poláková, P., Klimova, B. (2019) “Mobile Technology and Generation Z in the English Language Classroom—A Preliminary Study”, *Education Sciences*, Vol 9, No. 3, p 203.
Robertson, A. (2019) “Preparing for Generation Z: How can technology enhanced learning be firmly embedded in our students' learning experience? A case study from Abertay University”, In *INTED2019 Proceedings* (pp 5769–5773).
Tick, A. (2018) “Research on the digital learning and e-learning behaviour and habits of the early Z generation”, In *2018 IEEE 22nd International Conference on Intelligent Engineering Systems (INES)* (pp 33–38), IEEE, Spain.
Vinh, T. Q. (2020) “Understanding Generation Z students to meet target’s learning preference in the international integration age”, In *HUFLIT International Conference on Ensuring a High Quality Resource in the Modern Age* (pp 404–408), Hanoi, Vietnam.
Wajdi, M., Susanto, B., Sutiarso, M. A., Hadi, W. (2024) “Profile of Generation Z characteristics: Implications for contemporary educational approaches”, *KPSBSL*, Vol 1, No. 1, pp 33–44.
Wulandari, Y. F., Purihastine, M., Afianto, H., Bastian, Y., Murtiadi, M. (2023) “Tantangan komunikasi di era digital: Memahami generasi Z”, *AL-MIKRAJ: Jurnal Studi Islam dan Humaniora*, Vol 4, No. 1, pp 621–630.
Yu, E. (2020) “Student-inspired optimal design of online learning for Generation Z”, *Journal of Educators Online*, Vol 17, No. 1, pp 1–11.

Formative Assessment in Digital Classrooms: Comparison through Bar Model Representations

Claire H. S. Poh
Department of Mathematics and Mathematical Education, Faculty of Education, Charles University, Prague, Czech Republic

Clairepohhs@gmail.com

Abstract: Digital assessment introduces fresh possibilities for evaluating mathematics learning when students' work is created in digital settings. Teachers can modify task structures for remediating students' conceptual deficiencies and align the scope of assessed abilities and skills according to their learning needs. Two key processes underpin effective formative assessment: collecting data on student digital interactions and devising strategies to enhance performance. Among the many contributions of technology to contemporary pedagogy is its capacity to furnish students with an extensive suite of digital tools for exploration, practice, and representation. One such tool is the bar model virtual manipulative. The bar model, a core feature of the model method used in the Singapore mathematics curriculum, is a structured visual representation designed to support students' understanding of mathematical relationships in problem solving. In line with Bruner's Enactive–Iconic–Symbolic framework, the bar model occupies the iconic stage of learning, acting as a bridge between hands-on manipulation of objects and abstract symbolic reasoning. By using rectangular bars to represent known and unknown quantities, students are guided to visualise part-whole and comparison structures, comprising two key relational models that underpin many arithmetic and algebraic problems. This visual representation is particularly helpful for students who struggle with abstract concepts in word problems, as it allows them to explore mathematical representations dynamically. Moreover, research has shown that instructional strategy involving the comparison of visual representations effectively supports mathematics learning. A pilot study was conducted to explore the strategy's effectiveness with nine Grade 6 students, employing screen recordings and post-task group discussion as data collection instruments to capture student interactions and fractional reasoning while comparing bar models. Comparison of bar models fosters active learning through interaction with these representations, providing insights into students' mathematical thinking in the process. **The study highlights the role of visual modelling and scaffolding to promote** student-centred practices, fostering conceptual learning and relational reasoning in mathematics within technology-enhanced settings.

Keywords: Formative Assessment, Model Method, Comparison, Visual Representations, Student Dialogue

1. Introduction

Technology has played a key role in shifting classroom practices from traditional approaches centred on teacher demonstration and student practice to learning environments that promote students-driven engagement in the modelling process. Students can now actively engage in constructing mathematical models, with teachers stepping in to support learning through timely discussion and reflection. As international studies reveal a growing number of innovative practices (OECD, 2016), the integration of technology into mathematics classrooms continues to raise important pedagogical questions, particularly concerning how it reshapes teacher-student interactions, the role of representation, and students' mathematical reasoning. Rather than serving solely as instructional delivery mechanisms, digital tools create opportunities for students to demonstrate knowledge and errors in reasoning, receive timely feedback, and revise their thinking. Viewed through a formative assessment lens, using digital tools such as bar models on interactive platforms can support ongoing diagnosis of student understanding, misconceptions, and strategies, and enable more responsive instruction, where teachers can observe students' reasoning as it unfolds (Drijvers et al., 2016). Research has established that comparison effectively enhances mathematics learning as an instructional strategy (Rittle-Johnson et al., 2017). Building on evidence of its effectiveness, a programme was piloted at a Czech elementary school with nine Grade 6 participants who solved fraction-based word problems utilising a web-based bar model app on their mobile devices. The methodological approach involved collecting data from students' interactive activities while using the app, analysing their contributions during bar model comparison discussions, and interpreting patterns through qualitative analysis. Following this research design, the study investigates how comparing students' digital representations exposes misconceptions and helps teachers target conceptual gaps.

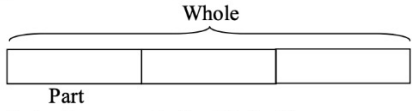
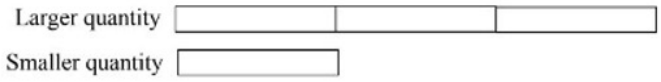
2. Theoretical Framework

2.1 The Model Method

Inspired by Greeno's part-whole and comparison schemas (Nesher et al., 1982; Kintsch & Greeno, 1985), the model method is a widely adopted pedagogy in Singapore primary mathematics teaching. **It is extensively used**

in teaching word problems that require reasoning with fractions, ratios, and percentages. Using this approach, students use rectangular bars to visualize mathematical relationships, facilitating comprehension of abstract quantities. The model method provides a visual framework that supports students' conceptualization of fractions by illustrating the structure of mathematical relationships in word problems. Table 1 illustrates the part-whole and comparison models, the two key relational concepts that underpin the model method.

Table 1: Part-whole model for multiplication and division & multiplicative comparison models (Kho et al., 2014, p. 277)

The following part-whole model represents a whole divided into 3 equal parts:  The model illustrates the concept of multiplication as: One part × Number of parts = Whole	Part-whole model: The total is determined by the multiplication of one part and the number of parts. Conversely, if we know the total and one factor, we can find the other factor through division.
 	Comparison model: The larger quantity is three times the smaller quantity, and conversely, the smaller quantity is one-third of the larger quantity. For example, if the larger quantity represents three units, the smaller quantity represents one unit. Together, they total four units, with a difference of two units between them.

2.2 Unitary Method

Complementing the model method, the unitary approach provides a structured strategy that enables learners to solve problems by first identifying the value of a single unit (part) and then scaling it to determine the value of multiple units (Fong, 1999). Though not included as part of Singapore's official mathematics syllabus, this strategy is often integrated into classroom teaching to support conceptual understanding and problem-solving involving fractions, ratios, proportions, and percentages.

2.3 Structure-Mapping Theory

Structure Mapping Theory (SMT), developed by Gentner (1983), provides a theoretical framework for understanding how learners make sense of new information through analogy and relational reasoning. SMT posits that learners interpret analogies by mapping structural relationships between a familiar base domain and a less familiar target domain. When students are presented with both a flawed and a correct bar model, the **incorrect solution often serves as the** *familiar base domain*, reflecting their intuitive reasoning or prior misconceptions. In contrast, the **correct solution acts as the** *less familiar target domain*, representing a structurally sound, yet less readily grasped, interpretation of the problem. By mapping the relational structure between these two models, students are prompted to **identify correspondences and structural mismatches**, such as misaligned quantities or misinterpreted part-whole relationships. Importantly, this comparison serves not just to reveal errors but to refine reasoning. The process shifts student focus away from surface features to **underlying relationships between parts and wholes**, or between quantities and their units.

2.4 Bruner's Modes of Representations

Bruner's (1966) Theory of Representation frames this study's approach to using bar models as visual tools that support learners in moving from enactive experiences to symbolic reasoning. Positioned within the iconic mode, bar models enable students to visualise mathematical relationships and transition toward formal expressions. Digital interactivity and structured dialogue enhance this progression, illustrating how Bruner's modes interact dynamically in the development of mathematical understanding.

2.5 Vygotsky's Sociocultural Theory

This study draws on **Vygotsky's sociocultural theory** (Vygotsky, 1978), which emphasizes the social nature of learning and the importance of cultural tools in the development of higher mental functions. The theory asserts that cognitive development occurs through **social interaction** and the use of **cultural tools** that mediate thinking.

2.5.1 Zone of Proximal Development (ZPD)

Vygotsky (1978) viewed learning as a fundamentally social process, emphasising the Zone of Proximal Development (ZPD) as the space where learning occurs through guided interaction. The ZPD is the gap between what a learner can do alone and with support, representing the optimal zone for learning through challenge and guidance from a more knowledgeable other (e.g., teacher, peer, or adult). Vygotsky proposed that learning begins through social interaction, with knowledge co-constructed interpersonally, and is later transformed into individual understanding through an "intrapersonal" (p. 131) process of internalization. Children develop understanding by engaging with more knowledgeable others through dialogue, questioning, and feedback. These interactions are not just supportive, they are the very **mechanism of cognitive growth.**

2.5.2 Cultural Tools

Vygotsky highlighted the role of **cultural tools** in shaping cognitive development, emphasizing that learning is not just about acquiring information but about **appropriating the tools of one's culture** to think and reason in new ways. In this study, the **bar model** serves as a **cultural tool** that scaffolds reasoning when introduced, modelled, and practiced within a social context. By representing part-whole, comparison, or unitary relationships, students engage with a shared system that helps them visualize and understand abstract concepts. More importantly, addressing misconceptions through dialogic interaction, questioning, and feedback enabled students to take the lead in their learning process, fostering deeper understanding and critical reasoning.

2.6 Formative Assessment Framework

Black and Wiliam (2009) describe formative assessment as an interactive process in which evidence of student thinking is continuously used to adjust instruction. This approach shifts assessment from end-point evaluation to a tool for shaping learning as it happens, guided by five core strategies:

1. Clarifying learning intentions and criteria for success
2. Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding
3. Providing feedback that moves learners forward
4. Activating students as instructional resources for one another
5. Activating students as the owners of their own learning

This study's design was shaped by Black and Wiliam's framework, with tasks developed to reflect core formative assessment strategies. For example, learning intentions were clarified through word problems that explicitly defined the visual reasoning goal of each task (Strategy 1). Teachers implemented bar model tasks to initiate discussion and uncover students' reasoning by having them construct and analyse visual representations (Strategy 2). The tasks were designed to support student dialogue around bar models, making student reasoning visible for the teacher to respond with appropriate feedback (Strategy 3). The tasks were structured to invite peer critique and collaborative meaning-making with the aim of activating them as learning resources for one another (Strategy 4). Lastly, the opportunity to construct, revise, and interpret their own models supported students in monitoring their own thinking, thus **encouraging ownership of learning** (Strategy 5). Through this alignment, the task design served as both a **diagnostic tool and a learning scaffold**, allowing the teacher to observe conceptual development, adapt instruction, and guide the class toward deeper understanding based on the evidence generated through interaction.

3. Research Questions

This study seeks to examine formative assessment and feedback through digitally supported mathematical experiences. The research questions guiding the study are as follows:

RQ1. In what way can comparison of correct and incorrect solutions be used as a formative assessment strategy to identify students' understanding and misconceptions of mathematical concepts?

RQ2. How does the use of solution comparisons in formative assessment help teachers identify learning needs and inform instructional planning?

4. Methods

4.1 Research Design

This study employed a qualitative research design aimed at exploring how teachers use student comparisons of correct and incorrect solutions as a formative assessment tool to inform task redesign. The focus was on capturing the reasoning processes of teachers as they interpreted student responses and considered instructional adaptations, rather than measuring the direct outcomes of the modified tasks.

4.2 Participants and Context

This study was conducted in a Grade 6 mathematics classroom at a Czech elementary school. The class consisted of 9 students aged 12 with varying levels of proficiency in the target topic, fractions. While the sample size (n = 9) may appear limited, it was selected based on practical considerations, including access to participants and the context of the study. Moreover, given the specific focus of the research, a smaller sample was sufficient to gather rich data that addressed the research objectives. The depth of data collected from these participants provides sufficient grounding for the analytical claims made in the paper. Additionally, although curriculum content may differ across schools, students are generally expected to develop fluency in fractional reasoning by exploring part-whole relationships, performing operations with fractions, and interpreting representations in various forms, including ratios, decimals, and percentages. The researcher also served as the teacher during the intervention. This dual role provided an opportunity for in-situ observation and interaction with students as they engaged with the tasks. Using the Jaccard Index (Real & Vargas, 1996), intercoder agreement was measured at 0.769 (76.9%), indicating substantial agreement (Landis & Koch, 1977). While the teacher-researcher role may have inherent biases, the involvement of independent intercoders ensured that any influence from the teacher's perspective was minimized, supporting the reliability of the coding process.

4.3 Intervention Design

The intervention consisted of a structured teaching sequence (Figure 1) spanning five 45-minute lessons organised into 3 phases. Phase One comprises an orientation session introducing students to the app's bar model interface, which they engaged with interactively to explore concepts, manipulate visual representations, and deepen their understanding of part-whole and comparison relationships. *Student understanding was assessed through a post-session quiz (Quiz 1), during which* the students' on-screen activities were recorded.

Phase Two, incorrect solutions were compiled from the recordings of Quiz 1 using screenshot captures. As part of the side-by-side comparison activity, an incorrect solution was selected and paired with a corresponding valid solution created by the researcher. Both solutions were displayed alongside each other on the class screen to engage students in collaborative analysis and discussion. The observation was documented to capture students' engagement with the comparison task. Figure 2 presents coded excerpts of student dialogue, illustrating the nature of their reasoning and peer interactions.

In the final phase, a second quiz was administered to assess students' learning progression. Digital data from Quiz 1 and Quiz 2 were processed in the Atlas.ti programme using a mixed-methods framework to identify meaningful patterns and support the development and refinement of coding categories.



Figure 1: Research design sequence

4.4 Data Collection and Data Analysis

The dataset analysed in this study was originally collected as part of a classroom-based project (Poh & Jančařík, 2025) (Figure 2). Preliminary quiz data from the first study were used to inform initial coding categories. The initial analysis from that study is currently under review. While the earlier study examined comparison as a strategy for teaching fraction, the same dataset is re-analysed through a different lens to explore comparison as an interpretative framework for formative assessment. A total of approximately 200 minutes of digital data and 45 minutes of recorded sessions were analysed to identify and categorize students' incorrect solutions and misconceptions. The analysis focused on Session 3, where students jointly explored and discussed the bar model solutions displayed in Table 2. Student dialogues and digital interactions were analysed as core data. The analytical process followed an inductive approach guided by partially pre-defined categories (Dey, 1999; Strauss & Corbin, 1990). As a first step, the digital transcripts were categorized by notable episodes that reflected critical instances of reasoning or interaction. As shown in Table 3, the episodes were assigned V-type codes, referring to visual attributes of the bar models and analysed in relation to the strategies reflecting part-whole reasoning, comparison concept and unitary method. These strategies were assigned C-type codes.

Table 3: Visualisation and conceptualisation coding schemes with descriptions

Coding Scheme	Coding Category	Description
		Students referring to...
Code V (Visualisation)	V-RP (partitioning into equal units)	the partitioning on the bar model (BM)
	V-RA (alignment)	the alignment of the partitions on the BM
	V-RSM (size of bar model)	the size (length) of the BM
	V-RS (shaded part)	the shaded part of the BM
	V-RL (labelling of units)	the labelling of units on the BM
		Students coping with the task by...
Code C (Conceptualisation)	C-PW (part-whole reasoning)	exploring part-whole reasoning
	C-C (comparison concept)	using comparison concept
	C-U (unitary method)	using unitary method

Two quizzes were used to track learning: Quiz 1 at the start and Quiz 2 at the end of the study (Figure 3). Statistical analysis showed a positive trend: seven of nine students improved, one remained the same (P2), and one declined slightly (P5). Mean scores increased from 57.1% to 59.6%. A paired t-test confirmed a significant gain (p = 0.033) with a large effect size (Cohen's d = 0.86). These findings suggest a positive impact but should be interpreted with caution due to the small sample size.

T	S/ R	Talk Turn	C-Codes	V-Codes
18	R	What is the difference between the two solutions?		
19	S3	This (RHS)... the two are (the) same long (length), this (LHS) ... (they have) longer and shorter (lengths).	C-C	V-RSM
20	R	Can someone tell me which solution is right and why.		
21	S8	This one (RHS) is right … because … it (the question) is "same amount left".	C-C	V-RSM; V-RS
22	R	Which section of the bar says, "same amount left"?		
23	S8	Here (RHS) ... (the) same length ... (the) first (upper bar) and (the) second (lower bar)	C-C	V-RA; V-RSM; V-RS
24	R	Do you mean the whole length or the blue parts (RHS)?		
25	S3	The blue part (RHS).	C-C	V-RSM; V-RS
26	R	The blue parts (RHS), ok. Why?		

27	S3	(RHS) Because “same amount left”.	C-C	V-RSM; V-RS

32	R	(RHS) So we know all the units are equivalent to $170. We need to find the value of one unit. Why?		
33	S7	(RHS) Find if how many units Maria (has), also Jan and how many units spent and how many units left...everything.	C-U; C-PW; C-C	V-RP; V-RA; V-RL
34	R	(RHS) Yes, if we know the value of one unit, we can calculate all the values. How do we find one unit?		
35	S2	(RHS) $170 divide (by) all the units.	C-U	V-RP

44	R	(RHS) Can you use another way to find the value of one unit? Can you see two units are equivalent to $10?		
45	S2	(RHS) $10 divide (by) 2 is $5...10 units times $5 is $50 ...Oh...	C-U; C-C; C-PW	V-RP
46	R	Ok. This (RHS) does not work out to $170. Let’s look at the other solution (LHS). What’s the difference?		
47	S3	(LHS) First one (upper bar) is longer and under (lower bar) is shorter	C-C	V-RA; V-RSM
48	R	(LHS) That means Maria has more money than Jan. How do we find one unit here?		
49	S2	(LHS) $170 divide (by) all the units.	C-U	V-RP
50	R	(LHS) Can you tell me exactly how many units?		
51	S8	(LHS) 3 units plus 3 units plus 2 units...8 units.	C-U	V-RP;
52	S2	(LHS) And plus $10.	C-C; C-PW	V-RS; V-RA, V-RL
53	S8	(LHS) Ok...$170 divide (by) 8 units plus $10.	C-U; C-C; C-PW	V-RS; V-RA, V-RL

***Legend**: T Turn: S/ R: Student/ Researcher; LHS: Left Hand Side; RHS: Right Hand*

Figure 2: A coded transcript of talk turns during side-by-side comparison of solutions

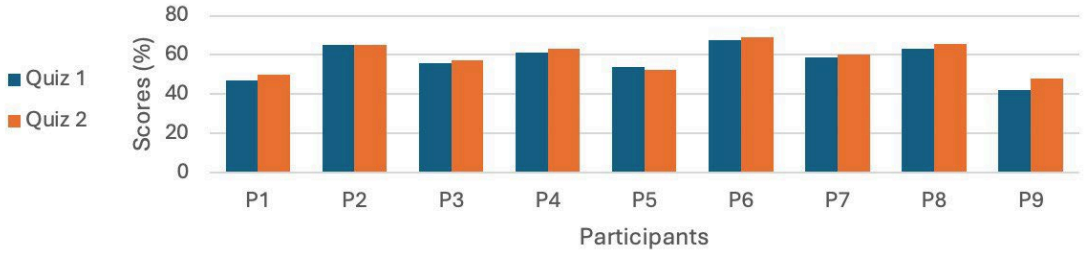
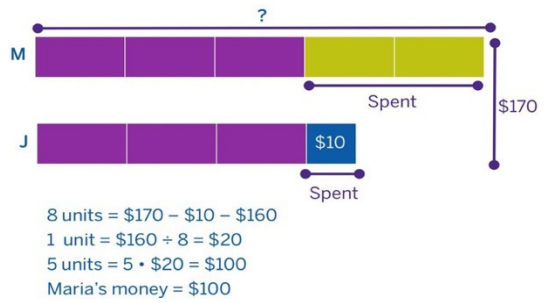
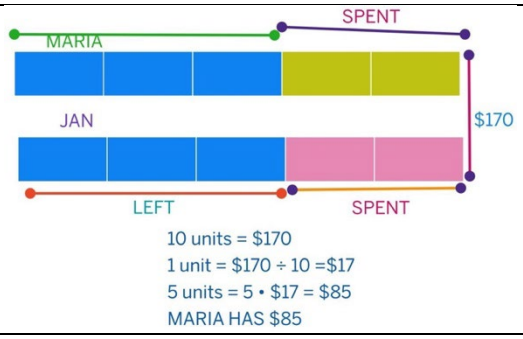


Figure 3: Student Performance (Quiz 1 vs Quiz 2)

5. Results and Implications

The following results emerged from a detailed analysis of qualitative data, supported by quantitative trends where applicable, in response to the guiding research questions.

Table 2: Comparison of valid and incorrect bar model solutions

<table>
<tr><td colspan="2">Maria and Jan have $170 altogether. If Maria spends $\frac{2}{5}$ of her money and Jan spends $10, then they will have the same amount left. How much money does Maria have?</td></tr>
<tr><td>Suggested Solution (LHS)</td><td>Filip's Solution (RHS)</td></tr>
<tr><td> 
</td><td> 
</td></tr>
</table>

***Legend**: LHS: Left Hand Side; RHS: Right Hand Side*

Sections 5.1 and 5.2 provide the basis for insights into RQ1: **In what way can comparison of correct and incorrect solutions be used as a formative assessment strategy to identify students' understanding and misconceptions of mathematical concepts?**

5.1 Use of Visual Representations to Support Comparison, Part-whole and Unitary Reasoning

5.1.1 Reasoning with comparison concept

Students demonstrated awareness of the comparison concept by interpreting visual representations that highlighted differences and relationships between quantities. When comparing amounts in the word problems, students showed an understanding of relational structure by identifying who had more, less, or the same (T19, T21, T23, T25, T27, T47). The comparison concept was evident as the student analysed the initial amounts, expenditures, and remaining quantities for both Maria and Jan, making relational judgments between them (T33, T52, T53).

5.1.2 Interpreting Part-whole Relationship

Part-whole understanding was evident the student's ability to identifying how amounts spent and saved relate to the total amount (T33, T52, T53). This demonstrated an awareness that the whole is composed of distinct but related parts, and that reasoning about either part could be used to infer or verify the whole.

5.1.3 Reasoning with Unitary Structure in Visual Representations

Students demonstrated an understanding of unitary structure through their ability to identify a known total ($170 – $10) associated with a specific number of equal parts (8 parts). From this, they used division to determine the value of a single unit, which they then multiplied by the required number of units to solve the problem (T35, T49, T51, T53). This process reflected flexible reasoning and an ability to navigate between parts and wholes using multiplicative strategies.

5.2 Correction of Error Through Collaborative Discussion

By comparing both correct and incorrect bar model solutions, students were prompted to articulate and justify their reasoning, which exposed misconceptions (T45). Students' capacity to reflect on and revise their reasoning was observed during a task where an initial misunderstanding emerged. The group had misinterpreted the **equal bar lengths** as indicating that *Maria and Jan had the same total amount of money* (T21), rather than recognising that the bars represented the **same amount remaining** after spending. Although they correctly noted that the "blue parts" (T25) of the bar model were equal—representing the money left—the critical distinction between what was *left* versus what was *originally had* was not initially clear. As they engaged in further discussion, the students began to question their initial assumption. This collaborative dialogue involved **justifying their interpretations, recalculating unit values**, and **re-examining the structure** of the model. Their joint reasoning led to the recognition that the original amounts of money could not have been equal, as the amounts spent

were different. This shift in understanding was reflected in their rejection of the initial model and the development of a corrected solution (T27, T33, T35).

5.3 Pedagogical Implications

The collaborative discourse illustrates how student discussion provided a platform for conceptual clarification, enabling them to correct their misconceptions. This highlights the importance of structuring classroom activities that promote collaborative inquiry, where students actively engage in shared problem-solving. Such interactions not only enhance mathematical reasoning but also encourage students to take ownership of their learning, ultimately improving their ability to apply concepts in novel contexts.

5.4 Leveraging Formative Insights for Instructional Design

Section 5.4 provides evidence-based responses to RQ2, addressing how teachers can act on these findings to refine their instructional approaches: How does the use of solution comparisons in formative assessment help teachers identify learning needs and inform instructional planning?

5.4.1 Eliciting Learning Needs Through Student Thinking

One key learning need identified in this task was the misidentification of structural equivalence (T45). Students appeared to confuse which quantity was equal across the two individuals, mistaking equal remainders for equal total amounts and consequently misrepresented this relationship in their bar models. While the visual models were intended to support reasoning (T23, T25, T27, T33), some students relied on surface features such as equal bar lengths, without attending to the relational meaning of the parts and wholes represented (T35, T45, T49, T51).

5.5 Didactic implications

The task highlighted a learning gap, suggesting a deeper issue with representational reasoning, where students may recognise individual quantities but struggle to coordinate them meaningfully within a part-whole structure. Specifically, they need greater support in distinguishing **what is being compared**, for instance, total amounts, amounts spent, or amounts remaining and how these values relate to one another in context.

5.5.1 Informing Pedagogical Practice

To address this learning need, instructions should include tasks that contrast different types of equivalence (e.g., equal totals vs. equal remainders), prompt students to describe key visual features of bar models (Table 3) and explain their reasoning. Peer comparison of alternative models (T45, T47) can help surface misunderstandings and support more accurate interpretations. One effective strategy is to design tasks with intentional ambiguity, requiring students to reason through the specific equivalence and reflect this accurately in their bar model. For example, students might be presented with the following question (Figure 4):

Maria and Jan each spent $\frac{3}{4}$ of their money. Maria had \$80 at first *and* Jan had \$60. *How much money do they have left altogether?*

This example is not a result of the study, but a design decision shaped by insights gathered during classroom observation. It demonstrates how the study's insights are operationalised in practice, bridging empirical observation with pedagogical action. The intended ambiguity in this task lies in the fact that the **same fraction refers to the portion spent**, rather than the total amount or the amount remaining. While both Maria and Jan spent $\frac{3}{4}$ of their money, the actual amounts differ due to their different original totals. This subtle distinction encourages students to think critically about what the bar model represents and reason proportionally, rather than assuming equivalence in absolute terms. Given that many bar model tasks typically emphasize equal totals or equal remainders, students may default to these more familiar interpretations. As a result, they may mistakenly assume that equal bar lengths indicate equal total amounts or remaining values, rather than correctly understanding that same fraction ($\frac{3}{4}$) refers to the portion spent, not identical quantities, as opposed to the previous scenario. This creates a productive tension that encourages deeper reasoning about part-whole relationships and the structure of the problem.

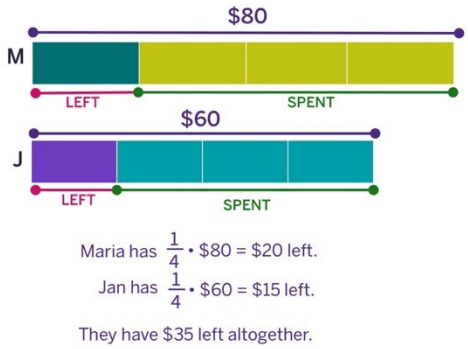


Figure 4: Suggested post-intervention task prompt

6. Discussion

This study offers pedagogical insights that students' constructions revealed both conceptual strengths and common misconceptions. While some students struggled with representation, others used units to reason effectively, highlighting bar models' role in externalising students' thought processes in ways that are accessible to both peers and teachers. Teachers can draw on these insights to inform instructional approaches through visual comparison tasks, suggesting that purposeful task design can target specific conceptual hurdles, including the misidentification of structural equivalence. Although the current implementation was shaped by a specific classroom context, the underlying pedagogical principles, such as using student-generated visual models and structured student discussion within a digitally mediated environment are adaptable to a range of school environments, student backgrounds and prior knowledge. Reflecting on this adaptability can inform efforts to embed such practices into standard classroom routines, supporting scalability without compromising pedagogical integrity.

7. Limitations

As with all research, this study has certain limitations that should be noted. Because the findings were closely tied to the teaching design, students' reasoning was shaped within the structure of the learning activities. This may have constrained the opportunity to observe students' spontaneous application of the concepts. Future studies could adopt a longitudinal approach to examine how sustained use of these technologies affects students' mathematical reasoning over time, including their ability to construct and critique models independently. Additionally, the use of group settings instead of pairs could have altered interaction patterns, possibly affecting the depth of individual engagement. Future studies could investigate whether findings hold across different group structures. Further, while students demonstrated conceptual understanding in discussions, quiz results may reflect technical difficulties with the unfamiliar app rather than actual learning gaps. Alternative assessment methods such as longitudinal observations or performance-based tasks might better capture students' conceptual progress.

8. Conclusion

This study highlights how digital assessment facilitates new forms of engagement for student thinking and reasoning as well as instructional practices and teacher response. When students engage with visual models, their thinking becomes visible in ways that support both learning and teaching. These interactions provide valuable diagnostic insights, helping teachers identify conceptual misunderstandings and deliver targeted instruction. Visual representations also create a platform for meaningful student-led dialogue, where reasoning can be explored collaboratively. Such practices promote deeper mathematical understanding and align with key principles of formative assessment.

Ethics Declaration

Ethical clearance was not required. The study occurred in regular classroom instruction without sensitive data. Responses were anonymised with pseudonyms, and no identifying information about schools or participants is disclosed.

AI Declaration

All content and analyses are the author's own with minor AI-assisted language refinement.

References

Black, P., & Wiliam, D. (2009). Developing the Theory of Formative Assessment. *Educational Assessment, Evaluation and Accountability*, *21*(1), 5–31. https://doi.org/10.1007/s11092-008-9068-5

Bruner, J. S. (1966). *Toward a Theory of Instruction*. Belknap Press of Harvard University.

Dey, I. (1999). *Grounding Grounded Theory : Guidelines for Qualitative Inquiry*. Academic Press.

Drijvers, P., Ball, L., Barzel, B., Heid, M. K., Cao, Y., & Maschietto, M. (2016). Uses of Technology in Lower Secondary Mathematics Education. In *ICME-13 Topical Surveys* (1st ed., pp. 1–34). Springer International Publishing. https://doi.org/10.1007/978-3-319-33666-4

Fong, H. K. (1999). Strategic Models for Solving Ratio and Proportion Problems. *The Mathematics Educator*, *4*(1), 34–51. The NIE Digital Repository. https://repository.nie.edu.sg/entities/publication/ed046a27-97b6-4a42-917d-d01593833aff/details

Gentner, D. (1983). Structure-Mapping: A Theoretical Framework for Analogy. *Cognitive Science*, *7*(2), 155–170. https://doi.org/10.1207/s15516709cog0702_3

Kho, T. H., Yeo, S. M., & Fan, L. (2014). *Model Method in Singapore Primary Mathematics Textbooks*. 29–31. University of Southampton.

Kintsch, W., & Greeno, J. G. (1985). Understanding and solving word arithmetic problems. *Psychological Review*, *92*(1), 109–129. https://doi.org/10.1037/0033-295x.92.1.109

Landis, R. J., & Koch, G. G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics*, *33*(1), 159–174. https://doi.org/10.2307/2529310

Nesher, P., Greeno, J. G., & Riley, M. S. (1982). The Development of Semantic Categories for Addition and Subtraction. *Educational Studies in Mathematics*, *13*(4), 373–394. https://doi.org/10.1007/bf00366618

OECD (2016) Innovating Education and Educating for Innovation*: The Power of Digital Technologies and Skills, Educational Research and Innovation.* OECD Publishing. https://doi.org/10.1787/9789264265097-en

Poh, C., & Jančařík, A., (2025). Side-by-side comparison of bar models as a strategy for teaching fractional relationship in word problems. In: J. Novotná & H. Moraová, *Elementary Mathematics: Building Strong (SEMT 2025),* pp. 352–362.

Real, R., & Vargas, J. M. (1996). The Probabilistic Basis of Jaccard's Index of Similarity. *Systematic Biology*, *45*(3), 380–385. https://doi.org/10.1093/sysbio/45.3.380

Rittle-Johnson, B., Star, J. R., & Durkin, K. (2017). The Power of Comparison in Mathematics Instruction: Experimental Evidence from Classrooms. *Acquisition of Complex Arithmetic Skills and Higher-Order Mathematics Concepts*, 273–295. https://doi.org/10.1016/b978-0-12-805086-6.00012-6

Strauss, A., & Corbin, J. (1990). *Basics of Qualitative Research: Grounded Theory Procedures and Techniques.* Sage

Vygotsky, L. (1978). *Mind in society: The Development of Higher Psychological Processes*. Harvard University Press.

Analysing Virtual Reality Applications in Built Environment Education: A Study of Existing Research

Ockert Pretorius[1] and Herman Myburgh[2]
[1]University of Johannesburg, Department of Urban and Regional Planning, South Africa
[2]University of Johannesburg, Institute for Artificial Intelligence Systems, South Africa

opretorius@uj.ac.za

Abstract: The application of Virtual Reality (VR) in built environment education has wide-ranging potential to enhance experiential learning through simulating accessible real-world scenarios for practical application of classroom concepts and providing a spatial scale for students. Relevant applications may have a transdisciplinary impact, with specific relevance to fields such as engineering, urban planning, and architectural studies. The continued diffusion of VR technology and applications may alter diverse sectoral value chains and production, necessitating educational responses in design, analysis, and management approaches. Evident is the importance of integrating related tools in tertiary education practices to enable the resilience, productivity, and competitiveness of built environment students. However, the lack of existing research restricts the development of best practice that is applicable to the diverse activities of built environment practitioners. This paper aims to investigate the existing body of knowledge to delineate lessons that inform tertiary sector stakeholders on the use of VR to support the development of graduate attributes in the process of teaching and learning. The research methodology applied is centred on a bibliometric review of current research. The VOSviewer (v1.6.20) software is utilized to identify relevant themes and trends among the publications. The latter is sourced from the Scopus database using keywords such as "virtual reality", "built environment", and "education". The most cited papers are also qualitatively analyzed to interpret the findings of the review. Findings indicate that current research themes include the application of VR in education and pedagogy, user perception and experiences in this regard, and informing practical training and decision making toward sustainable development and applied practice. The qualitative content review indicates four categories of VR application in built environment education, including visualisation, participation, and collaboration, knowledge creation and transfer, and an integrated approach. Recommendations include institutions utilizing said findings to inform curriculum transformation, improving student and stakeholder participation, supporting evidence-based teaching.

Keywords: Virtual Reality; Built Environment; Knowledge Transfer; 4IR; Cross-reality Environment.

1. Introduction

Technological advancements, such as Artificial Intelligence (AI), the Internet of Things (IoT), and VR, have the potential to radically transform diverse sectors of society, including tertiary education (Matsika & Zhou, 2021). VR, through facilitating the creation of immersive real-world and imagined virtual environments, may be utilized to support a range of activities relevant to teaching and learning (Campos et al., 2022). This includes experiential learning, student exposure to simulated real-world scenarios, and collaborative content engagement (Dai et al., 2022). This is especially relevant to the disciplines in the built environment, where activities and industries are anchored in a specific spatial context and stakeholders engage and collaborate in complex environments where design, development, and analysis approaches are dynamic and flexible. VR and other emerging technology have already catalyzed related changes in the fields of engineering, urban planning, construction, and architecture (Kim et al., 2013). This underlines the motive for their holistic incorporation in tertiary education pedagogies to support the ongoing competitiveness of built environment students in contributing to practice, policymaking, and academia.

However, there is limited research to guide built environment education stakeholders in terms of possible VR applications in teaching and learning related activities. Current research is limited to context- and discipline-specific use cases and lack a holistic framework that delineates best practice in this regard. This inhibits the systematic integration of this potentially transformative tool into teaching practice. Accordingly, the aim of this paper is to delineate and broadly categorize applications of VR technology in this context. The related research objectives are to analyse existing research on this topic, identify the prominent research themes reflective of potential applications and the way they have changed over time, as well as a detailed investigation of application cases. Identifying and grouping potential VR use cases supports curriculum development and transformation initiatives, while enabling relevant stakeholders and institutions to strategically align teaching practices with emerging technology to support sustained and resilient outcomes. To achieve the research aim, a mixed method research approach is applied in the form of a bibliometric review of existing research on this topic, the findings of which are augmented by a qualitative review of select high impact publications. The structure includes a literature review of VR and education related themes, an overview of the research methodology, a findings and discussion section, followed by the conclusion.

2. Literature Review

The literature review is focused on providing an introductory overview to VR technology, in addition to broadly delineating potential educational applications for technology.

2.1 Introduction to VR Technology

VR is a virtual, computer-generated environment that may be reflective of an existing physical space or a unique digital space (Campos et al., 2022). User immersion and interaction are to core characteristics of VR. The former may be facilitated by wearable technology, including a VR headset, which creates the perception of physical presence in the virtual environment for the user. Interaction, on the other hand, is enabled through controllers and sensors that capture and reflect user movements and decisions within the virtual environment (De Fino et al., 2023). VR may be grouped with other advanced technologies that form part of the Fourth Industrial Revolution (4IR), the application of which has the potential to revolutionize production and consumption processes (Matsika & Zhou, 2021), including AI, IoT, automation, 3-dimentional (3D) printing, and cloud computing. De Amicis et al. (2019:339) delineate certain advantages associated with the use of VR technology within the specific context of education and learning environments, asserting that “dynamic visualizations outperform conventional, static instructional materials”. Student engagement is heightened through “technology-mediated” teaching approaches, reflecting greater motivation and learning satisfaction after use. More information can be incorporated into dynamic virtual environments, while also being able to integrate multimedia content and data visualizations (De Amicis et al., 2019). Students are also exposed to diverse environments that may be “otherwise […] geographically unreachable”, while being able to analyse complex features of virtual sites in intricate detail. Disadvantages to VR use identified by Acevedo et al. (2024), on the other hand, include the high cost of hardware associated with the technology, and significant technical requirements needed to use related hardware and software, as well as creating and curating relevant content. Additional disadvantages include training requirements for first-time VR users for efficient application, uneven knowledge acquisition among users, and doubts regarding the transfer of skills from virtual to physical context (Acevedo et al., 2024).

2.2 Educational Applications for Technology

One aspect where technology may contribute to educational outcomes is knowledge transfer. This includes conveying the core theoretical and conceptual information on a specific theme to students (Jensen & Freeman, 2019), in line with the standards and competencies captured within a curriculum (Sahin, 2018). This is mostly done in a structured manner, where content and learning outcomes are communicated to students within the framework of predetermined objectives (Gunardi & Hartati, 2024). This initial prioritisation of transferring foundational knowledge to students is central to the teaching philosophy of essentialism (Kaminer, 2024). This is the building blocks in students comprehending and engaging with both basic and advanced themes in any discipline. The advantage of first focusing on core knowledge transfer is that it creates a predictable learning environment with clear expectations for the student (Strong et al., 2015). However, this approach may also reinforce “predetermined explanations for human interaction” (Kokkonen et al., 2022:1), which may limit critical thinking and problem-solving on the part of the student.

This highlights the importance of the second area in which technology, including VR, may affect outcomes in education, i.e. knowledge co-creation. In this aspect, as captured in the teaching philosophy of constructivism, students actively participate in knowledge creation through engaging with the taught content and the process of learning (Mimi et al., 2020). This is influenced by the personal context and perspective in which the student interprets the foundational knowledge, including social and cultural milieu. This catalyzes a nuanced and novel investigation of existing knowledge and culminates “learners actively constructing” new knowledge (Tan & Ng, 2021:1). For effective knowledge co-creation, students evaluate and analyse existing knowledge and related data through applying critical thinking (Sigalov & Cohen, 2025). In addition to reflecting on their own experiences, this is also done in collaboration and interaction with others. One advantage of knowledge co-creation is that students engage holistically with existing and new knowledge, while also increasing their social interaction and partnerships with other students (Siddique et al., 2024).

These two aspects, i.e. knowledge transfer and co-creation, form the basis of investigating potential VR applications in built environment education.

3. Research Methodology

To achieve the research objectives, this study applied a mixed method approach. Firstly, this includes a quantitative bibliometric review of research related to VR applications in built environment education. To identity relevant publications, the keywords “virtual reality”, “built environment” and “education” (including “teaching and learning”) were used as source concepts. Research analysed in this regard was limited to those found on the Scopus database due to the quality its indexed papers and ease of extraction from the database (Patel et al., 2023; Huston-Pretorius et al., 2024). The selected publications were limited to book chapters and journal publications due to access and impact considerations. Publication information, including authors, abstracts, keywords, and references, were downloaded from the database in comma-separated values (.csv) format. VOSviewer (v. 1.16.20) software was utilised to undertake the bibliometric review, with specific reference to generating the network and overlay visualisation (Van Eck & Waltman, 2018). The former depicts the primary keywords found in the publications, their linkages with other keywords, and research clusters that group the keywords that are linked to similar publications. This illustrates the prominent research themes among the publications. The overlay visualisation, on the other hand, depicts the average year of publication for each keyword, providing a visual guide on the manner in which research themes have changed over a delineated period.

The second component of the mixed method approach is a qualitative content review of the highest impact publications contained within the bibliometric review (Islam et al., 2021; Huston-Pretorius et al., 2024). Accordingly, the ten papers with the highest number of citations are utilized in this regard. Each full publication is downloaded and thematically analysed to identify the application of VR in its unique context to inform the findings of the paper. Artificial Intelligence (AI) software (i.e. ChatGPT from OpenAI) was utilised to provide an initial scoping of relevant publications. This select information was verified and expanded upon by the author within the delineated parameters of the study and analysis.

4. Findings and Discussion

This section incorporates an analysis of the keywords and publication trends inherent to the delineated research, in addition to the content review of the highest impact publications in line with the research aim and objectives.

4.1 Keywords and Publication Trends

Figure 1 illustrates the network visualisation of the different keywords included in the delineated publications. Related output includes the four prominent research clusters and the linkages between said clusters and individual keywords.

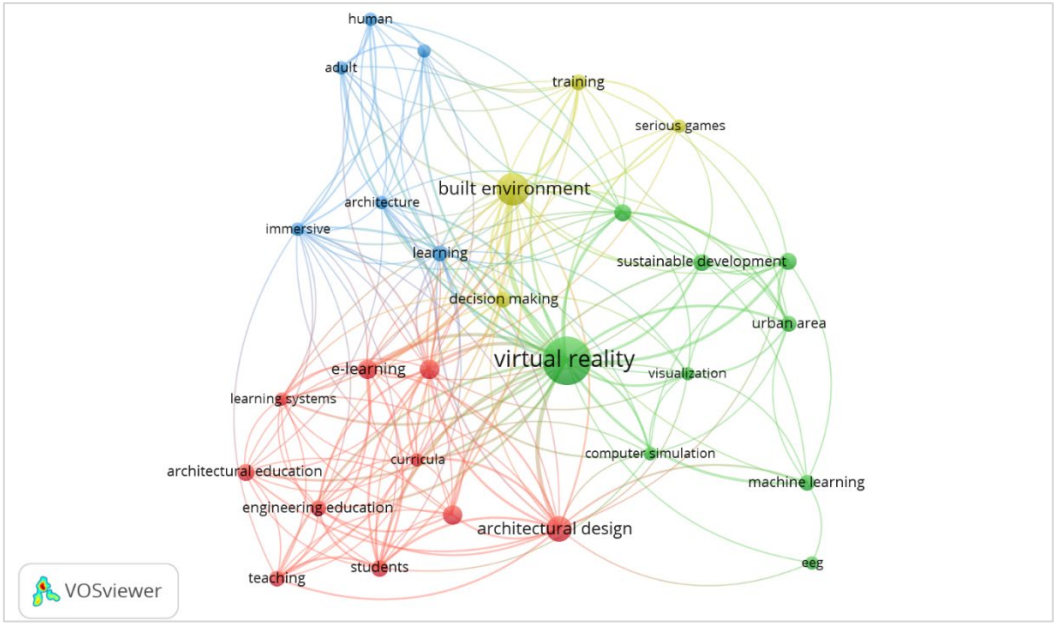


Figure 1: Network visualisation

Source: Authors (2025).

The red cluster captures keywords that are focused on education and pedagogy, with keywords that include *e-learning, learning systems, teaching,* and *curricula.* This may be indicative of the role of VR in formal education and curriculum development, with specific reference to *architectural* and *engineering education*. The green cluster incorporates keywords centred on technology and the urban context. Indicated keywords may indicate the application of VR and associated advanced technology within the specific spatial milieu of the built environment. The blue cluster connects keywords associated with the perceptual and experiential aspects of VR applications. This may be indicative of the connection between VR and engagement, individual learning experiences, and experiential learning. The yellow cluster integrates keywords with themes related to practical training and decision making. This is potentially indicative of the application of VR in professional skills development in diverse contexts. There are also linkages between these clusters and the keywords they represent. The education and pedagogy cluster illustrates significant linkages with the perceptual and experiential themes, potentially connecting VR and educational outcomes through student experiences, learning, and user perception. Another example is the linkages between research on the urban context cluster and practical training and decision making themes, alluding to the potential use of VR in connecting theoretical aspects inherent to sustainable development and applied practice.

Figure 2, on the other hand, illustrates the overlay visualisation.

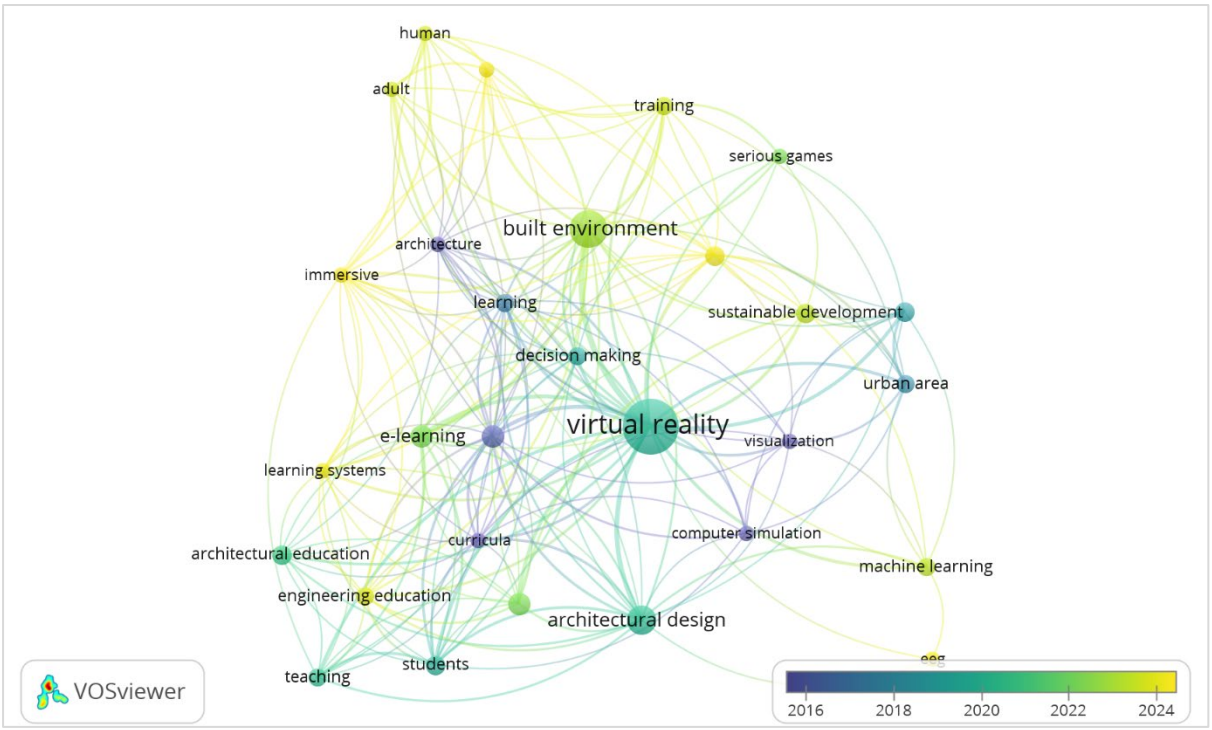


Figure 2: Overlay visualisation

Source: Authors (2025).

As illustrated in Figure 2, the established themes among existing research (published around 2016-2020) include *e-learning, curricula,* and *teaching*, i.e. the keywords predominantly that form part of the education and pedagogy cluster. Publications from 2020-2022 include keywords related to *architectural design, built environment, decision making*, and *visualization*. Emerging themes (2022-2024), on the other hand, are focused on keywords related to *sustainable development, serious games, machine learning, human, immersive,* and *training.* This is potentially indicative that the application of VR has changed from being used predominantly as an instrument in teaching and learning, with specific reference to the disciplines of architecture, engineering, and urban planning, toward a broader application linked to societal imperatives such as sustainability, practical skills development, and decision making. This wider scope is also supported by the emergent research focussed on VR integration with more advanced technology and data analysis (e.g. machine learning).

4.2 Qualitative Review

With reference to the qualitative content review, Table 1 indicates the 10 highest impact publications among the delineated research (in terms of citations). Indicated are the authors, the total citations, the disciplinary focus, and the application context.

Table 1: Ten most cited publications

Author(s)	Citations	Discipline Focus	Application Context
Lovreglio et al., 2021	114	Construction	Safety training
Doyle et al., 1998	110	Urban Planning	Urban modelling
Li et al., 2022	77	Urban Studies	Walkability perception
Pachouri et al., 2024	51	Built Environment	Sustainability
Ito et al., 2024	49	Urban Studies	Perception analysis
Jung et al., 2023	42	Healthcare Design	Hospital environments
Hong et al., 2016	39	Architecture Education	Design projects
De Amicis et al., 2019	26	STEM Education	Data literacy
Harrison et al., 2004	26	Accessibility	Wheelchair accessibility
De Fino et al., 2023	23	Urban Resilience	Disaster training

Source: Authors (2025).

As indicated in Table 1, the disciplinary focus of these publications ranges from construction management, urban planning, and architecture, with application contexts that include safety training, urban design, disaster risk management, and architectural design. The following discussion situates these publications in terms of their contribution in the application of VR in education.

4.2.1 Visualisation, Participation, Collaboration

In this sample, Doyle et al. (1998) provide the earliest investigation on the potential use of VR in education. This is centred on the modelling of virtual urban environments on web-based platforms. Applications include web mapping through 2-dimentional (2D) Geographic Information System (GIS) outputs where users could interact with different geospatial layers. Virtual Reality Modelling Language (VRML) is used to simplistically model urban environments which could be further explored by the user in a 3D format. These virtual worlds could be explored by multiple users using avatars in Virtual Internet Design Arenas, where participants are able to engage in designing and constructing their shared environment through text chat. Applications also included the integration of “photorealistic scenes” of real-world contexts captured by 360-degree photographs (Doyle et al., 1998:145). Interaction with these Virtual Streetscapes “is limited to the original location of the camera”, with users unable to move seamlessly between scenes (Doyle et al., 1998:146). The findings of the paper are directed toward improving planning practice through urban design and development control visualisation and modelling. Doyle et al. (1998:138) underline the participatory and collaborative potential of VR technology with the potential to “aid the decision making process, to democratise the planning process and to assist in the conveyance or dissemination of ideas”. This is applied in the context of innovation in education in related built environment fields. Environmental visualisation is the key contribution of the paper, despite the inherent limitations to the desktop screen-based VR experience. VR as an instrument for visualisation, participation, and collaboration is highlighted in this regard.

4.2.2 Knowledge Creation

Since the publication of Doyle et al. (1998), VR technology has seen significant development. This is illustrated by the use of VR headsets as presented by Li et al. (2022), which creates a sense of spatial presence in the virtual environment enabled by the user’s motor functions (i.e. head and neck movements). This provides a more

realistic and immersive user experience. While the user interface has improved, the virtual environments themselves are generated using similar tools. In the case of Li et al. (2022), users also interact with 360-degree street images, with the objective of analysing their experiences in a virtual urban environment in terms of street walkability. Gauging the user's perception of accessibility, safety, comfort, and pleasurability has the potential to directly inform theory and real-world decision making on "street walkability-oriented neighbourhood design" (Li et al., 2022:18). Increased VR technology and application development and integration may precipitate more nuanced educational outcomes: from the broad potential collaborative potential explained by Doyle et al. (1998), to the spatially targeted, field specific knowledge creation and decision making tool motivated by Li et al. (2022). The latter application is further illustrated in the meta-analysis undertaken by Ito et al. (2024:14), where it is concluded that VR technology enables stakeholders to "design experiments" to inform decision making in an exceedingly specific milieu (e.g. street design). Jung et al. (2023) use VR technology to investigate the neurophysiological response from participants to certain virtual building spaces, providing healthcare facility design insights prior to construction. Furthermore, Harrison et al. (2004) uses VR simulations of buildings to investigate wheelchair accessibility. One factor underlying this significant potential is the technology's effective simulation of real-world contexts that overcome the "limitations [of environmental audits] in terms of cost, time, and measurement scale" (Li et al., 2022:3).

4.2.3 Knowledge Transfer

VR applications may also support knowledge transfer within broad built environment contexts. De Fino et al. (2023) utilise VR headsets to immerse users in virtual training scenarios. This simulates hazardous situations in urban environments linked to disaster risks, including earthquakes and heat waves. Users are required to navigate said conditions and make appropriate risk-mitigating safety choices. This application, called a Virtual Reality-Serious Game (VR-SG), provides immediate corrective feedback on the validity of user input and decisions, allowing for step-by-step guidance to participants to increase their in-game and real-world awareness and preparedness to related scenarios. To enable active decision making, additional technology in the form of gesture controllers is required (De Fino et al., 2023). This training incorporates a "modular structure of self-contained learning units" to guide active knowledge transfer that is "engaging and authentic", as well as "scalable and flexible" to different disciplines (De Fino et al., 2023:9-10). This application presents a technical education tool that provides information from different contexts, while also effectively communicating strategies and influencing behaviour in line with broad objectives. A similar VR application is presented by Lovreglio et al. (2021), where simulations provide fire extinguishing training in different built environments. VR-enabled immersive knowledge transfer has catalysed "a significant increment […] of knowledge acquisition [and] retention", indicating its educational value (Lovreglio et al. (2021:143). This application integrates an additional technology, i.e. sensors, to track headset and handheld controller movement.

4.2.4 Integrated Approach

Nuanced VR applications may also bridge the gap between knowledge creation and knowledge transfer, combining immersive educational experiences with data generation that provide the user with new insights. This is highlighted by the case study of Hong et al. (2016:2), in which students use VR to investigate how spatial design features affect virtual users ("VUsers") in a simulated built environment. This includes analysing human-environment interaction such as pedestrian movement through walkways. This enables real-time testing of the effects of different design approaches and elements, which supports evidence-based design and bridging theory and practice in this regard. This is done through screen-based simulations, rather than being experienced through VR headsets (Hong et al., 2016).

Furthermore, Pachouri et al., (2024) state successful use of VR technology and applications in the long term require holistic integration with other advanced technology, including Artificial Intelligence (AI), the Internet of Things (IoT), and digital twins. Accordingly, "to accomplish real-time analysis and give useful information" to be applied within a specific built environment context, "the data collected from multiple sources such as sensors, cameras, LIDAR and AR/VR has to be processed more quickly" (Pachouri et al., 2024:7). This will strengthen the existing visualisation, simulation, and communication capabilities of VR, while expanding the knowledge creating and transfer capabilities. De Amicis et al. (2019) provides an example application of holistic VR integration in this regard. VR headsets are used to visualise digital twins of urban features, enabling users to interact with said features in the real world while accessing and projecting supplementary sensor data (e.g. building heat) through augmented reality (AR) to enhance insights. This constitutes "cross-reality environments" (XR) (Amicis et al., 2019:331), where the interface between the virtual and the physical built environment "are combined with

sonified and visual data to create a more immersive environment for data analysis and exploration". Through its ability to combine the real and virtual world, supplemented by visualised real-time data, XR represents an advanced VR application that may support educational, practical, and policymaking outcomes. It integrates VR into a more holistic approach to built environment and data visualisation and analysis which fosters collaboration, participation, and knowledge creation and transfer.

5. Conclusion

This paper aimed to delineate and categorize potential applications of VR technology in the context of built environment education. Prominent research themes, as per the findings of the quantitative bibliometric review, include the application of VR in education and pedagogy, also with consideration of the urban context, investigating user perceptions and experiences, and informing practical training and decision making toward sustainable development and applied practice. The latter constitutes the emergent application of VR from its initial focus as a teaching and learning tool. The findings of the qualitative content analysis indicate that there are four potential areas of VR application in education. Firstly, *visualisation, participation, and collaboration* focus on engagement and communication through 2D (screen) or 3D (VR headset) visualisation of virtual built environments, which enables participatory and collaborative learning. Another application is *knowledge creation*, which enables novel research through user interaction with virtual environments via immersive VR headsets and real-time data analysis. This may inform decision making on diverse fronts, including theory and practice. VR may contribute to *knowledge transfer* where the focus is on training and skills development. This may be achieved through VR simulations and more advanced user interaction through sensors and gesture control. Continuous and real-time corrective feedback to the user is one way of transferring related knowledge. VR applications also include an integrated approach, where VR is combined with other advanced technology, including AR, machine learning, and digital twins, where users are able to interact, visualize, and analyse data in real-time, while being immersed in both a virtual and physical reality (XR). This has the potential to support diverse theoretical, practice, and policy outcomes, and bridges knowledge transfer and creation.

Evidently, VR applications range from basic screen-based visualizations to fully immersive and integrated platforms applicable to education and other sectors. This ought to be used in built environment education to guide curriculum development and transformation, while positioning institutions are the forefront of 4IR, the Scholarship of Teaching and Learning (SoTL), and sustainable education initiatives. VR applications ought to be applied to improve student and other stakeholder participation in built environment education, while supporting research-lead and evidence-based teaching where students interact with data and evaluating diverse planning and design interventions. Transdisciplinary collaboration is required for the development of advanced cross-reality (XR) environments. This would enable diverse built environment education stakeholders in engineering, urban planning, architecture, and construction, among others, to collaborate in the development of virtual environments that are meaningful on a technical, pedagogical, and contextual level. Institutions ought to also be capacitated to overcome potential challenges associated with VR application in teaching and learning, including high costs, technical and training requirements, transferability of skills, and potential uneven knowledge acquisition by students.

Limitations to the study include its focus on Scopus-indexed publications at the exclusion of papers in other journals and databases, in addition to the qualitative content analysis being centred on the highest impact publication at the exclusion of lower cited papers. Future research ought to focus on discipline-specific applications of VR technology and investigating the nuanced perspectives of teachers and students on the use of said technology within the education aspects delineated in this paper.

Ethics Declaration

No ethics clearance is required for this secondary data research.

AI Declaration

AI software (i.e. ChatGPT from OpenAI) was utilised to provide an initial scoping of relevant publications. This select information was verified and expanded upon by the author.

References

Acevedo, P., Magana, A.J., Benes, B. and Mousas, C. (2024) 'A systematic review of immersive virtual reality in STEM education: advantages and disadvantages on learning and user experience', *IEEE Access*, 12, pp. 189359-189386.

Campos, E., Hidrogo, I. and Zavala, G. (2022) 'Impact of virtual reality use on the teaching and learning of vectors', *Frontiers in Education*, 7, pp. 1-15.

Dai, C., Ke., F., Dai., Z. and Pachman, M. (2022) 'Improving teaching practices via virtual reality-supported simulation-based learning: Scenario design and the duration of implementation', *British Journal of Educational Technology*, 54, pp. 836-856.

De Amicis, R., Riggio, M., Badr, A.S., Fick, J., Sanchez, C.A. and Prather, E.A. (2019) 'Cross-reality environments in smart buildings to advance STEM cyberlearning*', International Journal on Interactive Design and Manufacturing*, 13, pp. 331-348.

De Fino, M. Tavolare, R., Bernardini, G. and Quagliarini, E. (2023) 'Boosting urban community resilience to multi-hazard scenarios in open spaces: A virtual reality – serious game training prototype for heat wave protection and earthquake response', *Sustainable Cities and Society*, 99, pp. 1-14.

Doyle, S., Dodge, M. and Smith, A. (1998) 'The potential of web-based mapping and virtual reality technologies for modelling urban environments', *Computers, Environment and Urban System*, 22(2), pp. 137-155.

Gunardi, A. and Hartati, S. (2024) 'Essentialist educational philosophy (doctrine and its influence in the context of modern education', *Journal of Innovation in Teaching and Instructional Media*, 4(3), pp. 179-188.

Harrison, C.S., Grant, M. and Conway, B.A. (2004) 'Haptic interfaces for wheelchair navigation in the built environment', 13(5), pp. 520-534.

Hong, S.W., Schaumann, D. and Kalay, Y.E. (2016) 'Human behavior simulation in architectural design projects: An observational study in academic discourse', *Computers, Environment and Urban Systems*, 60, pp. 1-11.

Huston-Pretorius, Engelbrecht, C. and Pretorius, O.R. (2024) 'Curriculum transformation in South African tertiary institutions: Current research on narratives of change', in Proceedings of the 1st International Conference on Education Research, Cape Town, November 2024, pp. 91-99.

Islam, A., Hassini, S. and El-Dakhakhni, W. (2021) 'A systematic bibliometric review of optimization and resilience within low impact development stormwater management practices', *Journal of Hydrology*, 599, pp. 1-18.

Ito, K., Kang, Y., Zhang, Y., Zhang, F. and Biljecki, F. (2024) 'Understanding urban perception with visual data: A systematic review', *Cities*, 152, pp. 1-30.

Jensen, D. and Freeman, S. (2019) 'Stepping to center stage: the rise of higher education as a field of study', *The Journal of Educational Foundations*, 32(1-4), pp. 24-48.

Jung, D., Kim, D.I. and Kim, N. (2023) 'Bringing nature into hospital architecture: Machine learning-based EEG analysis of biophilia effect in virtual reality', *Journal of Environmental Psychology*, 89, pp. 1-16.

Kaminer, T. (2024) 'The subjugation to contingency: Popper, postructuralism, and fear of the plan', *Planning Perspectives*, pp. 1-19.

Kim, M.J., Wang, X., Love, P.E., Li, H. and Kang, S.C. (2013) 'Virtual reality for the built environment: a critical review of recent advances', *Journal of Information Technology in Construction*, 18(14), pp. 279-305.

Kokkonen, L., Jager, R., Frame, A. and Raappana, M. (2022) 'Overcoming essentialism? Students' reflections on learning intercultural communication online', *Education Sciences*, 12(579), pp. 1-17.

Li, Y., Yabuki, N. and Fukuda, T. (2022) 'Measuring visual walkability perception using panoramic street view images, virtual reality, and deep learning', *Sustainable Cities and Society*, 86, pp. 1-18.

Lovreglio, R., Duan, X., Rahouti, A., Phipps, R. and Nilsson, D. (2021) 'Comparing the effectiveness of fire extinguisher virtual reality and video training', *Virtual Reality*, 25, pp. 133-145.

Matsika, C. and Zhou, M. (2021) 'Factors affecting the adoption and use of AVR technology in higher and tertiary education', *Technology in Society*, 67, pp. 1-12.

Mimi, A., Terver, A. and Avaan, W.I. (2020) 'Towards enhancing the teaching and learning of participatory theatre: perspectives from the constructivist approach', *Journal of Education Management*, 2(1), pp. 157-165.

OpenAI. (2025) 'ChatGPT'. Available at: https://chatgpt.com/ (Accessed: 10 September 2025).

Pachouri, V., Singh, R., Gehlot, A., Pandey, S., Akram, S.V. and Abbas, M. (2024) 'Empowering sustainability in the built environment: A technological Lens on industry 4.0 Enablers', *Technology in Society*, 76, pp. 1-18.

Patel, A. K., Singh, M., Singh, K., Patel, A. K., Varma, A. K. and Kuri, R. (2021) 'Visualizing publication trends in Webology Journal: a bibliometric review based on the SCOPUS database (2006-2020)', *Library Philosophy and Practice (ejournal),* 5995, pp. 1-24.

Sahin, M. (2018) 'Essentialism in philosophy, psychology, education, social and scientific scopes', *Journal of Innovation in Psychology, Education and Didactics*, 22(2), pp. 193-204.

Siddique, M., Jabeen, R. and Bhutto, A. (2024) 'Interdependence of critical thinking and active participation in constructivist learning for public secondary students', *International Journal of Trends and Innovations in Business & Social Sciences*, 2(3), pp. 423-432.

Sigalov, S.E. and Cohen, A. (2025) 'Leveraging Wikipedia for educational innovation: a higher education course model for enhancing students' competencies and collaborative knowledge creation*', International Journal of Educational Technology in Higher Education*, 22(27), pp. 1-28.

Strong, A.C., Watson, M.K. and Llewellyn, D.C. (2015) 'What makes an undergraduate course impactful? An examination of students' perceptions of instructional environments', in Proceedings of the American Society for Engineering Education (ASEE) Annual Conference & Exposition, Seatle, Washington, June 2025.

Tan, C. and Ng, C.S.L. (2021) 'Constructivism in education'. Available at: https://oxfordre.com/education/display/10.1093/acrefore/9780190264093.001.0001/acrefore-9780190264093-e-92 (Accessed: 03 June 2025).

Van Eck, N.J. and Waltman, L. (2018) 'VOSviewer manual'. Available at: https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.8.pdf (Accessed: 10 September 2025).

The PCC Model in Online Teaching: A Framework for Effective Practice

Md Mizanur Rahman
School of Engineering & Computing, Regent College London, London, UK

mohammadm.rahman@rcl.ac.uk

Abstract: Numerous online teaching models exist, each offering distinct pedagogical strengths and implementation challenges. The PCC (Preparation, Collaboration and Consolidation) model, rooted in the flipped learning approach, is a widely adopted online teaching model in higher education that promotes active learning, collaborative knowledge construction, reflective practice, self-regulated learning and peer engagement. Despite its strengths, the PCC model faces several challenges such as limited digital-pedagogical expertise among lecturers, time constraints for course design, and insufficient institutional support. Furthermore, the lack of a clearly defined implementation framework and ambiguous around stakeholder roles hinder its effectiveness and scalability. This study undertakes a comprehensive review of the PCC model alongside other established online teaching models, including flipped learning, blended learning, and MOOC-based learning, highlighting their pedagogical foundations, common challenges and evaluation gaps. Drawing on this analysis, it proposes a structured, practice-oriented actionable implementation framework designed to address current limitations. The framework introduces a four-stage lifecycle - Planning, Development, Delivery and Feedback & Refinement, supported by clearly articulated stakeholder roles, mechanism for student engagement, and specific metrics aligned with each stage of the PCC model. Comparative analysis across these models demonstrates that the proposed implementation framework advances beyond the existing approaches by offering a systematic pathway for adoption that strengthens stakeholder collaboration and student engagement, improves scalability, and enhances learning outcomes. In addition, the framework incorporates emerging innovations and techniques, including adaptive platforms, AI-driven feedback systems and collaborative technologies. These advancements are shown to increase learner interaction, foster continuous improvement and support sustainable adoption in resource-constrained contexts. By aligning pedagogical design with institutional structures and technological opportunities, this study highlights how the PCC model can contribute significantly to online teaching through systematic and structured implementation. The study contributes both theoretically and practically: it clarifies how the PCC model fits within contemporary online teaching theories and provides step-by-step guidance for educators, instructional designers and institutional leaders to implement it effectively and achieve measurable benefits.

Keywords: PCC Model, PCC Implementation Framework, Online Teaching Models, PCC Implementation Lifecycle, Flipped Learning, Active Learning

1. Introduction

Since COVID 19, the demand for online teaching has increased significantly. Nowadays, most of the training providers, particularly Higher Education (HE) institutions and a growing number of learners prefer online mode of study. Recent statistics clearly indicate that the popularity of online learning is increasing due to flexibility, adaptability, convergence and broad accessibility. Peck (2025) showed that 63% of the learners choose online learning, while NCES (2025) and Austin (2025) reported that 73% of the learners prefer online learning over in-person classes.

Online teaching benefits both learners and institutions. Learners save travel time and money, and can manage home responsibilities, and access rich digital resources at their own pace, supporting diverse learning preferences and self-directed learning (Joosten et al., 2019). For institutions, it reduces pressure on physical resources and streamline administrative processes such as automated attendance capturing and course management. However, online teaching differs from face-to-face delivery and requires specific pedagogical approaches, and teaching models, methods, techniques and tools. Lecturers who are unfamiliar with online specific strategies or unprepared for course design may compromise learning quality. Multi-country surveys show that nearly half of the university lecturers face challenges due to insufficient digital-pedagogical skills, time constraints, and minimal institutional support (Jisc, 2023), leading to poorly structured lessons, inaccessible materials, or inadequate assessment and feedback.

Choosing an appropriate teaching model for online teaching can be both a strategic and institutional decision. Successful implementation requires coordinated institutional support, along with adequate resources and facilities, to help lecturers integrate the model effectively into online lessons and achieve learning goals. The Preparation, Collaboration and Consolidation (PCC) model is one of the most popular online teaching models, building on the structure of the widely adopted flipped learning or flipped classroom approach. The model begins with learners' individual preparation, moves to collaborative work and ends with reflection. The

structured approach to online HE courses, encompassing phases of PCC model, addresses some of the limitations of the earlier models by promoting active engagement and deeper learning (Evanick, 2024).

The PCC model in online HE promotes active, collaborative learning, reflective practice, and peer engagement. It supports learners' structured progression, aligning with cognitive development and social constructivist principles, and enhances motivation and understanding (Kerimbayev et al., 2023). Benefits diminish if learners skip preparatory activities or collaborative tools are not strategically integrated.

This paper reviews established and emerging online teaching models, specially flipped learning, the PCC model, blended learning and MOOC(Massive Open Online Courses)-based learning models, to explore their role in enhancing course delivery and quality, as well as raising awareness among lecturers, learners and institutions of the requirements for effective online courses. Following the introduction, the paper is organized into five sections. Section 2 reviews literature on online teaching models and strategies, with particular attention to the flipped learning and the existing PCC model, as well as their implementation and evaluation challenges. Section 3 proposes a PCC implementation framework these challenges. Section 4 discusses emerging innovation and techniques to enhance the PCC model, Section 5 presents a comparative analysis and potential benefits, and Section 6 discusses how the proposed framework addresses gaps identified in the literature, evaluates its performance, and concludes the paper.

2. Literature Review

There is no single, universally accepted blueprint or framework for effective online teaching, though traditional face-to-face or classroom teaching is well established and supported by well-established pedagogical frameworks. As a result, online teaching may suffer from poor design and fragmented implementation. According to Rasheed et al. (2020) due to poor instructional design, inadequate technical infrastructure, or lecturers limited digital competence, learners are more likely to experience low engagement and academic achievement, and high dissatisfaction.

In the context of online teaching, teaching models, strategies, and techniques play crucial roles in shaping effective learning experiences. Teaching models—such as flipped learning, blended learning, hybrid delivery, and problem-based learning (PBL)—provide structured frameworks that guide the overall design and organisation of online courses (Bonk and Graham, 2020). Teaching strategies refer to the specific methods used within these models to facilitate learning, including gamification, asynchronous discussions, interactive multimedia, and personalised feedback (Martin & Bolliger, 2023; Huang et al., 2021). Teaching techniques are the actions or tools employed to implement teaching strategies in practice – such as using breakout rooms for groupwork and integrating quizzes for formative assessment (Killen, 2016). Each teaching model, strategy and technique brings its own set of pedagogical strengths and implementation challenges. This literature review examines the effectiveness, benefits and challenges of widely established online teaching model, PCC, and the strategies and techniques aligned with the model.

The flipped learning or flipped classroom approach is widely recognised as one of the most useful and empirically supported online teaching models. It comprises two mandatory components – Pre-Class (Asynchronous) and Live Class (Synchronous) focusing on active learning, and an optional Post-Class or extension component. A comprehensive meta-analysis of 198 tertiary-level studies reported that the model has a moderate positive effect on learner performance (Zou et al., 2020). Furthermore, a 2023 Bayesian meta-analysis of 26 HE studies reported an even larger overall positive effect on learning outcomes using pre-class video systematically with interactive in-class activities (Chen et al., 2023). However, the effectiveness of the model merely depends on meticulous content design, selection of pre-class learning materials (such as videos or readings), and the development of high quality active-learning components (Gutiérrez-González et al., 2024; Rasheed et al., 2020).

Despite its strengths, the flipped classroom model lacks a structured mechanism for post-class consolidation, which is treated as optional. This can limit opportunities for deeper reflection, revision and long-term knowledge retention, particularly in online teaching where learners may often need additional support or scaffolding approach. The PCC model is an extension of the flipped classroom model, with the addition of structured consolidation component, which addresses the weaknesses of the flipped learning model (Zainuddin and Halili, 2016). Predominantly applied within HE contexts, the PCC model aims to design fully online courses using research-based learning principles.

The PCC model is increasingly recognised for its alignment with three key educational psychology principles - Constructivism, Vygotsky’s Zone of Proximal Development (ZPD), and Bloom’s Taxonomy, and this alignment

attracts educators for effective online learning environments. The PCC model supports learners in building their knowledge and confidence through a structured process of progressive and active engagement from preparation to consolidation via collaboration components (Bruner, 1996). In the preparation stage, learners engage with the instructional content independently, building initial mental models, which are then expanded and refined in the collaboration stage through social negotiation or discussion – a core process of constructive learning (Kerimbayev, Umirzakova & Shadiev et al., 2023). The model also supports Vygotsky's Zone of Proximal Development (ZPD), particularly during collaborative activities where learners go beyond their individual capacity through scaffolding learning opportunities such as guided discussion with the help of knowledgeable peers or lecturers to narrow the ZPD gap (Mwale & Mumba, 2024; Raslan, 2024). The sequential design of the PCC model aligns with Bloom's revised Taxonomy by scaffolding learning across cognitive levels: the preparation stage facilitates lower-order cognitive skills of remembering and understanding; the collaborative stage encourages learners to apply and analyse knowledge in interactive contexts; and the consolidation stage supports higher ordering thinking through evaluation, synthesis and reflective practices (Heller, 2022).

Though three-stages of a structured approach such as PCC model are suitable for online courses, they require high instructional planning and tight coordination across all three stages, which can be resource-intensive and time-consuming for lecturers (Baig & Yadegaridehkordi, 2023). The model relies heavily on pre-class or preparation stage, which may pose consistent risks and limit its effectiveness if not adequately supported. For example, if learners fail to engage with preparation or pre-class materials before live sessions, the effectiveness of other two stages – collaboration and consolidation can be severely diminished (Peng et al., 2025). For large online cohorts, maintaining the consolidation or post-class stage through reflection or revision activities may be challenging (Suraworachet, Zhou & Cukurova, 2022). Consequently, although the PCC model demonstrates strong theoretical and practical potential, its success merely depends on learner commitment (e.g., completing pre-class activities before starting live sessions), management support and lecturer effectiveness (e.g., using productive and interactive teaching materials to engage learners and completing consolidation stage well at the end), otherwise it would be hard to apply effectively in all online courses.

One of the challenges in effectively implementing the PCC model in HE is the lack of well-defined metrics or indicators to evaluate success at each stage, which hinders the measurement and evaluation gaps (Hainz et al., 2021). The study by Geary et al. (2023) examined how institutions attempt to introduce new programs using the PCC model and how effectively those programs were implemented. The study found that institutions do not track how well lecturers and learners collaborate, which aspects or stages are effective or need improvement, and what factors may put that success at risk. Without such measures or well-defined metrics, the PCC model may sometimes be ineffective in an online teaching environment.

Implementing the three interrelated stages of the PCC model can sometimes be challenging for institutions and may pose risks. The preparation stage requires all stakeholders, including learners and management should have sufficient prior knowledge over the model. Studies reported that when learners complete their preparatory work, subsequent teamwork becomes both deeper and durable (Song et al., 2025). The model needs institutional investment in orientation resources and digital scaffolding; without strategic support and adequate funding, the process may be significantly disruptive (Bryant et al., 2023). During the collaboration stage, lecturers face the heaviest workload as they need more time for planning and content development, which accelerates tensions between teaching, research and service obligations (Demir, Czerniak & Hart, 2013). Zach and Avugos (2024) identified time pressure and uneven resource allocation as primary technical barriers to sustained collaborative practice, while Hora (2016) showed that such constraints lead lecturers to take shortcuts instead of undertaking time-consuming full redesigns. The consolidation stage is easily and often underestimated and overlooked, even though it is very crucial to achieving high potential and mastery of the subject (University of Melbourne, 2024). Across all three stages, successful implementation of the PCC model depends on a robust collaborative infrastructure. Early planning and activity-tracking mechanisms are essential to keep multiple stakeholders aligned and engaged (Svensson et al., 2021).

The rapid expansion of online and blended learning has intensified the demand for pedagogical approaches that effectively blend teaching, social and cognitive presences to enhance engagement and achievement. Established models such as flipped learning and existing PCC, offer benefits for engagement and achievement but have numerous limitations. Existing studies (e.g., Geary et al., 2023; Hainz et al., 2021; Rasheed et al., 2020) emphasize conceptual strength of these models but lack operational guidelines and fail to provide actionable, stage-specific evaluation metrics. In addition, these models highlight practical barriers—such as technological, pedagogical, and organizational constraints that hinder scalable implementation, such as limited digital resources, inadequate institutional support (Dziuban et al., 2018).

Recent studies also emphasize that most online teaching models, including flipped learning, the existing PCC, blended learning and MOOC-based approaches, face persistent challenges such as low student motivation and engagement, limited interaction, lack of immediate feedback, and unequal digital access. For example, Celik et al. (2023) highlight how the COVID-19 pandemic exposed these weaknesses in HE and argue that without management support, even established models struggle to achieve consistent outcomes. Similar concerns are reported by Mizza et al. (2025) regarding blended learning approaches, noting that inconsistent institutional support and limited digital competence among lecturers reduces effectiveness. Other popular online models, such as MOOC-based online learning, also suffer from high dropout rates and low learner commitment due to minimum interaction and inadequate scaffolding (Celik et al., 2023; Sosa-Díaz et al., 2025). These challenges clearly indicate that sustainable online teaching requires more than sound pedagogical design; it also demands clearly defined stakeholder roles, strong institutional support, and the integration of adaptive innovations.

In my recent observation within a HE context where the PCC model is implemented, I found that nearly half of the learners demonstrated limited awareness and understanding of the model itself or had not engaged in preparatory activities. They often reported their limited awareness of the PCC model due to their busyness for other commitments, lack of role models, and insufficient dialogue about the model within academic setting (Almansour & Almoayad, 2024). A recent study by Chase (2023) surveyed learners to assess their preparedness, behaviours, attitudes and expectation regarding teacher-learner collaboration and revealed that many learners lacked awareness of collaborative frameworks and focused to actively introduce and articulate such models to the learners by the lecturers. Collectively, these gaps indicate that for effective online teaching, institutions need an actionable framework that integrates stakeholder roles, implementation stages, evaluation metrics, and institutional readiness.

3. An Implementation Framework for the PCC Model

To overcome challenges and issues and address the need for a metric to evaluate the success of each stage of the PCC model, as identified in the literature review (e.g., Geary et al., 2023; Hainz et al., 2021; Rasheed et al., 2020), this paper proposes an actionable implementation framework as a strategic solution. The framework focuses on coordinated stakeholder engagement, structured implementation cycles, and stage-specific metrics to support continuous improvement and scalability, aligning and integrating teaching, social, and cognitive presences (Edumadze & Govender, 2024). The proposed framework comprises three key components, as shown in Figure 1: **Stakeholder involvement**, **Implementation lifecycle**, and **Monitoring & Evaluation**. Among these, the Implementation lifecycle is central, guiding the process through four iterative cycles—**Planning, Development, Delivery, and Review & Refinement**—that ensure continuous improvement and effective execution of the existing PCC model.

The PCC implementation framework was developed through a combination of recent literature review, reflection observation of PCC model applied in several online degree and masters courses at Regent College London, and consultations with colleagues and students. Observations of student behaviours, performance and institutional challenges helped determine the implementation guidelines for each stage of the framework, clarify the roles of management, lecturers and students and establish metrics to measure student success. During the development of the framework, an iterative development process was applied to ensure that it aligns with practical online teaching, addresses common gaps identified in several models discussed in the literature, and adapts to diverse online learning contexts.

- **Stakeholder involvement** – Learners, lecturers and management, including support and administrative staff should be working together to implement the existing PCC model.
    - **Senior management** - should formally recognize the PCC model as the default pedagogical design for online courses. They should allocate adequate resources for staff workload relief, ensure access to instructional design expertise, provide necessary digital tools, and support staff training and development structures.
    - **Learners** - must be oriented to the model through early engagement or inductions, onboarding materials and sessions, and clear expectation-setting. Low-stakes familiarization tasks can help learners build confidence, reduce anxiety and better understand the learning model. For example, learners are expected to complete preparatory activities (such as watching videos or completing quizzes) before starting live sessions, actively participate in collaborative activities and engage with consolidation activities to reinforce their understanding of the subject to be taught.

- **Lecturers** - need adequate time and access to appropriate tools to prepare content aligning with each stage of the PCC model. They are responsible for facilitating collaborative tasks and integrating meaningful consolidation activities to reinforce learning. Lecturers should be well prepared to implement the model by following proposed implementation lifecycle and playing crucial role in monitoring and evaluating learners' performance throughout the implementation process.
- **Other staff** – roles of other staffs such as support and administrative are essential in ensuring the technical, scheduling, supporting and communication infrastructure needed to successfully implement and sustain the PCC implementation lifecycle.

- **Implementation lifecycle** – The PCC implementation framework follows a four-step iterative cycle, applicable at the lesson, module and program level. The implementation lifecycle can be applied by the lecturers several times if needed across teaching weeks or adjusted based on feedback.
  1. **Planning** – Lecturers should identify module objectives and align them with the original three stages of the PCC model - Preparation, Collaboration and Consolidation.
  2. **Development** – Lecturers should design specific activities and select appropriate tools (e.g., Edpuzzle, discussion forums, Flipgrid and Breakout rooms) to develop lesson content in alignment with the original PCC model.
  3. **Delivery** – Lecturers should deliver live sessions that enable learners to engage in collaborative activities, both synchronously (during live sessions) and asynchronously (outside of live sessions). Emerging innovations and techniques – such as those discussed in Section 4 – can be applied during this cycle to enhance the delivery experience.
  4. **Feedback & Refinement** - Lecturers should analyze feedback and learn analytics to evaluate the effectiveness of the implementation lifecycle, then revise and enhance course content, activities and delivery methods to improve implementation of the PCC model.

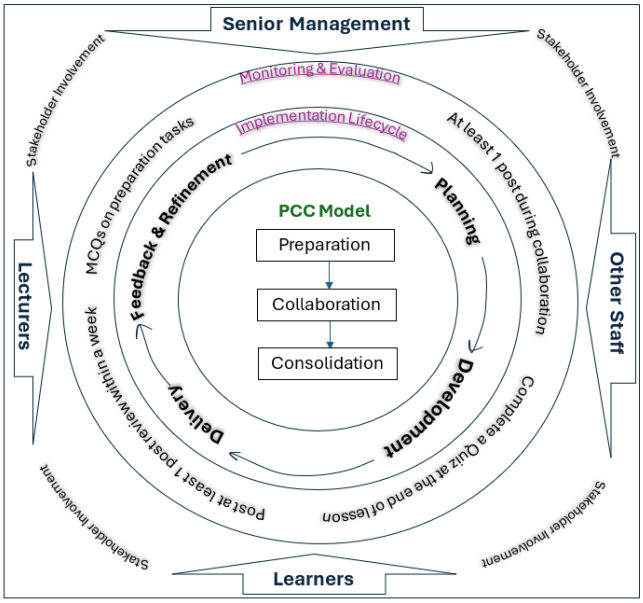


Figure 1: Implementation of PCC model – an actionable framework

5. Monitoring and evaluation – Each stage of the PCC model should include monitoring and evaluation mechanisms. Some examples are provided below. Allocating marks for informal assessment can motivate learners to actively participate, thereby supporting the effective implementation of the PCC model:

- Preparation stage: This should include a 15-minute video clip or reading, followed by 5 minutes of MCQ questions. Each learner must complete this task within 24 hours prior to the live session.
- Collaboration stage: Each learner needs to post at least once during the group task in each session.
- Consolidation stage: On the same day each learner will complete a quiz and within one week, each learner needs to submit a reflection post.

4. Emerging Innovations and Techniques That Enhance the PCC Model

Successful implementation of the PCC model requires lecturers to continuously adapt to technological advances, pedagogical teaching strategies, methods, techniques and tools, and learner needs. While platforms like Canvas, Moodle, or Blackboard provide basic infrastructure to manage preparatory content, coordinate collaboration activities, and support consolidation activities through integrated tools and plugins, recent innovations in digital learning environments, AI-driven tools and collaborative technologies offer new opportunities for senior management. These innovations enable the application of the PCC model across all online courses, enhancing implementation and contributing to better organizational outcomes. These innovations, along with other pedagogical techniques also support the proposed implementation framework of the PCC model, particularly the implementation lifecycle: Planning, Development, Delivery and Feedback & Refinement.

4.1 Adaptive Learning Platforms to Support Preparation

Adaptive learning platforms such as Smart Sparrow, Knewton, McGraw-Hill ALEKS, DreamBox Learning and Carnegie Learning help lecturers personalise learning, assess performance, and boost engagement using AI to analyse behaviour, adjust content in real-time, and provide scaffolding before collaborative tasks (Yaseen et al., 2025). These platforms support both preparation and consolidate stages of the PCC model by reducing lecturers' content design time. In preparation, learners engage in self-paced activities, such as short videos and MCQs, while adaptive features personalise learning and guide progress throughout the course.

4.2 Collaborative Technologies and Peer-teaching Enhancements

In the collaboration stage, real-time tools that allow multiple learners to work simultaneously on a shared task or document, such as Microsoft Teams, Google Workspace, Slack, Padlet/Jamboard and Miro/MURAL, are highly beneficial for facilitating structured group interactions, synchronous discussions, and co-creation of content. According to Panadero & Järvelä (2015), using structured peer learning designs such as jigsaw, gallery walk, reciprocal teaching, team-based learning, role play or snowball/think-pair-share strategies with these collaborative tools can significantly enhance learner motivation and knowledge construction. The use of virtual reality (VR) and augmented reality (AR) help learners work together in more interactive, practical ways, especially in STEM (Science, Technology, Engineering, and Mathematics) and professional education settings (Radianti et al., 2020).

4.3 AI and Learning Analytics for Consolidation

In the consolidation stage, AI-driven feedback tools such as Grammarly, Turnitin Revision assistant, Carnegie learning MATHia, Socratic by Google, Jill Watson (Georgia Tech), Otter.ai and Khan Academy with GPT integration are increasingly used to provide instant, formative feedback to thousands of learner inputs simultaneously. Learning analytics dashboards offers even more such as learners' participation patterns, performance trends and cognitive engagement. These performance related data are critical for the Feedback & Refinement stage of the proposed implementation framework for successful online course design and delivery (Ifenthaler & Yau, 2020).

4.4 Microlearning and Modular Design for Flexible Delivery

Emerging practices like microlearning, delivering content in short, focused bursts and bite-sized units, and modular design support flexible and learner-centered delivery. Modular approaches help learners manage their cognitive load, allow lecturers to adapt content based on feedback, and assessment data (Littlejohn and Hood, 2018) and enable the implementation of structured and reusable content throughout the lifecycle.

4.5 AI Assisted Teaching and Content Creation

AI-assisted teaching tools such as ChatGPT, Cognii, Gradescope (by Turnitin), Duplingo (Squirrel AI) and Quizlet AI help lecturers for creating fast prototyping of quizzes, videos, and case-based materials, and grading written and numerical answers quickly. However, they also require strategic integration to support pedagogical values, uphold academic integrity and align with the PCC model (Luckin et al., 2022).

4.6 Stakeholder Dashboards and Institutional Readiness

Institutions should increasingly invest in stakeholder-specific dashboards that offer relevant and tailored insights to all stakeholders, including senior management and lecturers, enabling real-time monitoring of key metrics

across the proposed implementation framework of the PCC model. These dashboards support data-driven decision-making, enhance transparency and facilitate effective resource allocation (Al-Fraihat et al., 2020).

5. Comparative Analysis and Anticipated Benefits

5.1 Comparative Analysis with Existing Models

The proposed PCC implementation framework addresses critical gaps across several contemporary online teaching models, including flipped learning, blended learning, MOOC-based learning and the existing PCC models by embedding structured processes such as stakeholder involvement, integration of emerging innovations and technologies, institutional readiness measurements and continuous monitoring. Table 1 presents comparative analysis across these models, showing that while each offers certain strength, they also suffer from limitations such as insufficient stakeholder engagement, lack of structured implementation cycles and inadequate integration of emerging technologies. The proposed PCC implementation framework mitigates these gaps through a comprehensive, interactive and scalable approach designed to enhance learner engagement, institutional readiness and sustainable delivery in HE contexts. Table 1 compares all these four models across six dimensions or characteristics that are crucial for the effectiveness of online teaching.

Dimensions	Existing PCC	Flipped Learning	Blended Learning	MOOC-based Learning	Proposed Framework
Stakeholder Involvement	Limited to lecturer and learner	Moderate (lecturer-driven)	Limited (institution + learner)	Minimal (platform-driven)	Comprehension: learners, lecturers, management, support staff
Structured Implementation Cycle	Absent	Partially present	Partial (course-level cycles)	Absent	Four-stage lifecycle (Planning, Development, Delivery, Feedback & Refinement)
Monitoring & Evaluation Metrics	Minimal	Limited	Moderate	Minimal	Stage-specific with feedback loops and analytics integration
Integration of Emerging Technologies	Low	Moderate	Moderate	Low	High (AI, adaptive platforms, VR/AR, dashboards)
Scalability and Adaptability	Challenging	Moderate	High	Very high	Designed for scalability across courses and contexts
Institutional Readiness Emphasis	Low	Medium	Low–Medium	Low	Strong focus on governance, resources, and training

Table 1: Comparing analysis of existing models and proposed Implementation PCC Framework

5.2 Anticipated Benefits

Considering the gaps highlighted in Section 3 - Literature review, the complexities/issues associated with four contemporary online teaching models, and insights from consultations with colleagues and students, the proposed framework is expected to offer the following benefits:

- **Improved learner engagement** – Combining three stages – Preparation, Collaboration and Consolidation with adaptive and collaborative technologies, learners are more likely to engage actively throughout the learning cycle.
- **Consistent quality across courses** – The incorporation of the structured four-stage lifecycle (Planning, Development, Delivery, Feedback & Refinement) promotes consistency and standardization, thereby reducing variability or differences in implementation across courses and lecturers.
- **Actionable monitoring and evaluation** – Stage specific metrics and dashboard integration support data driven decision-making, allowing lecturers to monitor learner performance and evaluate content effectiveness in real-time
- **Institutional readiness and scalability** – The framework focuses governance structures, training, and resource allocation, ensuring readiness for large-scale adoption across courses and lecturers.

- **Alignment with emerging innovations** – The framework accommodates emerging AI-driven tools, adaptive and collaborative technologies, and microlearning strategies, ensuring adaptability to future educational trends and technological advancements.

Based on reflection observations and the iterative development of the framework, most colleagues and students agreed that if all stakeholders clearly understand and fulfil their responsibilities, and if management including lecturers implement the framework systematically, including measuring their performance at each stage, students' learning outcomes are likely to improve significantly.

6. Discussion and Conclusions

This paper critically examines several established online teaching models, including the PCC model as a comprehensive online teaching model in HE, and highlights its pedagogical strengths such as promoting active learning, collaborative knowledge construction, reflective practice, self-regulated learning and peer engagement. However, despite the strong pedagogical strengths of these established online models, they continue to face significant implementation challenges such as the absence of well-defined evaluation metrics and ambiguity around stakeholder roles. Due to these challenges, many of these models are often ineffective and fail to deliver meaningful learning experiences for learners.

To address the issues identified, the paper proposes a structured implementation framework that incorporates stakeholder-specific responsibilities, implementation lifecycle of planning, development, delivery and feedback & refinement, along with actionable evaluation metrics. The implementation framework provides clear guidance on how to effectively implement the PCC model in HE contexts. The paper predominantly discusses the integration of emerging innovations and techniques for enhancing the scalability, effectiveness, and learner engagement of the PCC model. Through comparative analysis, the proposed implementation framework demonstrates its ability to address critical gaps observed across flipped learning, blended learning, MOOC-based learning, and the existing PCC models. These gaps include low learner engagement, limited interaction, insufficient stakeholder involvement, lack of institutional and structured evaluation mechanisms, inconsistent institutional support and inadequate scaffolding, which often lead to student disengagement and high dropout rates. By embedding systematic processes, data-driven monitoring, and technological innovation, the implementation framework offers a comprehensive and sustainable solution. Anticipated benefits include improved learner engagement, consistent quality across online courses, actionable evaluation mechanisms and sustainable implementation in diverse educational contexts.

By aligning pedagogical strategies (such as flipped learning and peer collaboration) with technological advancements (such as AI-driven feedback systems and adaptive learning platforms), and institutional readiness (including adequate resources, policies, staff training and support structures), this study bridges theory and practice. It offers a roadmap for the effective and practical implementation of the PCC model. HE institutions can implement the framework in their online courses more effectively and efficiently to enhance learning experiences.

While the proposed PCC implementation framework addresses many challenges of online teaching models, including flipped learning, blended learning, MOOC-based learning and the existing PCC, this study has some limitations. This is primarily a conceptual model, based on literature reviews, observations and reflections, and informal consultations, without formal empirical testing or large-scale implementation. Future research should explore empirical validation of the framework across diverse disciplines, institutional contexts and student populations to ensure its long-term sustainability, scalability and adoption of the PCC model in varied HE settings.

Ethics Declaration

Ethical approval was not required for this research, as it involved analysis, literature review, and framework development without the participation of human or animal subjects.

AI Declaration

AI-assisted tools were used solely to enhance language clarity, streamline content to meet the extended 6,000-word limit and ensure adherence to ICER 2025 formatting and reference guidelines. All research content, analysis, and conclusions were independently developed and verified by the authors.

References

Al-Fraihat, D., Joy, M. & Sinclair, J. (2020) Evaluating e-learning systems success: An empirical study. *Computers in Human Behavior*, 102, pp.67–86. Available at: https://doi.org/10.1016/j.chb.2019.08.004 [Accessed: 16 June 2025].

Almansour, M. & Almoayad, F. (2024) Exploring challenges and perceptions in the learning environment: an online qualitative study of medical students. *BMC Medical Education*, 24(1), Article 147. Available at: https://bmcmededuc.biomedcentral.com/articles/10.1186/s12909-024-05116-8 [Accessed: 20 August 2025].

Austin, L. (2025) Online Learning Statistics 2025 Report: Trends, Growth, ROI & Costs of Effective Education. [online] 13 June. Available at: https://entrepreneurshq.com/online-learning-statistics/ [Accessed: 21 August 2025].

Baig, M.I. & Yadegaridehkordi, E. (2023) Flipped classroom in higher education: a systematic literature review and research challenges. *International Journal of Educational Technology in Higher Education*, 20(1), Article 61. https://doi.org/10.1186/s41239-023-00430-5 [Accessed: 20 June 2025].

Bonk, C.J. & Graham, C.R., 2020. *The Handbook of Blended Learning: Global Perspectives, Local Designs*. Wiley.

Bruner, J., 1996. *The Culture of Education*. Harvard University Press.

Bryant, J., Golden, R., Hobbet, D. & Jefferson, I. (2023) *Strengthening higher education outcomes through partnerships, alliances, and mergers*. McKinsey & Company.

Celik, I., Gedrimiene, E., Silvola, A. & Muukkonen, H. (2023) Response of learning analytics to the online education challenges during pandemic: Opportunities and key examples in higher education. *Learning Analytics Review*, 15(2), pp. 45-58.

Chase, C. C. (2023) The learner's role in collaborative teaching: Exploring students' preparedness, behavior, and expectations. *arXiv*. Available at: https://arxiv.org/abs/2401.02964 [Accessed: 30 June 2025].

Chen, X., Zou, D., Cheng, G., Xie, H. & Su, F. (2023) Effects of flipped language classrooms on learning outcomes in higher education: A Bayesian meta analysis. *Australasian Journal of Educational Technology*, 39(2), pp.65–97. Available at: https://ajet.org.au/index.php/AJET/article/view/8019 [Accessed: 26 June 2025].

Demir, B., Czerniak, C. & Hart, L. (2013) Faculty collaboration and the lesson study model in higher education. *College Quarterly*, 20(1), pp.1–18.

Dziuban, C., Graham, C. R., Moskal, P., Norberg, A., & Sicilia, N. (2018) *Blended learning: The new normal and emerging technologies. International Journal of Educational Technology in Higher Education*, 15(3). Available at: https://doi.org/10.1186/s41239-017-0087-5 [Accessed: 20 June 2025].

Edumadze, J.K.E. & Govender, D.W. (2024) The community of inquiry as a tool for measuring student engagement in blended massive open online courses (MOOCs): a case study of university students in a developing country. *Smart Learning Environments*, 11(1), Article 19. Available at: https://doi.org/10.1186/s40561-024-00306-9 [Accessed: 15 May 2025].

Evanick, J., 2024. Instructional design for online education: Which model is best? *eLearning Industry*. Available at: https://elearningindustry.com/which-instructional-design-model-is-best-for-online-higher-education [Accessed: 20 May 2025].

Geary, E., Allen, K.-A., Gamble, N. & Pahlevansharif, S. (2023) Online learning during the COVID-19 pandemic: Does social connectedness and learning community predict self-determined needs and course satisfaction? *Journal of University Teaching & Learning Practice*, 20(1), Article 13. Available at: https://eric.ed.gov/?id=EJ1382334 [Accessed: 22 May 2025].

Gutiérrez-González, R., Zamarron, A. & Royuela, A. (2024) Video based lecture engagement in a flipped classroom environment. *BMC Medical Education*, 24, Article 1218. Available at: https://bmcmededuc.biomedcentral.com/articles/10.1186/s12909-024-06228-x [Accessed: 12 May 2025].

Hainz, K., Ferguson, R. & Sharples, M. (2021) Learning analytics in higher education – a preponderance of analytics but very little learning? *International Journal of Educational Technology in Higher Education*, 18(1), Article 12.

Heller, R. S. (2022) Applying Bloom's revised taxonomy in online course design: A case study in business education. *Online Learning Journal*, 26(2), pp.85–101. Available at: https://doi.org/10.24059/olj.v26i2.3122 [Accessed: 02 June 2025].

Hora, M.T. (2016) Navigating the problem space of academic work: How workload and curricular affordances shape STEM faculty decisions about teaching and learning. *AERA Open*, 2(4), pp.1–19.

Huang, R., Tlili, A., Chang, T.-W., Zhang, X., Nascimbeni, F. & Burgos, D. (2021) Disrupted classes, undisrupted learning during COVID-19 outbreak in China: Application of open educational practices and resources. *Smart Learning Environments*, 8(1), pp.1–15. Available at: https://doi.org/10.1186/s40561-021-00149-8 [Accessed: 18 May 2025].

Ifenthaler, D. & Yau, J. Y. K. (2020) Utilising learning analytics to support study success in higher education: A systematic review. *Educational Technology Research and Development*, 68, pp.1961–1990. Available at: https://doi.org/10.1007/s11423-020-09788-z [Accessed: 26 May 2025].

Jisc (2023) 2023/24 UK higher education teaching staff digital experience insights survey findings. Available at: https://digitalinsights.jisc.ac.uk/reports-and-briefings/our-reports/2023-24-uk-higher-education-teaching-staff-digital-experience-insights-survey-findings [Accessed: 21 August 2025].

Joosten, T., Cusatis, R. & Harness, L. (2019) Are quality indicators of online courses able to predict student success? *Online Learning*, 23(4), pp.354–378. Available at: https://doi.org/10.24059/olj.v23i4.1432 [Accessed: 26 May 2025].

Kainz, K., Metz, A. & Yazejian, N. (2021) Tools for evaluating the implementation of complex education interventions. *Evaluation & the Health Professions*.

Kerimbayev, N., Umirzakova, Z., Shadiev, R., & Jotsov, V. (2023) A student-centered approach using modern technologies in distance learning: A systematic review of the literature. *Smart Learning Environments*, 10, Article 61. Available at: https://doi.org/10.1186/s40561-023-00280-8 [Accessed: 11 June 2025].

Killen, R., (2016) *Effective Teaching Strategies: Lessons from Research and Practice* (7th ed.). Cengage Learning.

Littlejohn, A. & Hood, N. (2018) *Learning Analytics in Higher Education*. Routledge.

Luckin, R., Holmes, W., Griffiths, M. & Forcier, L. B. (2022) *Intelligence Unleashed: An Argument for AI in Education*. Pearson Education.

Martin, F. & Bolliger, D. U. (2023) Designing online learning in higher education. In: O. Zawacki-Richter & I. Jung, eds. *Handbook of Open, Distance and Digital Education*. Springer, pp.1217–1232. Available at: https://doi.org/10.1007/978-981-19-2080-6_72 [Accessed: 26 May 2025].

Mizza, D., Reese, M. & Malouche, M. (2025) Flipped classroom evaluation and blended learning potential. *Springer Journal of Educational Technology*, 12(1), pp. 22-35.

Mwale, S. & Mumba, K. (2024) Collaborative online learning and the zone of proximal development: A Zambian higher education perspective. *Journal of Digital Learning Research*, 11(1), pp.45–58. Available at: https://doi.org/10.1016/j.jdrl.2024.01.005 [Accessed: 16 June 2025].

National Center for Education Statistics (NCES) (2024) Distance education enrollment and preferences. U.S. Department of Education. Available at: https://nces.ed.gov/ [Accessed: 15 April 2025].

Panadero, E. & Järvelä, S. (2015) Socially shared regulation of learning: A review. *European Psychologist*, 20(3), pp.190–203. Available at: https://doi.org/10.1027/1016-9040/a000226 [Accessed: 09 May 2025].

Peck, D. (2025) Online Learning Statistics: The Ultimate List in 2025*. DevlinPeck.com. Available at: https://www.devlinpeck.com/content/online-learning-statistics [Accessed: 31 March 2025].

Peng, W., Yang, Y., Zhang, Z. & Li, T. J. (2025) GLITTER: An AI-assisted platform for material-grounded asynchronous discussion in flipped learning. *arXiv preprint*. Available at: https://arxiv.org/abs/2504.14695

Radianti, J., Majchrzak, T.A., Fromm, J. & Wohlgenannt, I. (2020) A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, 147, 103778. Available at: https://doi.org/10.1016/j.compedu.2019.103778 [Accessed: 27 April 2025].

Rasheed, R. A., Kamsin, A. & Abdullah, N. A. (2020) Challenges in the online component of blended learning: A systematic review. *Computers & Education*, 144, 103701.

Raslan, G. (2024) The impact of the Zone of Proximal Development concept (scaffolding) on students' problem-solving skills and learning outcomes. In: K. Al Marri et al., eds. *BUiD Doctoral Research Conference 2023*. Lecture Notes in Civil Engineering, 473, pp.59–66. Available at: https://doi.org/10.1007/978-3-031-56121-4_6 [Accessed: 25 June 2025].

Song, M.H., Lim, J., Lee, S., Ihm, J. & Park, J. (2025) Enhancing group outcomes: The role of individual preparation in collaborative learning. *BMC Medical Education*, 25, 524.

Sosa-Díaz, M.-J., Garrido-Arroyo, M.d.C. & González-Delgado, M.Y. (2025) Transformation of Educational Models in Higher Education During and After 'Emergency Remote Teaching'. *Education Sciences*, 15(9), pp.1249. Available at: https://doi.org/10.3390/educsci15091249 [Accessed: 21 September 2025].

Suraworachet, W., Zhou, Q. & Cukurova, M. (2022) Impact of combining human and analytics feedback on students' engagement with, and performance in, reflective writing tasks. *arXiv*. Available at: https://arxiv.org/abs/2211.08222 [Accessed: 21 August 2025].

Svensson, L., Andersson, P. & Nilsson, S. (2021) Practices and strategies for enhancing learning through collaboration between vocational teacher training institutions and workplaces. *Empirical Research in Vocational Education and Training*, 13(12), pp.1–22.

University of Melbourne, 2024. Reflection and consolidation activities. *Learning Environments Teaching Guides*. Available at: https://www.unimelb.edu.au/tli/learning-design-and-assessment/building-cohorts-creating-community/reflection-and-consolidation-activities [Accessed :22 August 2025].

Yaseen, H., Mohammad, A. S., Ashal, N., Abusaimeh, H., Ali, A. & Sharabati, A.-A.A. (2025) The impact of adaptive learning technologies, personalized feedback, and interactive AI tools on student engagement: The moderating role of digital literacy. *Sustainability*, 17(3), pp.1133. Available at: https://doi.org/10.3390/su17031133 [Accessed: 23 May 2025].

Zach, S. & Avugos, S. (2024) Co teaching in higher education: Implications for teaching, learning, engagement and satisfaction. *Frontiers in Sports and Active Living*, 6, 1424101.

Zainuddin, Z. & Halili, S. H. (2016) Flipped classroom research and trends from different fields of study. *International Review of Research in Open and Distributed Learning*, 17(3), pp.313–340. Available at: https://doi.org/10.19173/irrodl.v17i3.2274 [Accessed: 02 July 2025].

Zou, D., Chen, X., Cheng, G. & Xie, H. (2020) Effects of flipped classrooms on learning outcomes in higher education: A Bayesian meta analysis. *Australasian Journal of Educational Technology*, 36(4), pp.90–109.

Building Information Modelling (BIM) Issue Introduced in Master Academic Level

Alcínia Zita Sampaio
Department of Civil Engineering and Architecture, Higher Technical School, University of Lisbon, Lisbon, Portugal

zita.sampaio@tecnico.ulisboa.pt

Abstract: Building Information Modelling (BIM) is a methodology supported on the generation of a virtual three-dimensional (3D) model of building projects, providing engineers the visualization and the necessary data to support planning, construction and managing. The data base of the BIM model allows professionals to develop all activities that are normally worked out over the project data. In the last decades, BIM has been adopted in all sectors of the construction industry. As so, learning the BIM topic within the construction education, regarding its concept, the range of its applicability and the most used BIM tools, is currently required. Civil engineering schools have the mission of training future engineers by offering curricular subjects, master courses and workshops concerning the current advanced computer technology. As so, the upcoming engineers should acquire the ability to use the available BIM tools in the distinct sectors of the construction industry and to recognize the advantages in developing collaborative BIM projects. The text presents a master curriculum, for students of the last academic level, offered by the Civil Engineer Department of the University of Lisbon. The master course presents the concept of BIM and the large range of its applicability. The programmatic schedule begins with the generation of a building digital BIM model, composed of parametric objects, followed by the development of different design steps. The main activities are related with the collision analyses between disciplines, the construction planning, the cost estimation and the sustainability study. The course transmits in an evolutionary and sequential way the learning issues necessary to improve the BIM skills of the students, required in their future activity as civil engineers.

Keywords: BIM, Engineering Education, Student's Skills, Master Course, Contents, Evaluation

1. Introduction

The Building Information Modelling (BIM) methodology concept focuses on the development of a single digital model. The database of the BIM model includes, in an organized way, all the information generated, manipulated and actualized concerning the building design, construction and management (Khattra and Jain, 2024). The BIM processes include the creation and the management of digital representations of physical and functional characteristics of the buildings or infrastructures. Understanding the BIM concept and is range of applicability, involves the recognizing of its benefits and limitations on the elaboration of the entire set of tasks required in the construction process (Chen *et al.*, 2023). BIM has spread worldwide as a digital construction tool, an innovative method essential in the development of building projects and an important integration capability in the management of projects, throughout the building project lifecycle (Wang and Chen, 2023). The database of the BIM model supports the development of each design phase required in the building lifecycle context. The processes of transferring, manipulating and generating new data, are managed using the BIM tools resources, based on advanced technologies. The development of BIM projects is supported on an effective teamwork coordination and the correct management of the database of the model (Jung and Joo, 2011).

The master course, considered in the present text, was designed for students to learn the essential concepts of BIM, and the basic skills to create and manipulate a BIM model. Those skills must include how to use common BIM modelling tools, how to retrieve information from a BIM model and how to develop subsequent tasks (Salmi *et al.*, 2025). The virtual 3D model generation is the first stage in a BIM collaborative project (Yilmaz *et al.*, 2019). This step is based on the use of parametric objects generated, selected and adapted for each building project. Civil engineering students should take advantage of the new job opportunities that are emerging around the process of the global adoption of BIM, complementing there training with BIM knowledge. As so, education, that goes normally more slowly and lags easily behind the industry, must follow the BIM skills requirement (Raad *et al.*, 2023). The new civil engineers should acquire competencies in BIM allowing them to be able to participate in the process of the digital transformation of the construction sector. (Wang *et al.*, 2023). BIM education must address the challenges faced by educators in adapting to the digitalization demands of the architecture, engineering, construction, and operation sectors (Ozaer and Chen, 2021) (Sampaio, 2018)..

The present BIM master course was defined with the objective of integrating BIM knowledge and procedures into the current educational curricula. The new didactic programme issue explores a theoretical context for enhancing civil engineering and architectural education through the integration of BIM into the current curriculum and teaching methods. As BIM implementation covers various sectors of the construction industry,

the engineer should know what the available basic BIM tools in the market are, and how they can be manipulated to support the development of a huge range of activities in the building design and construction. BIM methodology interferes with all aspects involved in the project in construction:

- At the initial stage, concerning the generation of the shape of the building (architecture);
- At different phases of the structural analysis process (structural solution design and detailed reinforced drawings production);
- At the budget estimation (take-off materials and estimation of costs);
- At the construction planning stage (linking the Gantt map with construction components of the model);
- At the building occupation management (supporting the maintenance activity and the establishment of repair or rehabilitation projects).

In order to add the BIM topic to the current course offered to students, at the University of Lisbon, it was proposed the introduction of the BIM methodology subject in a master unit. This new curricular unit was inserted at the level of last year of the Civil Engineering course. The curricular program was established to encompass several primordial educational steps and presents a subject methodology involving distinct specialties:

- Introduction to the topic and to the parametric modeling process, pointing out the benefits and limitations of its adoption in the construction industry;
- Reference to the construction sectors in which the BIM has had greater visibility and success;
- Use of BIM tools, and explore their potentialities and specificities;
- Develop of a large set of specific tasks, supported in BIM platforms;
- Create and overlapped the model disciplines components, allowing users to analyse the eventual conflict between all design components;
- Verify the correctness of data transferred between components of the project using distinct software;
- Comparative analyse of the benefits and limitation identified in the project development, when confronted with the traditional way;
- Establishment of a methodology of collaborative work required in the process of its implementation.

With the introduction of the master course into the current curricula, the teachers intend to improve the student's skills. The BIM topic is inserted at the final stage of the student's education. The finalist students can more easily recognize the relevance of BIM's adoption in the sector and understand that the new competence will be useful for them in the future job market. These aspects justify and reinforce the introduction of the BIM course at the last academic year. However, the new BIM unit is elective and is offered to all branches of the Master curriculum. Besides the fields of building and structures, the sectors of architecture, management, and hydraulic systems can be latter also be involved. The training of collaborative working teams, involving this diversity of domains is, naturally, enrichment for students, for the Department of Civil Engineering teaching activity and for the school. The master's course is taught during one academic semester, with a relevant involvement of other teachers of fundamental civil engineering subjects. A pilot experiment was first experimented at the 2020/2021 academic year. The course structure has been adjusted since then until the current academic year.

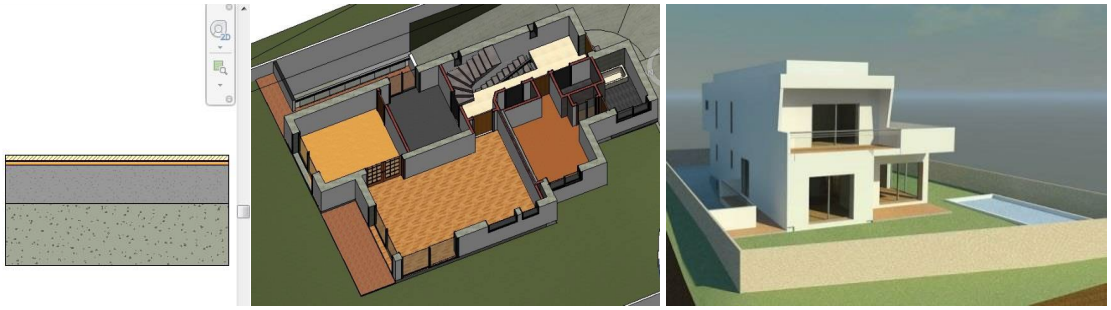
2. Teaching BIM Methodology

The BIM issue requires the enlightenment of concepts, its applicability and the level of implementation worldwide to students. However, the practical component is what makes the student able to act in different contexts and phases of the project. Therefore, the practical use of teaching basic BIM tools is essential in the course. The training provided should enable the student:

- To carry out the model generation of different disciplines and tasks, namely data transfer between phases, reuse and create new information;
- To be critical in every step regarding the correctness of the data transferred and know how to perform in accordance in order to obtain correct data;
- To add data concerning all disciplines components over the unique and centralized BIM model, meet its organization and learn how to establish effective management of information;
- To extract data from the model and to define the usual documents usually required in the construction project.

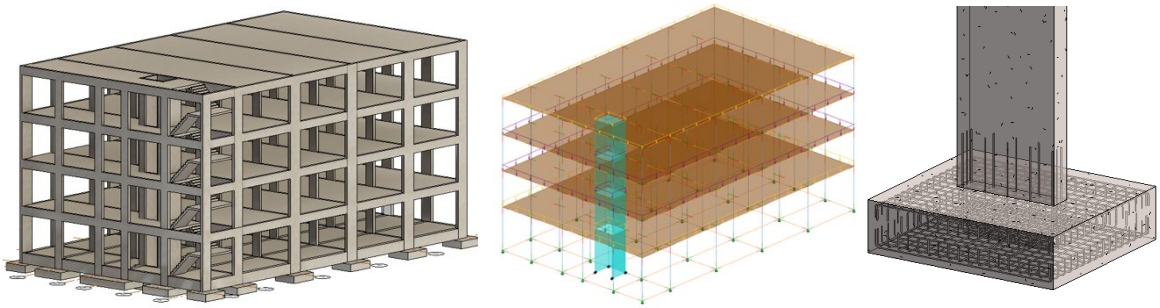
As an approach of training and learning how the BIM involves various aspects of the project, namely, the initial architectural component, it was proposed, in each new academic year, the implementation of a complete project over a distinct real case study. The student initializes the contact with the BIM methodology with the generation of the architectural model, and then proceed with the development of the other components that complete he multidisciplinary building project. Different stages of the learning process was established:

- Creation the architectural model using basic parametric objects associated to graphic patterns and to physical proprieties of the material (Figure 1);
- Generation of the structural models, physical and analytical, and the reinforcements detail (Figure 2);
- Definition of mechanical, electrical and plumbing (MEP) model concerning the service networks of water supply and waste and of the electrical installation (Figure 3)
- Realizing the clash detection analysis between the modelled disciplines of the project (Figure 4);
- Planning the construction process with the association of several model components to the Gantt map tasks, creating 4D BIM models (Figure 5);
- Extracting the required information from the model in order to obtain tables of take-off quantities of components and material (Figure 6).



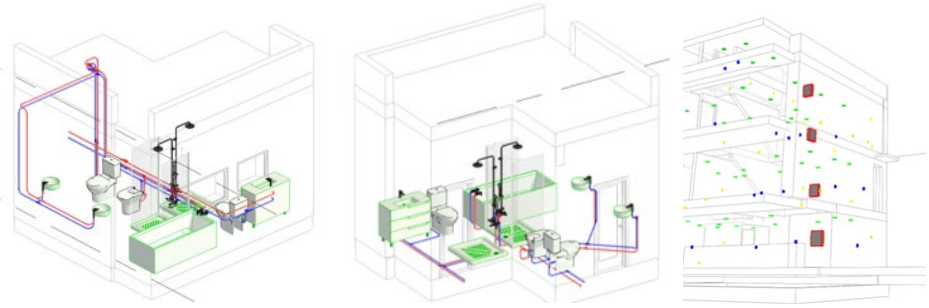
a b c

Figure 1: Model of the architectural component: parametric object of a slab (a), perspective of the model submitted to a horizontal cut (b) and a complete model(c).



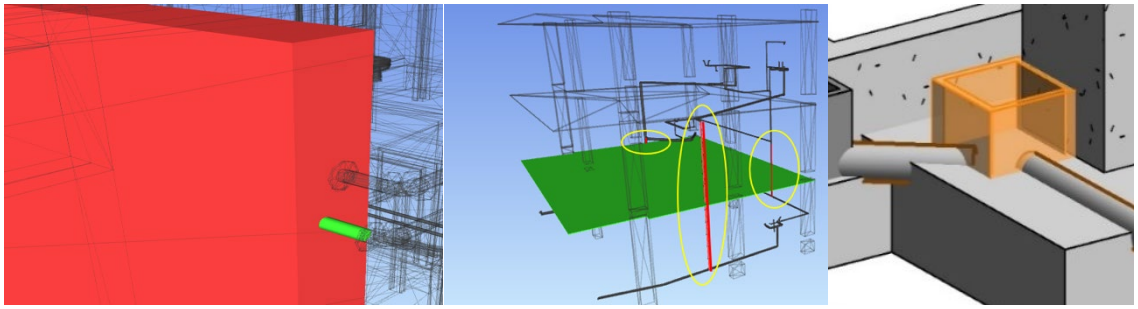
a b c

Figure 2: Model of the structural component: physical (a), analytical (b) and reinforcements detail (c).



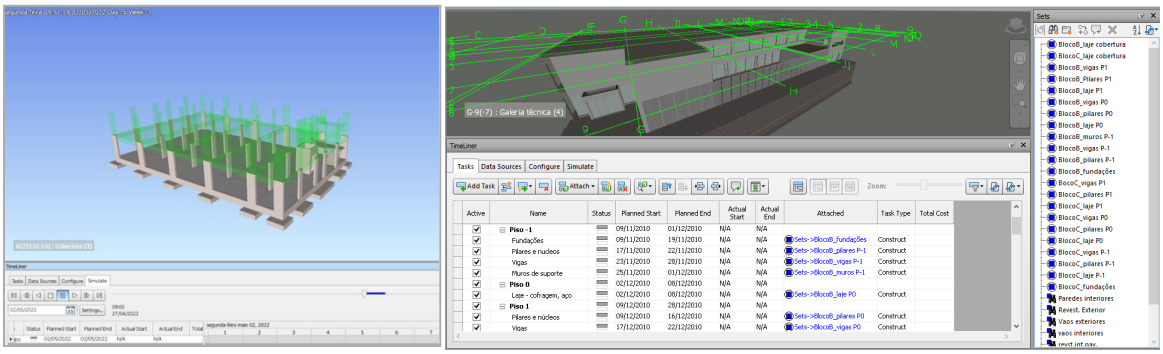
a b c

Figure 3: MEP models of service networks: water supply (a), water waste (b) and electric system (c).



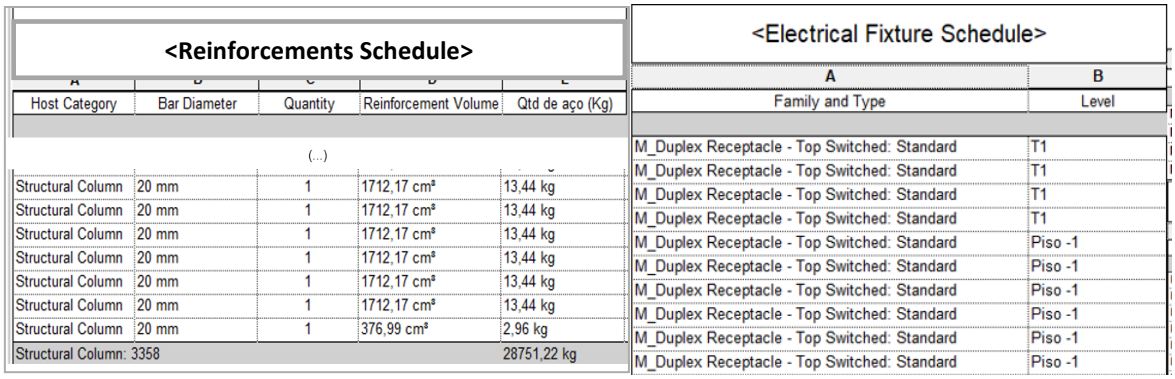
a b c

Figure 4: Clash detection analysis: between pipe and structure (a), water networks (b) and foundation (c).



a b

Figure 5: 4D BIM models creation: Foundation stage (a) and association of elements to Gant map tasks (b).



<Reinforcements Schedule>

Host Category	Bar Diameter	Quantity	Reinforcement Volume	Qtd de aço (Kg)
		(...)		
Structural Column	20 mm	1	1712,17 cm³	13,44 kg
Structural Column	20 mm	1	1712,17 cm³	13,44 kg
Structural Column	20 mm	1	1712,17 cm³	13,44 kg
Structural Column	20 mm	1	1712,17 cm³	13,44 kg
Structural Column	20 mm	1	1712,17 cm³	13,44 kg
Structural Column	20 mm	1	1712,17 cm³	13,44 kg
Structural Column	20 mm	1	376,99 cm³	2,96 kg
Structural Column: 3358				28751,22 kg

<Electrical Fixture Schedule>

A	B
Family and Type	Level
M_Duplex Receptacle - Top Switched: Standard	T1
M_Duplex Receptacle - Top Switched: Standard	T1
M_Duplex Receptacle - Top Switched: Standard	T1
M_Duplex Receptacle - Top Switched: Standard	T1
M_Duplex Receptacle - Top Switched: Standard	Piso -1
M_Duplex Receptacle - Top Switched: Standard	Piso -1
M_Duplex Receptacle - Top Switched: Standard	Piso -1
M_Duplex Receptacle - Top Switched: Standard	Piso -1
M_Duplex Receptacle - Top Switched: Standard	Piso -1
M_Duplex Receptacle - Top Switched: Standard	Piso -1

a b

Figure 6: Take-off of material´s quantity: structural columns (a) and electrical fixture (b).

2.1 Programmatic Content of the BIM Issue

The curricular program of the syllabus consists of different modules' trying in order to address all topics that will be useful for the future civil engineer. The sequence of items starts from the generic concepts reaching a comprehensive use of all the information added to the centralizer BIM model, throughout the all course. The BIM model is composed of the selected disciplines (architecture, structures and services) and must contains all the information that later is needed to define drawings and maps of quantities or to support construction planning and building maintenance. The list of the main topics and the respective items are as follow regarding the adequate numbered sequence:

1. Introduction to BIM concept:

- State-of-the-art, application, benefits and limitations;
- Parametric modeling process;

- Model detail levels and project phases;
- BIM implementation strategies in enterprises.

2. Interoperability capacity and standardization:

- Information transfer formats;
- Collaborative platforms and systems managers of BIM projects;
- Limitations of BIM interoperability in design management.

3. Model of the architectural solution:

- BIM base tools frequently used;
- General aspects of BIM base software (interface, parametric objects and unit definition);
- Initial settings of the modelling process (orthogonal grids and level of floors);
- Selection and edition of parametric objects (walls, windows, doors, floors, and roofs);
- Display views of the model (drawing plants, elevations, horizontal and vertical sections, axonometric perspective);
- Getting information query (type of objects or materials proprieties).

4. Model of the structural solution

- Re-use of information of the architectural model overlapping the new component;
- Selection and edition of structural parametric objects (columns, slabs, foundations);
- Association of material and physical properties to objects;
- Transposition of geometric model to analytical structural model.

5. Structural analyses:

- Transposition of structural model to a structural analysis software;
- Verification of the correctness of the transferred information;
- Structural analyses;
- Definition of reinforcement details;
- Transfer of structural results information to the initial BIM model;
- Elaboration of details drawings of the structural reinforcements.

6. MEP model:

- Networks and services equipment;
- MEP software-mechanical, electrical, and plumbing engineering;
- Modelling of water and sewerage networks;
- Analysis of conflicts between components.

7. Construction planning:

- Establishing milestones in Gantt map;
- Generation of the 4D BIM model;
- Use of BIM viewers;

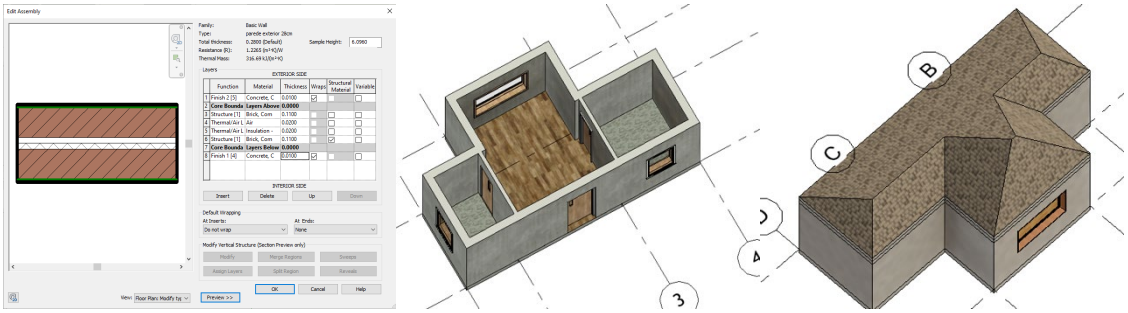
8. Extraction of information from the model:

- Maps of materials' quantity;
- Definition of technical drawings;
- Budgets estimation.

9. Coordination and management of information:

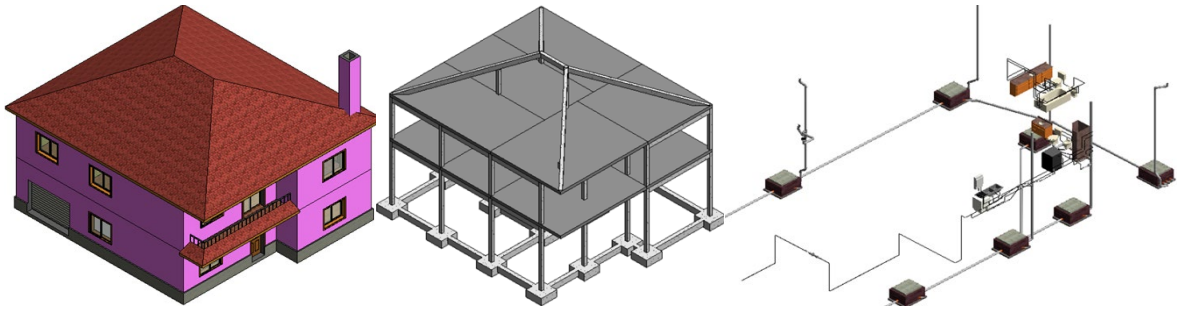
- Collaborative project (team and BIM work methodology);
- Analysis of advantages and limitations in BIM processes.

The students carry out the same exercises operated over a didactic example, a family house (Figure 6), and after they are invited to develop the same experience over a more complex and real case (figure 7).



a b c

Figure 7: Didactic example of a small house: parametric object (a), architectural walls (b) and roof (c).



a b c

Figure 7: Final project: architecture (a), structures (b) water waste system (c).

The workshops and the individual exercise were developed using the BIM software resources available in the computer lab of the Department of Civil engineering, equipped with the updated software required in the course.

2.2 Evaluation and Expected Results

The knowledge assessment is carried out on a final draft. A final and collaborative project is required to be developed by each student and it must include:

- Elaboration of architectural, structural and MEP models;
- Overlapping components and making the required analysis of conflict detection;
- Structural analyses including representation of detailed reinforcement drawings;
- Planning the construction process and defining the respective 4D model;
- Getting maps of quantities take-off and elaboration of budgets concerning several design stages.

For the preparation of individual BIM design concerning the application of BIM over real cases, a set of initial information is provided, composed of CAD drawings and the characteristics of the building components for a posterior comparison, between traditional way and BIM performance. This teaching methodology of BIM, makes students working in a collaborative way, more likely to work later in the context of the development of multidisciplinary projects in their future profession. The integration of all construction processes and the centralization of the created data in the unique BIM model, are the principal fundaments of BIM. The biggest drawback in this process is that each student does not develop in a balanced way its capabilities in relation to different specialties. However, the collaboration is needed and, bearing, transmission of knowledge is somehow made between the members of the working team. Performing a complex job and obtaining success is of course challenging and a cause for satisfaction for the student, making the students more confident in the individual achieved ability in using BIM in the development of future real projects. As a result, the students adds skills in the subject BIM:

- Along the course the student acquires knowledge concerning the applicability of BIM and its benefits in various areas of the project, as well as the working collaborative methodology inherent to BIM concept;

- The students are able to set important guidelines in the process of BIM implementation in an engineering office;
- The attendees are sufficiently capable to indicate which are the changes and the adjustments that must be made on the professional team and on the methodology practice, in order to establish collaborative platforms;
- The knowledge and training gained enables the students to perform with success the projects as may be requested by means of an innovative methodology, for which only a few engineers are currently trained.

In the national context, and in the current early stage of BIM implementation, the student, as a future professional, constitutes an important difference in a world of scarcity of job opportunities, motivated by the current enlarged activity of the construction industry.

2.3 Master Thesis and Professional Short Course in BIM

In the last academic years, the search for BIM theme in Master thesis context, has been great. The thesis' supervision has been one of the teachers' activity most involved in the BIM subject. All evaluated thesis were inserted in the digital platform of IST allowing its consult by the students of the Civil Engineering Department. Below are listed some of the most recent research works (Figure 8):

- Moreira, N.A, Application of BIM methodology in the maintenance of railways (Moreira, 2024);
- Figueiras, J.P. Contribution to the implementation of BIM methodology in structural design: case of box-section viaduct (Figueiras, 2023);
- Sarmento, R.S. BIM implementation in multidisciplinary project development: 4D and 5D models and VR integration (Sarmento, 2023);
- Gomes, N.E., Analysis of BIM technology capabilities in the generating of 4D models (Gomes, 2022);
- Sequeira, P.M., Structural design in a BIM environment: technological advances in information transfer (Sequeira, 2022);
- Azevedo, G.F., Implementation of BIM methodology in structural design: adaptation of procedures and information management (Azevedo, 2022).

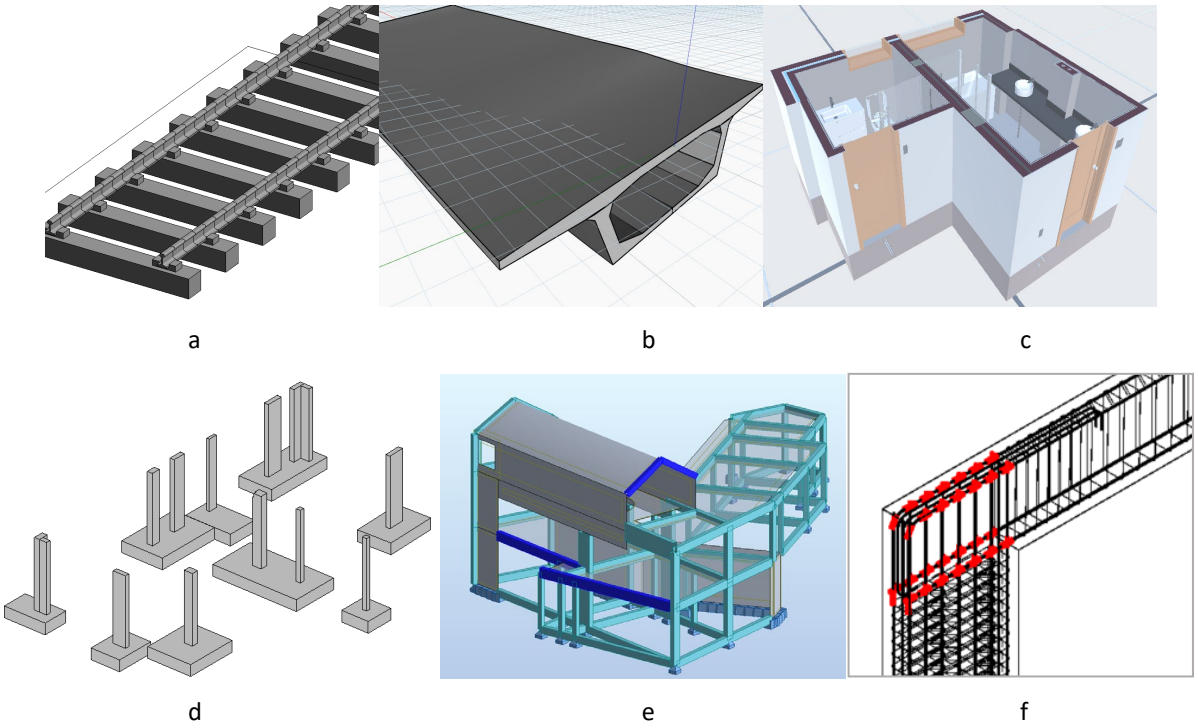


Figure 8: Master thesis: railway (a), viaduct (b) VR/AR technology (c), 4D model (d), structure (e) and reinforcement (f).

Additionally, within the Department of Civil Engineering of the University of Lisbon, BIM professional workshops have been organized. The last short course that was offered in November 2024, includes the basic notion of BIM, its implementation degree worldwide, and the large range of BIM applicability required distinct in a complete project (Figure 9).



a b c

Figure 9: Images presented in a BIM professional short course: architecture (a), structures (b) and sanitary room (c).

3. Conclusions

The Department of Civil Engineering of the University of Lisbon follows the newest advances in technology that can be applied in the Construction activity. The BIM methodology, its concept and the available based tools are important issues to be taught to civil engineering students. The present report describes the curricular program approach of an academic unit proposed and applied in order to introduce this emergent topic in the scholar activity.

The motivation and contextualization are referred in detail as well as the teaching methodology. Some examples that were worked out in classes by students follow the detailed programmatic content; some images, presented along the text, illustrate the positive result achieved with the course. Other activities supporting the course are also described, namely, master thesis and short professional courses.

As referred, BIM implementation is a new process that requires study, practice, research and dissemination. The described teaching work is a positive contribution that goes in the right way in the digital transformation of the construction industry.

Ethics Declaration

No ethical clearance is needed

AI Declaration

No AI tool was applied.

References

Azevedo, G.F. (2022) “Implementation of BIM methodology in structural design: adaptation of procedures and information management”, *Master’s Thesis*, University of Lisbon, Lisbon, Portugal.

Chen, S., Zeng, Y., Majdi, A., Salameh, A.A., Alkhalifah, T., Alturise, F.H. and Ali, E. (2023) “Potential features of building information modelling for application of project management knowledge areas as advances modelling tools”, *Advances in Engineering Software*, vol. 176, 103372, ISSN 0965-9978, https://doi.org/10.1016/j.advengsoft.2022.103372.

Figueiras, J.P. (2023) “Contribution to the implementation of BIM methodology in structural design: case of box-section viaduct”, *Master’s Thesis*, University of Lisbon, Lisbon, Portugal.

Gomes, N.E. (2022) “Analysis of BIM technology capabilities in the generating of 4D models”, *Master’s Thesis*, University of Lisbon, Lisbon, Portugal.

Jung, Y. and Joo, M. (2011) “Building information modelling (BIM) framework for practical implementation”, *Automation in Construction*, 20(2), pp. 126-133, https://doi.org/10.1016/j.autcon.2010.09.010.

Khattra, S. and Jain, R. (2024) "Building Information Modelling: a comprehensive overview of concepts and applications", *Advances in Research*, vol. 25, pp. 140 – 149, https://journalair.com/index.php/AIR/article/view/1145

Moreira, N.A (2024) "Application of BIM methodology to communication routes", *Master's Thesis*, University of Lisbon, Lisbon, Portugal.

Ozaer, Z. and Chen, Z., (2021) "A methodological approach to excellence in BIM oriented architectural education", *ARCOM Doctoral Workshop on Contemporary Advances in Research Methodology in Construction Management*, https://doi.org/10.13140/RG.2.2.26105.29281

Raad, L., Maya, R. and Dlask, P. (2023) "Incorporating BIM into the academic curricula of faculties of architecture within the framework of standards for engineering education", *International Journal of BIM and Engineering Science,* Vol.6, Issue 2, pp. 08-28,https://doi.org/10.54216/IJBES.060201

Salmi, J., Ye, Z., Ninic, J. and Heikkilä, R. (2025) "BIM for mining: automated generation of information models using a parametric modelling concept", *International Journal of Rock Mechanics and Mining Sciences*, 186, 106032, ISSN 1365-1609, https://doi.org/10.1016/j.ijrmms.2025.106032.

Sampaio, A.Z. (2018) "Proposal of curricular program to introduce BIM in a Civil Engineering school", book: Springer International Publishing AG, HELIX 2018, LNEE 505, Innovation, Engineering and Entrepreneurship, 2019, pp. 1131–1137. https://doi.org/10.1007/978-3-319-91334-6_156.

Sarmento, R.S. (2023) "BIM implementation in multidisciplinary project development: 4D and 5D models and VR integration", *Master's Thesis*, University of Lisbon, Lisbon, Portugal.

Sequeira, P.M. (2022) "Structural design in a BIM environment: technological advances in information transfer", *Master's Thesis*, University of Lisbon, Lisbon, Portugal.

Wang, L., Huang, M., Zhang, X., Yan, X., Jin, R., Wanatowski, D., Cheshmehzangi, A. and Chohan, N. (2023) "Incorporating BIM into the upper-division curriculum of construction engineering and management", 48(3), pp. 482-501, https://doi.org/10.1080/15623599.2021.1979300

Wang, T. and Chen, H.M. (2023) "Integration of building information modelling and project management in construction project life cycle", *Automation in Construction*, Vol. 150, 104832, ISSN 0926-5805, https://doi.org/10.1016/j.autcon.2023.104832.

Yilmaz, G., Akcamete, A. and Demirors, O. (2019) "A reference model for BIM capability assessments", *Automation in Construction*, Vol. 101, pp. 245-263, https://doi.org/10.1016/j.autcon.2018.10.022.

Academic One-Day Course Offered to Improve Engineers' BIM Skill

Alcínia Zita Sampaio
Department of Civil Engineering and Architecture, Higher Technical School, University of Lisbon, Lisbon, Portugal

zita.sampaio@tecnico.ulisboa.pt

Abstract: The construction industry has been adopting the new Building Information Modelling (BIM) methodology as the main approach of working, covering all sectors, including design, construction and maintenance. Construction enterprises have been demanding the University to carry out professional courses in order to be able to update their professionals with this new methodology. Recently, a design and construction office requested a one-day BIM training course, to increasing the BIM knowledge of the employees. The short course was properly designed to present the basic concepts, to experience the handling of the BIM modelling software most used, and to disseminate the large range of BIM applicability. The proposed professional action covers the areas of construction (conflict analysis, planning, and material quantity), structures (interoperability, analyses, and the transfer of information between software types), and the recent heritage building information modelling (HBIM) perspective. For it, the applied didactic procedure was based on the presentation of case studies related to situations of conflict between disciplines, of interoperability problems, and of rehabilitation of old buildings. This training involved all the company's employees, composed of designers, architects, civil engineers and economists. The difficulties found in the course are mainly due to the heterogeneity of the attendees, who have different interests and specific familiarity perspectives. The course was held with the objective of initiating professionals in the new topic and to acquiring knowledge in BIM adoption, in a way they can apply in their company. The participants followed the course with great interest and satisfaction, formulating several questions contextualized in the particular field of expertise of each professional. The course aims to contribute to the dissemination of the potential of BIM in the design, construction, and refurbishment of historical buildings. The course was evaluated in its generality and topic taught, resulting in a positive grade.

Keywords: BIM, On-day Course, Improving Skills, Construction, Management, Professionals

1. Introduction

The Building Information Modelling (BIM) methodology is currently the main digital support for the elaboration of distinct construction activities. A BIM project is developed using advanced BIM software allowing the professional team to create and to manipulate the information contained in the BIM model database (Sacks *et al.*, 2018). The methodology implementation supports the development of different stages of the project. For it, an adequate interoperability capacity between the BIM systems most used, is required to perform a large range of BIM applicability. Distinct BIM tasks are related to the various types of analysis or simulation performed over the building design information, namely the required tasks such as budgeting, construction planning, maintenance and management after occupation (Volk *et al.*, 2014).

BIM is a methodology involving a set of procedures supported by advanced technology software, based on the parametric modelling concept. In the elaboration of a project, a BIM digital model is generated, the BIM model. It is composed of parametric objects, representing with accuracy the building in analyses. The BIM model database contains the information necessary to develop distinct type of tasks, which are usually executed over the project documentation, namely, budgets, energetic simulations or construction schedules. The digital model supports a complete integration of the design stages, construction phase, or maintenance and management activities, improving the degree of collaboration among the team professionals.

The BIM concept has been implemented in the construction industry at the beginning of this century as an immersive innovation in the sector. Its benefits were quickly recognised, reflected in the quality of the projects that were developed, based on an effective process of integration and clear collaboration between partners, related to the distinct specialties involved in the construction activity (Lu *et al.*, 2014).

BIM computational tools are a strong support for the development of the different disciplines of the project, enabling their parametric modelling and easy access to all the information centralized in the BIM model created in along the project elaboration. In all areas of construction, namely, owner, designers, builders and managers, has verified the benefits in adopting BIM methodology in their activity and interest. This fact has led to its growing acceptance, at a global level and in an exponential way, leading government entities to establish rules of action and mandatory implementation dates in public construction (Khattra and Jain, 2024). In addition, the school has the mission, essential in society, to train future engineers with the fundamental teachings related to different themes in the field of construction, and should also be attentive to the technological innovations

applicable to the sector. Naturally, construction-related companies follow this perspective, encouraging professionals to seek training actions that can add to professionals the knowledge, in the BIM context, required in a globalized industrial world, increasingly competitive.

The current attention of Civil Engineering education is oriented to BIM, and it is up to the school, as the main trainer of the future engineer, to introduce this theme, as a concept that should be transmitted, contributing to support all new subjects, included in the curriculum, on a BIM-based digital support (Sampaio, 2021):

- The requirement of BIM skills in the sector, has imposed an educational maturity of alert in relation to the need in society, which has led to a progressive adaptation of the curricula taught;
- The school have been contributing positively to the updating of knowledge of professionals in the sector, through the organization of BIM training courses, in accordance with the interest and expectation expressed by the offices and public entities;
- Industry and the school are partners in finding the best strategy for establishing effective ways of teaching useful to the community.

The construction industry has demanded from schools an offer aimed at the specificity of the profession, focusing on different perspectives. Engineers and architects recognize that in a globalized world, in the pursuit of their activity, the use of BIM platforms, leads to the achievement of better products and the establishment of more competitive projects. The constant demonstration of the benefit inherent to the use of the BIM methodology, which has been registered in the various sectors, motivates designers and managers to acquire knowledge related to the concept and scope of its applicability. Professionals from all sectors are interested in knowing the BIM concept and the scope of its applicability and technical schools have been organising BIM training activities to help adding knowledge and competitiveness to industry professionals.

A short course, presented in November of 2024, at the University of Lisbon, included the methodological concepts and a wide range of the applicability sectors inherent to the development of projects in BIM. This text reflects the contents of the course. The organizational structure of the course introduces the underlying fundaments of the methodology, such as parametric modelling and interoperability, and presents the scope of the applicability of BIM.

2. Professional Course

The professional course, titled “BIM methodology: construction, structures and HBIM”, included within the activities of the Department of the Civil Engineering, of the University of Lisbon, was the most recent event offered to professionals of the construction industry. The range of professional englobes architects and civil engineers coming from consult enterprises and public organizations. The objective in attending the course was to improve their skills in order to increase competences in each particular domain of the construction activity. The contents of the program in presented in Table 1.

Table 1: Contents of the professional course “BIM methodology: construction, structures and HBIM”.

Topic	Contents
Building Information Modelling (BIM)	Concept, applicability and implementation; Parametric modelling, interoperability, and centralization; BIM tool practice in generating model structures.
BIM in construction	Conflict analysis; Adding parameters to objects; Construction planning; Quantification of materials
BIM in structural design	Interoperability; Transfer and consistency check; Graphic documentation and information centralization
Heritage Building Information Modelling (HBIM)	Concept and collection of information; Digital capture of images (photogrammetry, scanner and drones); Generation of specific families of parametric objects; Documentation file (as-built); Practical case: reconversion of a heritage building.

This follow some activity online BIM courses concerning BIM modelling project, Revit architecture and structural, and also modelling plumbing and water supply systems. The contents of those type of course included: integrating architecture, structural, and mechanical disciplines; BIM architectural modelling; advanced

techniques for architectural walls; creating detailed ceilings; structural modelling of foundations and substructures; modelling beam elements and columns; HVAC coordination and modelling.

2.1 Introduction to BIM

The introduction of the main fundaments of BIM started with the exposition of the principal concept, the range of applicability and the state-of-the-art of its implementation around the wold. The fundamental BIM notion is the generation of a centralized digital model of all construction-related information (Lozano-Díez *et al.*, 2018). BIM is frequently defined as a digital representation of the building or infrastructure, strongly supported by parametric modelling and standard formats of data. Collaborative projects can be developed over the model, requiring the use of advanced technologies and a high level of interoperability.

A practical lesson concerning the use of BIM-based tool, introduces the concept of parametric modelling, essential, to the understanding of the development of multitasking. In the modelling process, the first step is to define the base settings (work units, elevation levels, and alignments), followed by the selection and adaptation of parametric objects, associated to physical properties (Araújo, 2016). As an example of how to handling with a BIM-based tools, a structural BIM model was created (Figure 1).

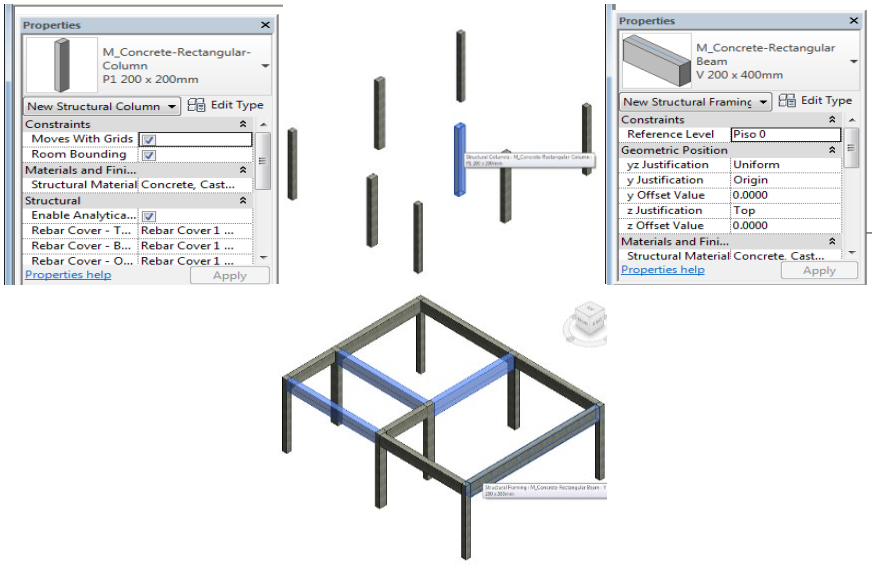


Figure 1: Modelling columns and beams.

After, there were obtained several tables of take-off of materials and elements from the generated BIM model (Sampaio, 2020) (Figure 2).

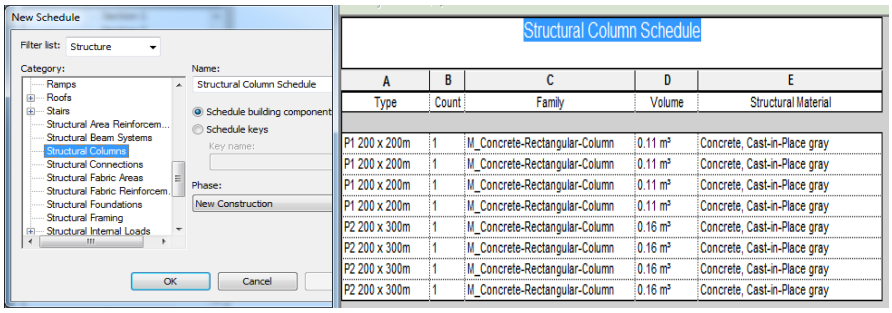


Figure 2: Interface with selection and table of columns extracted from the model.

2.2 BIM in Construction

The BIM modelling software allows to overlap the three modelled disciplines (architecture, structures and mechanic) and to support the definition of each component by a direct analysis of conflicts, identified by the system with the visualization of inconsistency messages. An analysis over the conflicts detected over the selected projects was also exposed to the audience. There are several software with conflict analysis-oriented

capabilities, namely, Tekla BIMsight, Navisworks, and Solibri Model Checker tools. In the study case shown in the course, the models of Mechanical, Electrical, and Plumbing (MEP) and structures were overlapped and an analysis of inconsistency was applied. In it, using the Navisworks and Tekla BIMsight systems a set of conflicts were listed and visualized (Figure 3)..

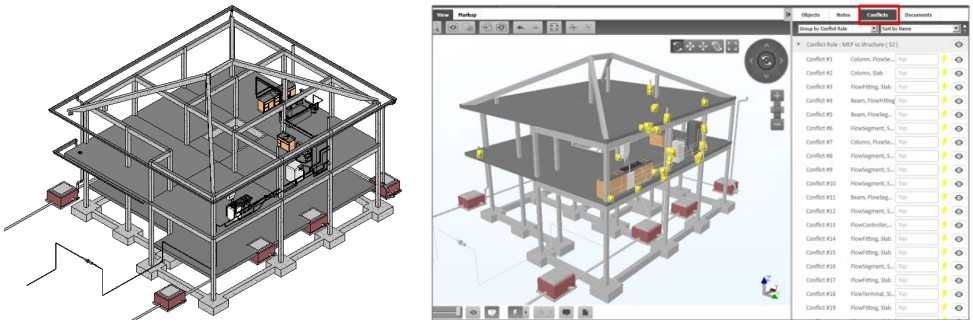


Figure 3: Identification of conflicts between models using the Navisworks BIM viewer software.

After running a conflict analyses system, the modeller adjusts each conflict situation over the BIM model, using the BIM modelling system. The conflicts detected were after adjusted accordingly in order to obtain correct situations (Figure 4).

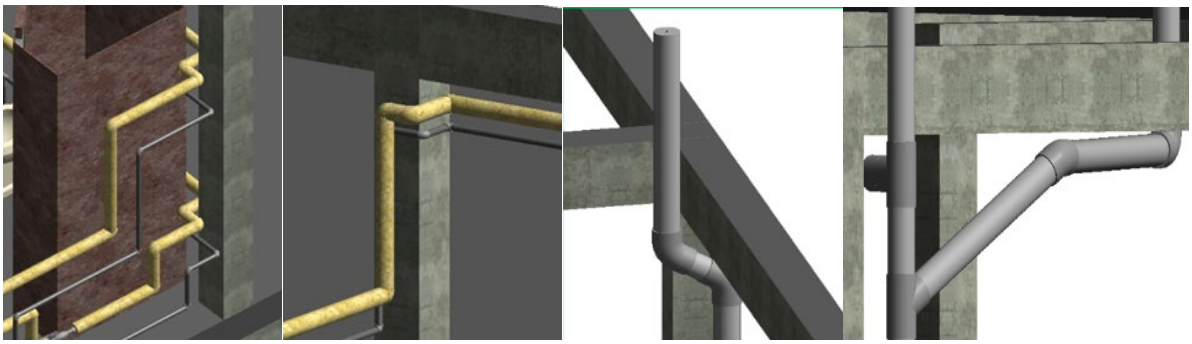


Figure 4: The required changes were after performed using a BIM modeller software.

The course also illustrates how to generate a 4D BIM model, relating to the construction process of a building (Jung and Joo, 2011). First, the complete 3D BIM model of the structural project must be defined and after the constructive sequence must be planned (phases and periods of execution). Also the allocation of human resources must be established. The construction schedule in presented in the form of a Gant map (Figure 5).

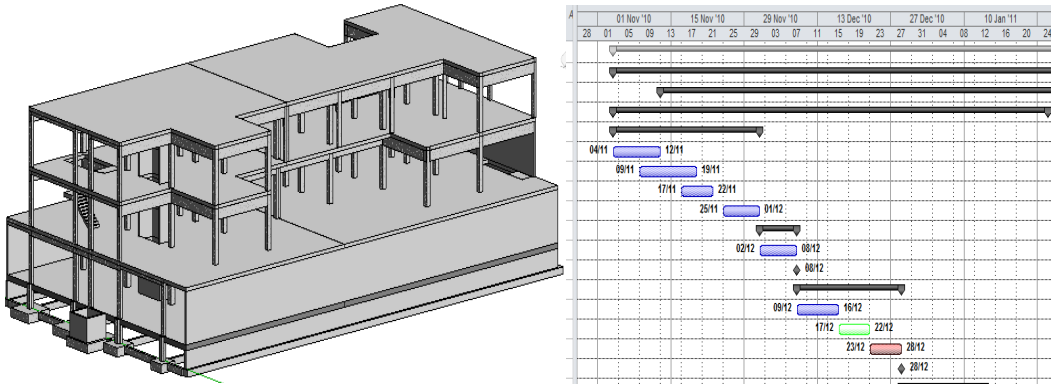


Figure 5: 3D BIM model of a structural project and the Gant map.

The 4D model is created using the Navisworks software, a BIM viewer system. The BIM model representing the structural project was exported from the modelling system to the selected BIM viewer. The model was transferred in the native format of data. In addition, the construction planning (Gantt map) file is also transferred from the Ms Project system to the Navisworks. In this software, the next step considers the association of the construction components of the imported model, forming groups or sets, with the respective construction activity identified in the Map schedule (Figure 6).

This procedure allows users to generate a 4D BIM model of the construction. The 4D model is activated and a animated simulation of the planned construction is visualized (Figure 7).

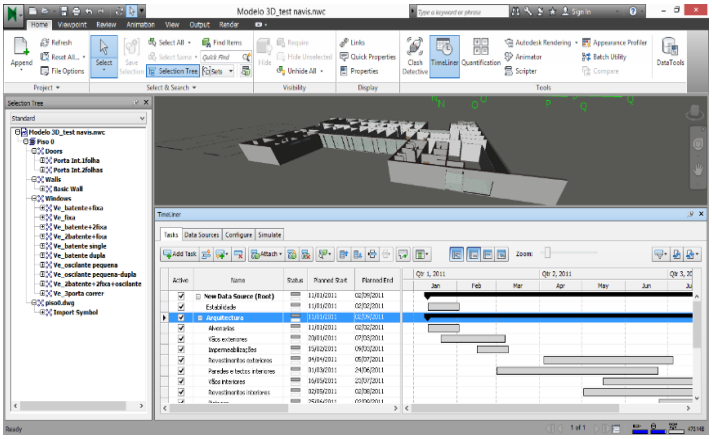


Figure 6: Generation of a 4D BIM model, by linking model elements to the respective construction task.

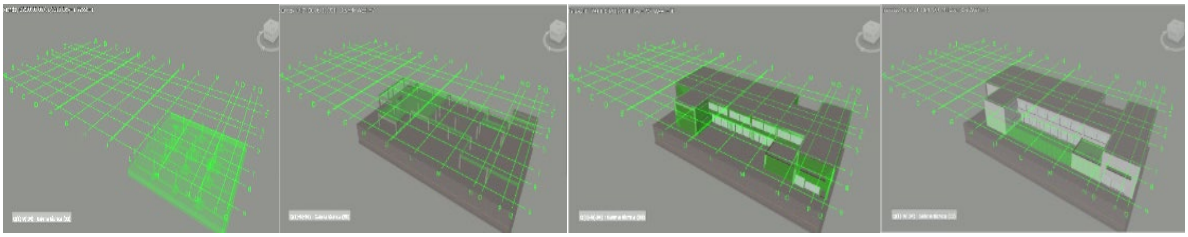


Figure 7: Simulation of the construction process.

2.3 BIM in Structural Design

Throughout the development of a project and later construction and use, several processes transferring data between software, are normally performed, and for that, a high level of interoperability, between the software used, is required. In a structural design, the transposition of models between the BIM modelling software and the structural analysis tool, is necessary. In the course, the process of transposition of structural models between modelling and calculation systems (two-way flow) was analysed in several situations involving (Sampaio *et al.*, 2021):

- ArchiCAD, Revit and AECOsim modelling system tools;
- SAP, Robot and ETABS structural dimensioning tools.

The transposition of models between systems is supported:

- in the native format, when the software belong to the same manufacturer;
- by recourse to the universal data transfer standard, the Industry Foundation Classes (IFC) format.

Concerning the structural design, the interoperability capacity, the transfer and verification of consistencies and the centralization of information and graphic documentation were performed over the selected case study presented in course (Oliveira and Sampaio, 2019). The interoperability capability analysis, verified in each model transposition process, is evaluated over several case studies of distinct volume and use (Figure 8).

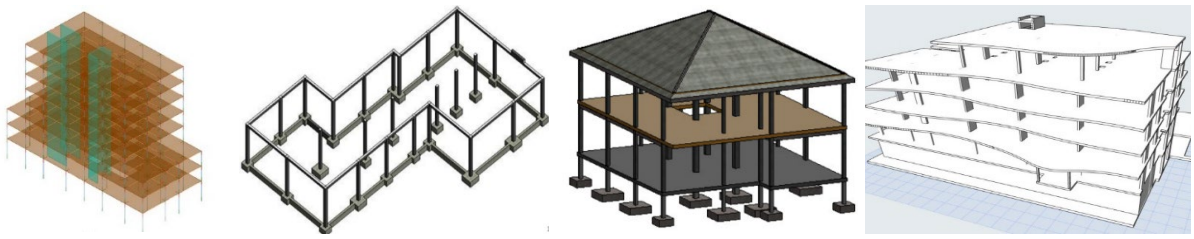


Figure 8: Structural BIM models of distinct buildings.

First, the BIM models were transferred from the modeller system to the analyses software and the geometric consistency was evaluated. Several inconsistencies were observed: stair elements were not recognized (remodelled as sloped slabs in the analyses system); the foundations were not transposed (considered as supports). However, the structural elements (columns, beams and slabs), grids and material, concrete C30/37 and A500 NR SD steel were correctly transposed, but the analytical axis of some linear finite elements and rigid connections were adapted (Figure 9).

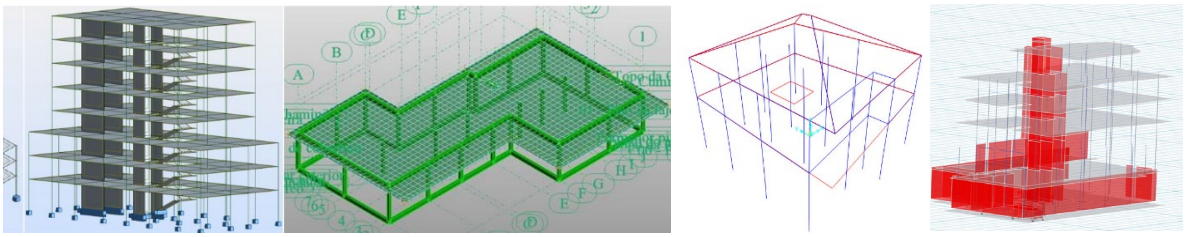


Figure 9: Structural BIM models transferr Tunkevichus Olga and Kovalerchik Arseniy, Konstantin Bagrationi ed to analyses software.

The level of interoperability between BIM-based modelling and calculation systems was assessed. It was found that:

- There are advantages of using Revit/Robot integrated platforms;
- The data flow modelling/calculation can be done with confidence, while the reverse flow is inefficient;
- The advantages are essentially related to the easy initial modelling, with some ability to transfer information post-calculation;
- It is appropriate to perform the detailing of reinforcements in the calculation system, as it allows a high capacity for the production of 3D designs and, subsequently, the inaccuracies are easily adjusted.

2.4 HBIM Concept

A recent BIM perspective the Historic or Heritage Building Information Modelling (HBIM) is applied on studies involved in the maintenance or reparation of buildings historical value or heritage relevance. Recent research related to HBIM addresses (Penjor *et al.*, 2024):

- The standardization of architectural configurations and creation parametric objects representative of applicable and reusable forms in the old construction;
- The analysis of constructive techniques used in order to identify the materials used and the solutions applied;
- The archive of registration documents, studies carried out or previous interventions and their availability for consultation by experts involved in the project.

It is required to understand geometric rules, in parametric terms, from the books of architectural patterns to the HBIM modelling process (Lagüela *et al.*, 2024). The documents of the municipal archives provides data concerning the characterization of the construction (historical epoch and traditional construction systems), the registration of refurbishing interventions and local inspection reports. In addition, the documentary collection, along with municipal archives, composed of drawings of plants, elevations and cut, referring to different dates and with yellows and reds, bring a complete description of the old building (Figure 10). Sets of specific parametric object must be generated to allow the generation of old buildings with accuracy.

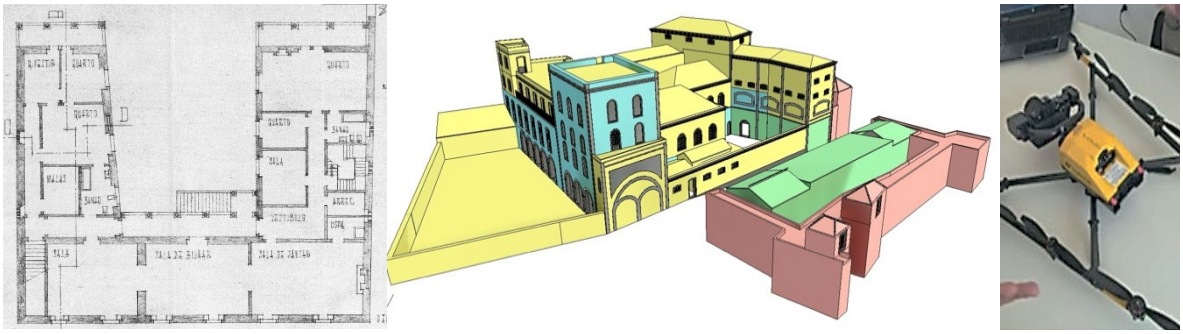


Figure 10: Technical drawing of an old building, stratigraphic representation and drone equipment.

The stratigraphic analysis covers the study of the constructive steps, which are represented through different colours, leading to a clear visual perception. In an HBIM process, it is also frequently necessary to establish a station of laser devices, properly positioned, so that, later, the points obtained can be unified, in a single cloud of space points (Figure 11). A practical case of reconversion of a building of heritage value was presented (Pinto, 2020). A proposal for the adaptation of an old building, located in Lisbon, requiring the reorganization of internal compartmentalization, but preserving their architectural characteristics, illustrated an application of HBIM (Figure 11).

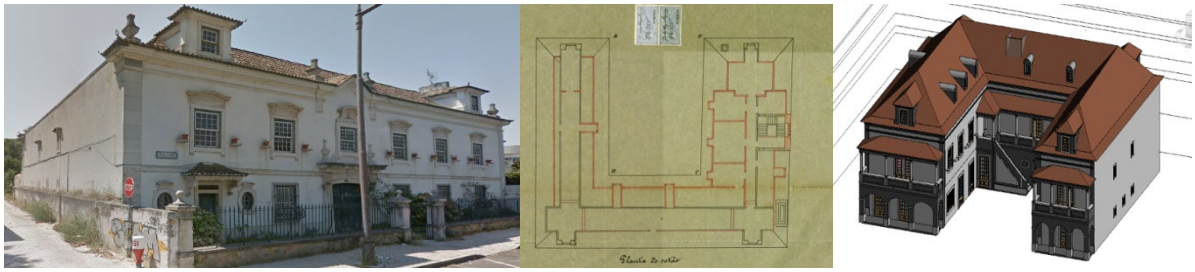


Figure 11: Building of heritage value, old drawing and BIM model of the proposal.

Within HBIM, the creation of families of specific parametric objects was required for the rigorous representation of a building of patrimonial value. As a basis for modelling, it was requested to collect the existing documentation in the Municipal Archive of Lisbon, to obtain photographs from outside and inside of the building and the registration of detailed sketches. In addition, to allow a correct geometry represented in the form of parametric objects, it was necessary to add the material type and adjust the physical and mechanical properties, in order to respect the ancestral techniques of construction. The work contributes to empowering the HBIM library of parametric objects of building components.

3. Course Evaluation

Once the training course is completed, participants are invited to respond to a small survey that allows them to convey to the coordinator and trainers their satisfaction regarding the initial expectations and what direction future courses may take in order to better meet the needs of the community. The statistical treatment was provided by the organization, illustrating in a quantitative way the quality of the course and the preferences of the topics covered, according to the perspective of the participants (Table 2).

Table 2: Evaluation of the professional course "BIM methodology: construction, structures and HBIM".

Topic	Comments
Building Information Modelling (BIM)	- Important inclusion of practical component in the training, allowing attendees learning to handle the using of a BIM tool. - Very practical, pragmatic, and available instructor who performed well as the course coordinator. - Easy empathy with the trainees and accessible responses to the questions raised. - There was a lack of IT support in the practical session and the practical case requires more time.

Topic	Comments
BIM in construction	- The available time clearly demonstrated the construction simulation capability, presenting the basic concepts in BIM, allowing for a more in-depth study in the future. - The trainer was very quick in the explanation and available to clarify questions appropriately, successfully presenting the advantages of usage.
BIM in structural design	- Practical trainer, explicit in the topics addressed, good ability to convey information and was able to respond to the questions raised. - Interesting and well-structured presentation of a practical example of software use and the application of BIM. - Demonstration of the software's potential and its limitations, well illustrated with appropriate examples.
Heritage Building Information Modelling (HBIM)	- In case of interest for very practical application in the activity of the coordinating designer. - The trainer expresses themselves clearly and demonstrates good theoretical and practical knowledge.

Compared to online BIM courses, this course adds the practical component, which adds value to the course, as it leads to a better understanding of the concept and application of BIM. The table also included the limitations identified by the participants, which supported the adjustment of the course program to be taught in the upcoming iterations of the course. Following this, the attendees listed some suggestions of topics to be included in future BIM courses: practical course on BIM; BIM applied to underground works; exploration of the BIM methodology in management and coordination; practical courses on other BIM-based software; standardization and parameterization of construction objects; characterization of BIM models 5D/6D/7D and 8D.

The course aimed to contribute to the dissemination of the potential of implementing the BIM methodology in sectors such as infrastructure, construction planning, conflict detection, or structural analyses, and was oriented to the various sectors of the construction industry. The level of satisfaction expressed by participants was analysed. The final comments were confronted with the expectation of the participants and interest in the courses.

4. Conclusions

A one-day course, BIM methodology: construction, structures and HBIM, was offered, at the University of Lisbon, to professionals of the construction industry. The contents of the training action was organized in order to cover a wide range of the applicability of BIM in the sector, and with the most recent achievements. The participants demonstrated a global interest in all topics presented, formulating questions oriented to their particular expertise. The global satisfaction of the attendance was good.

Naturally, the course, taught to a heterogeneous audience with different backgrounds, addresses the participants' initial expectations in a distinct manner. However, the overall assessment is very satisfactory, and it is noted that the topics that were most appreciated are related to the practical component, infrastructure, conflict detection, and parametric objects. According to the suggestions concerning topics to be addressed in the future, the coordination intends to include a more practical component regarding the use of BIM tools, not only for modelling but also for conflict detection, construction planning, or even structural calculation. However, its duration should be longer, with plans for courses to be two days long.

The main purpose of the course was to transmit the main concepts, the strategies of working in each type of BIM application and the reference to the main benefits and limitations. All parts of the course, including practice, construction, structures and HBIM, were essentially illustrated with study cases selected in accordance with the audience. Industry professionals feel the need to update themselves in the BIM context and the course contributes in a positive way to this learning. An in it the school and the industry collaborated in order to establish an interesting and useful program.

Ethics Declaration

No ethical clearance is needed

AI Declaration

No AI tool was applied.

References

Araújo, L. (2016) Development of a wall library in BIM methodology, Master's thesis in construction, University of Lisbon, Lisbon, Portugal,.

Jung, Y. and Joo, M. (2011) "Building information modelling (BIM) framework for practical implementation", *Automation in Construction*, 20(2), pp. 126-133, https://doi.org/10.1016/j.autcon.2010.09.010.

Khattra, S.K. and Jain, R. (2024) "Building Information Modelling: A comprehensive overview of concepts and applications, advances in research", *Advances in Research*, 25 (5), pp. 140 – 149, journalair.com/index.php/AIR/article/view/1145

Lagüela, S., Sánchez-Aparicio, L.J., González-González, E., Ospina-Bohórquez, A., Maté-González, M.Á. and González-Aguilera, D. (2024) "From 3D models to historic building information modelling (HBIM) and digital twins: a review", Diagnosis *of Heritage Buildings by Non-Destructive Techniques*, pp. 387-419, ISBN 9780443160011, https://doi.org/10.1016/B978-0-443-16001-1.00015-2.

Lozano-Díez, R.V., López-Zaldívar, O., Herrero del Cura, S. and Mayor, P.L., (2018) "First experiences in the rule of the BIM environment: The case of the degree in Building of the Polytechnic University of Madrid", *Advances in Building Education: Educative Innovation in buildings*, 2 (1), 109-121, http://polired.upm.es/index.php/abe/article/view /4233

Lu, W., Fung, A., Peng, Y., Liang, C. and Rowlinson, S. (2014) "Cost-benefit analysis of Building Information Modelling implementation in building projects through demystification of time-effort distribution curves", *Building and Environment*, Vol. 82, pgs. 317-327, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2014.08.030,

Oliveira, J.D. and Sampaio, A.Z. (2019), "BIM in structures: analysis of interoperability", *International Conference on Structural Analysis of Advanced Materials*, Ischia, Italy, https://aip.scitation.org/toc/apc/2196/1

Penjor, T., Banihashemi, S., Hajirasouli, A. and Golzad, H. (2024) "Heritage building information modelling (HBIM) for heritage conservation: Framework of challenges, gaps, and existing limitations of HBIM", *Digital Applications in Archaeology and Cultural Heritage*, 35, E00366, ISSN 2212-0548, https://doi.org/10.1016/j.daach.2024.e00366.

Pinto, A.M. (2020) "The design of structures in BIM: reconversion of building of patrimonial value. Master's Thesis, University of Lisbon, Lisbon, Portugal.

Sacks, R., Eastman, C., Lee, G. and Teicholz, P. (2018) "BIM Handbook: A Guide to Building Information Modelling for Owners, Designers, Engineers, Contractors, and Facility Managers", Third Edition, ISBN:9781119287537, DOI:10.1002/9781119287568, John Wiley & Sons, Inc.

Sampaio, A.Z. (2021) "BIM education required in construction", book: *Sustainability and Automation in Smart Constructions*, Ch. 1, pp. 3-9, Advances in Science, Technology & Innovation, Springer, Cham, https://doi.org/10.1007/978-3-030-35533-3_1

Sampaio, A.Z., Antunes, B.G. and Almeida, N. (2020) "Quantity take-off process supported by Building Information Modelling (BIM) methodology", book: *Sustainability and Automation in Smart Constructions*, Ch. 4, pp 21-28, Advances in Science, Technology & Innovation, Springer, Cham, https://doi.org/10.1007/978-3-030-35533-3_4

Sampaio, A.Z., Gomes, A.M. abd Farinha, T. (2021) "BIM methodology applied in structural design: Analysis of interoperability in ArchiCAD/ETABS process", *Journal of Software Engineering and Applications*, ISSN Print: 1945-3116, DOI: 10.4236/jsea.2021.146012

Volk, R., Stengel, J. and Schultmann, F. (2014) "Building Information Modelling (BIM) for existing buildings: Literature review and future needs", *Automation in Construction*, vol. 38, pp. 109 – 127, ISBN 0926-5805, https://doi.org/10.1016/j.autcon.2013.10.023

Integrating the Hidden Curriculum into an Edu-socio Model for Student Success

De Wet Schutte
Centre for Student Support Services (CSSS) in the Office for Academic Skills (OAS), University of the Western Cape (UWC), South Africa

dschutte@uwc.ac.za

Abstract: The journey of a university student involves ongoing adaptation to a unique, ever-evolving, multidimensional academic and social environment. No first-year student, particularly those who are first-generation, can be fully prepared for this new educational landscape upon leaving secondary school. Nevertheless, all successfully enrolled students and university management aim for "student success." This research utilised the dendrogram technique to analyse the typical university student's journey towards academic success, identifying the core elements of the hidden curriculum that serve as scaffolding for all students across disciplines and the spectrum of academic performance, enabling them to navigate their academic curriculum effectively. Drawing on a comprehensive literature review on student success, the dendrogram technique was employed in the conceptualisation process to identify and model the universal core elements of the hidden curriculum from existing research. This process shaped the findings into an edu-socio model of student success comprising six domains of core academic skills with 22 logically related essential elements. It is contended that these core domains and elements are directly linked to students' potential academic performance, reflecting the complex, dynamic, and evolving academic-focused edu-socio environment that students must navigate to achieve their academic goals and graduate. Considered the fundamental building blocks of student success, no hierarchical order can be assigned to the identified domains and elements, as all contribute to students' achievements and success. This edu-socio model for student success also served as the theoretical foundation for the Student Success Thermometer, an early warning self-assessment tool designed to inform students of their status concerning the hidden curriculum and their readiness for academic success. It is proposed that the edu-socio model and assessment tool can be applied across diverse university settings, guiding the development and evaluation of academic interventions and student support services across disciplines and campuses.

Keywords: Student success; Core Academic Skills; Hidden Curriculum; Edu-socio Model; Student Support.

1. Introduction

Student success is a key concern for both university management and academics. However, stakeholders interpret the concept differently, as there is no consensus on what constitutes student success. Weatherton & Schussler (2021, p. 2) describe this variation by stating that the "meaning of student success depends on the context and who you ask, making a singular, unifying definition largely impossible.

1.1 Academic Success from a Student's Perspective

Most articles about student success examine the attributes of successful students, such as personal development, social skills, and workplace skills, often referred to as the "holistic" development of students. In this article, student success is defined as the outcome of academic achievement from a student's perspective, specifically graduating within the designated timeframe for a specific qualification (Finn & Rock, 1997).

1.2 Research Problem

From a student's perspective, Finn and Rock (1997) argue that student success is viewed as the overall achievement of passing each academic year and ultimately graduating. It is not surprising that most research in the field of "student support" concentrates on first-year students and the academic challenges they face during the transition from secondary school to university, where they are "expected" to succeed (Wrench et al., 2013, pp. 730–746; Wang et al., 2013, pp. 205–212; Torenbeek et al., 2010, pp. 659–675; Credé et al., 2012, pp. 133–165; Gilbreath et al., 2011, pp. 47–62; Manik, 2015, p. 107). This research aims to create a student success model that emphasises academic achievement (graduation) and combines theory and practice as the foundation for a universal early warning self-assessment tool.

1.3 Research Question

The research question arose from a thorough review of extensive literature on student success and support, aiming to identify key educational and social factors that foster student achievement across university settings. It was developed in response to the question: What makes a successful university student? Additionally, it is

theorised that the absence of these attributes would address the counter-research problem statement: What leads to an unsuccessful university student?

2. Methodology

A scientific model is developed by integrating real-world research applications with scientific logical reasoning and conceptual interpretation (Gilbert, 2004, pp. 115-130). The data used in this study's modelling process were gathered from an extensive literature review on student success, combined with a content analysis of 28 electronic student self-assessment tools currently in use. In this research, the dendrogram technique (Schutte, 2006, pp. 616-630) was applied to help develop a model related to student success. During the problem formulation and research design, an inductive approach was adopted to support the process of identifying and logically integrating concepts, based on domains and elements extracted from the literature and the analysis of electronic tools in practice. Throughout the modelling process, the focus on student success skills was defined as skills academically associated with the environment relevant to students' academic achievement, which are commonly found in any tertiary educational institution.

3. Findings: Modelling the Results

The dendrogram (Figure 1) provides a comprehensive overview of the core skills identified and integrated, both theoretically related and practice-driven, emphasised in the literature that every university student should master across various settings for academic success. The contents of this summative inductive dendrogram are presented as a universal university edu-socio student success model (Figure 2). This model also serves as the operational and evaluation framework for all three response-to-intervention (R.T.I.) levels, within which core academic intervention and support services at any university aim to address student needs for academic success (Christo, 2014, pp. 33-44).

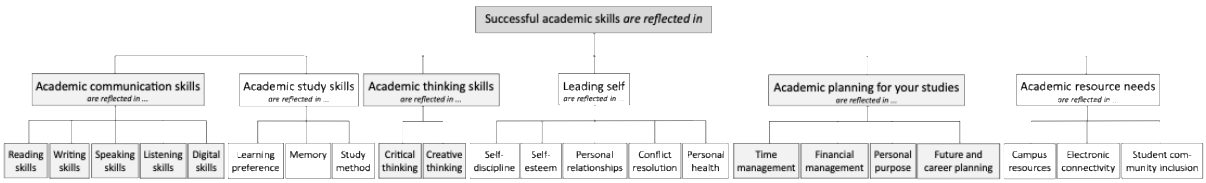


Figure 1: Inductive dendrogram of the edu-socio model for student success and support services.

3.1 Logical Identification and Integration of Domains and Elements into the Edu-socio Student Success Model

The following discussion explains the logical reasoning behind the 22 elements linked to each of the six domains in the dendrogram, reflecting the universally essential hidden curriculum skill sets necessary for students' academic success, as identified in the literature (Figure 1).

3.2 Domain 1: Academic Communication Skills

Within the university environment, academic communication for student success is highly structured and includes various modes, such as formal lectures, which mainly aim to develop listening skills and share information through both formal and informal discussions with lecturers and peers. This involves speaking (Iksan et al., 2011, p. 74) and listening skills (Sen, L., 2009, pp. 26-43). Furthermore, academic reading skills may involve specific comprehension abilities that require subject-specific vocabulary (subject jargon) through reading textbooks and other written materials (Sabbah et al., 2020, pp. 138-142; Iksan et al., 2011, p. 74). In today's computer-centric information age, essential computer literacy is crucial for academic success in any university setting. Students rely heavily on computers to access course materials, conduct research, communicate with lecturers and peers, write assignments, use specialised programmes, and manage administrative tasks (Nash, 2009, pp. 88-92). From this, it can be concluded that in this edu-socio framework, the fundamental academic communication skills needed for students to succeed at any university are the five skills (elements) mentioned above: (i) reading, (ii) writing, (iii) listening, (iv) speaking, and (v) digital communication skills.

3.3 Domain 2: Academic Study Skills.

The underlying logical inductive argument is that successful academic study skills among students are reflected in (i) an academic learning style preference that works for the student (Lowery, 2009, pp. 57-60; Cekiso, 2011, pp. 1298-1309; Xing, 2023, p. 264), (ii) study method (Mutsotso & Abenga, 2010, pp. 811-812), and (iii) a strong memory that helps in integrating new knowledge with existing information (Dolgova et al., 2020, p. 1632) as well as recalling subject content during reflection and examinations that suit each student. Although some learning styles, such as visual, auditory, kinaesthetic, and reading/writing, may be more common among music students than mathematics students, the purpose of including this domain in the edu-socio student success model is not to identify the optimal combination of learning styles for inclusion. Instead, it aims to recognise that, at a fundamental level, specific effective academic study skills are necessary, reflected in (i) a preference for academic learning and (ii) a study style that incorporates (iii) practical memory skills tailored to each student's needs, enabling them to succeed academically. However, what is crucial is that students must adopt a learning style that best suits them to achieve academic success.

3.4 Domain 3: Academic Thinking Skills

There is a broad consensus among educators that critical thinking skills are vital for student success and form the foundation of academic (scientific) thinking. This skill is essential for analysing the conditions or reasons that lead an author or speaker to make a particular statement or reach an inevitable conclusion. (Van der Zanden et al., 2018, p. 58; Afkhaminia et al., 2018, p. 177; Huber et al., 2016, p. 431-432; Lai, 2011, pp. 41-44; Shim & Walczak, 2012, p. 16). However, for this model, good academic thinking skills include both critical and creative thinking skills (Van der Zanden et al., 2018, pp. 72-74; Fatmawati et al., 2019, pp. 1-9). Critical and creative thinking are two interconnected aspects of academic work. Essentially, creative thinking for a university student involves deliberately gaining new insights and diverse ideas by reorganising existing knowledge to develop new information through the perspective of critical and creative scientific thinking, thus addressing gaps in current knowledge (Fatmawati et al., 2019, p. 7).

3.5 Domain 4: Leading Self to Academic Success

The leading self, sometimes called “self-agentic capabilities” (Nnadozie et al., 2023, p. 15), is the ability of students to influence and guide their thoughts and actions to successfully achieve their academic goals (Bandura, 2008). In this proposed educational-social model of student success, the inductive argument suggests that, at its core, the relevant attributes of the leading self that contribute to academic success are reflected in five logically connected elements (attributes): (i) self-discipline for academic work (Zimmerman & Kitsantas, 2014, pp. 145-155; Şimşir & Dilmaç, 2020, pp. 153-171; Shim & Walczak, 2012, pp. 16-30; De Wit et al., 2012, pp. 1-25), (ii) positive academic self-esteem among peers (Zhou et al., 2015, pp. 163-179), (iii) relationships that boost academic performance (Swenson Goguen et al., 2011, pp. 319-377; Dyson & Renk, 2006, pp. 1231-1244; Saud, 2021, p. 58), (iv) skills to manage intra- and interpersonal conflicts in ways that support academic achievement (Hiester et al., 2009, pp. 521-538; Sax and Weintraub, 2014, pp. 113-127), and (v) personal physical and psychological health that meets the demands of academic success (Zakir et al., 2023, pp. 4598-4604; Fenning & May, 2013, pp. 635-650). Although various personal attributes are often emphasised and described by researchers advocating for a “holistic approach” to personal health, this domain and its elements aim to define only the core needs directly linked to a student's successful academic performance.

3.6 Domain 5: Academic Future Planning

Both van Rooij et al. (2018, p. 761) and Ma and Shea (2019, p. 8) found that the success of first-year students is positively related to a subject choice that aligns with their anticipated career orientation. Thus, effective academic and future planning are also considered fundamental aspects linked to student success. The inductive reasoning used in generating the elements of this domain is that successful academic planning for a student is reflected in a clear (i) career orientation (Azhenov et al., 2023, p.7) and is associated with a definite (ii) personal purpose in life (Pfund et al., 2020, p. 104). However, a successful future career orientation is also demonstrated through sound financial planning (Naidoo & McKay, 2018, p. 167) and time management skills (Razali et al., 2018, p. 6), which support a student's journey towards achieving academic success. Supported by the literature, these four elements are regarded as essential skills related to academic planning for the future domain that students must adequately master throughout their university journey.

3.7 Domain 6: Academic Resource Needs

Recognising the importance of support services as a vital component of student success in helping university students transition from secondary school to university, this edu-socio model suggests that adequate support for academically successful students is reflected in three core elements: (i) the accessibility and awareness of campus support systems when needed, (ii) a strong sense of belonging within the student community, and (iii) sufficient electronic connectivity between students and the university's information and support services. Johnson et al. point out that thriving students familiarise themselves with the diverse services and resources available on campus in these three areas, which they can utilise when necessary to assist them in their academic journeys (Johnson et al., 2022, p. 10; Ramsey et al., 2007; Sevinc & Gizir, 2014). A sense of community inclusion among students involves having a friend who shares academic interests during discussions and preparations for exams or assignments, as well as experiencing feelings of discrimination and exclusion due to disability, race, gender, religion, or any perceived marginalisation (Stewart-Ginsburg et al., 2023, pp. 396-399). On any modern university campus, academic communication and information are distributed electronically, and internet access is regarded as a basic necessity for engaging with academic research publications and documented discourses. Without adequate and functional internet connectivity (hardware or software), students are unable to access various academic sources, communicate with lecturers, or submit assignments (Costello et al., 2022, pp. 314-326; Russo et al., 2014, pp. 84-96).

4. Facilitation of Student Support on Campus

Van Rooij et al. (2018, pp. 749–767) propose that the level of "preparedness" for academia when entering the university campus as a first-year student, along with the "responsiveness" to the constantly changing academic demands, serves as a crucial indicator of their academic success or failure. Historically, student support has focused on those at risk of academic failure. Since the aim of this article is to develop a universal model that identifies and incorporates only the core skills necessary for academic success within the tertiary edu-socio environment of a typical university setting, it is, in essence, a quest for what Gilbreath et al. (2011, p. 47) refer to as the “student-university fit” between students and their edu-socio environment. It is understood that all university campus environments exhibit differences that can be described as variations of elements such as educational approaches, institutional traditions, educational facilities, and a range of social factors, which may include the institution’s history, cultural traits of lecturers and students, the physical environment (including location, architecture, campus layout, open spaces, and recreational facilities), and the available student support services, to name a few. Within this complex and multidimensional educational-social context, students must continually navigate their way toward their ultimate goal of graduation. Although some combinations and the significance of this variation in edu-socio elements may result in unique tendencies, this research aimed to identify the fundamental components that can inform a universal model for student success support services encompassing six core domains (Figure 2). Considered core skills, they are deemed vital for success across all educational and social (edu-social) environments, with academic performance levels serving as an indicator of the degree of the “student-university fit” (Gilbreath et al., 2011, p. 47).

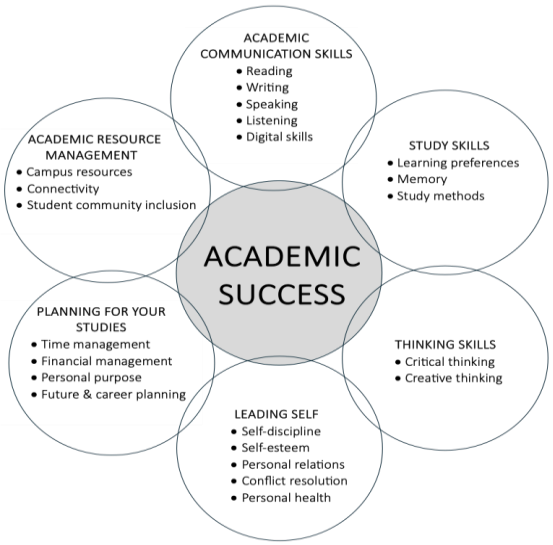


Figure 2: The Edu-socio Model for Student Success: Domains and Elements

Alongside the range of academic criteria or requirements for student success identified by various researchers, it is proposed that these six domains and their 22 associated skill elements of this edu-socio model for student success represent the essential universal core skills students need for academic success at all universities. Consequently, poor performance by a student in any of the 22 sub-clusters acts as an early warning signal of potential academic underperformance, possible failure, and the potential need for individual intervention or adjustment. The model also proposes a universal composite academic skills scaffolding for student support services across the spectrum of academic performance and university settings, encompassing all aspects of the three-tier response-to-intervention (RTI) standard protocol approach (Christo, 2014, pp. 33-44).

Based on the edu-socio model for student success, the Student Success Thermometer — a self-assessment study alert tool — was developed. The evaluation provides students with a personal profile of their level of studiousness, based on six domains and 22 related elements of the hidden curriculum. The results were successfully tested and are currently utilised by students at a university in South Africa. The tool uses faculty and academic year as independent variables to prioritise hidden curriculum intervention strategies, based on composite results derived from these two variables. It is currently employed in designing intervention workshops and coaching content by the Office for Academic Skills.

5. Conclusion

This article aimed to identify the core edu-socio elements across university campuses that influence students' academic performance. Six domains were identified, covering various factors, including unique educational (pedagogical) approaches, campus traditions, facilities, and psycho-social aspects. These factors include elements such as institutional history, distinctive teaching characteristics, the cultural and anthropological makeup of the student body, and the physical environment, which includes the institution's location, architecture, campus layout, open spaces, recreational facilities, and available student support services. Collectively, these are referred to as the universal edu-socio environment. However, as the core domains and elements linked to students' potential academic performance, this edu-socio model reflects the complex, unique, and constantly evolving academic-focused edu-socio environment that students must navigate to achieve their academic goals and graduate. This edu-socio model for student success highlights the universal elements derived from various existing models and their contributions to student success. As the fundamental elements of student success, it is impossible to assign a hierarchical order to these six identified domains and their 22 associated elements. This edu-socio model also functions as a potential framework for intervention strategies implemented by student support services across university environments, all aimed at the singular goal of student success on the path to graduation.

Ethical & AI Declaration

The Humanities and Social Sciences Research Ethics Committee of the University approved the methodology and amendments for the development of the Student Success Thermometer©.

The author also declares that AI was not used to generate any content for this article.

References

Adebayo, B. (2008). Cognitive and Non-Cognitive Factors Affecting the Academic Performance and Retention of Conditionally Admitted Freshmen. *Journal of College Admission*. https://files.eric.ed.gov/fulltext/EJ829456.pdf.

Afkhaminia, F., Siamian, H., Behnampour, N., Moghimi, A., & Karimpour, S. (2018). Study of Student Success Indicators Based on the Viewpoints of the Students of Mazandaran University of Medical Sciences. *Acta Informatica Medica*, *26(3).* https://www.ejmanager.com/mnstemps/6/6-1536659046.pdf?t=1737720953

Álvarez, M.M. & Maestre, B.R. (2021). What Makes a Good University Student? *International Journal of Humanities, Social Sciences and Education, 8(11)*. https://www.arcjournals.org/pdfs/ijhsse/v8-i11/14.pdf.

Alyahyan, E., Düştegör, D. (2020). Predicting academic success in higher education: literature review and best practices. *Int. J. Educ. Technol. High Educ.*, 17(3). https://doi.org/10.1186/s41239-020-0177-7.

Azhenov, A., Kudysheva, A., Fominykh, N. & Tulekova, G. (2023). Career decision-making readiness among students in the higher education system: Career course intervention. *Frontiers in Education, 8(1097993).* file:///Users/user/Desktop/feduc-08-1097993.pdf

Bandura, A. (2008). Toward an Agentic Theory of the Self. In H. W. Marsh, R. G. Craven, & D. M. McInerey (Eds.), Self-Processes, Learning, and Enabling Human Potential (pp. 15–49). *Advances in Self-Research, Greenwich, CT: Information Age Publishing*.

Cekiso, M.P. (2011). Profiling learning style preferences of first-year University students: Implications for course design and instruction. S.A.J.H.E., 25(7). https://journals.co.za/doi/pdf/10.10520/EJC121405.

Christo, C. (2014). Critical Characteristics of a Three-Tiered Model Applied to Reading Interventions. California School Psychologist, 10. https://doi.org/10.1007/BF03340919.

Costello, M.A., Nagel, A.G., Hunt, G.L., Rivens, A.J., Hazelwood, O.A., Pettit, C. & Allen, J.P. (2022). Facilitating connection to enhance college student well-being: Evaluation of an experiential group program. American Journal of Community Psychology, 70(3-4). https://doi.org/10.1002/ajcp.12601.

Credé, M., & Niehorster, S. (2012). Adjustment to college as measured by the student adaptation to college Questionnaire: A quantitative review of its structure and relationships with correlates and consequences. Educational Psychology Review, 24. http://dx.doi.org/10.1007/s10648-011-9184-5.

Crisp, G., Taggart, A., & Nora, A. (2015). Undergraduate Latina/o Students. *Review of Educational Research, 85(2).* https://doi.org/10.3102/0034654314551064.

De Wit, K., Heerwegh, D. & Verhoeven, J.C. (2012). Do ICT Competences Support Educational Attainment at University? Journal of Information Technology Education: Research, 11(1). Informing Science Institute. Retrieved April 5, 2024, from https://www.learntechlib.org/p/111490/.

Dolgova, V., Golieva, G., Kondratieva, O., Kapitanets, E., & Shayakhmetova, V. (2020). Studying The Relationship of Memory Properties And Performance Of College Students. Series: The European Proceedings of Social and Behavioural Sciences https://www.europeanproceedings.com/article/10.15405/epsbs.2020.10.05.215.

Dyson, R. & Renk, K. (2006). Freshmen adaptation to university life: Depressive symptoms, stress, and coping. Journal of Clinical Psychology, 62(10). http://dx.doi.org/10.1002/jclp.20295.

Fatmawati, A., S Zubaidah, S., Mahanal, S. & Sutopo. (2019). Critical Thinking, Creative Thinking, and Learning Achievement: How They Are Related. *Journal of Physics: Conference Series, 1417, Mathematics, Informatics, Science and Education*. https://iopscience.iop.org/article/10.1088/1742-6596/1417/1/012070/pdf

Fenning, B.E. & May, L.N. (2013). "Where there is a will, there is an A": Examining the roles of self-efficacy and self-concept in college students' current educational attainment and career planning. *Social Psychology of Education, 16*. https://link.springer.com/article/10.1007/s11218-013-9228-4.

Finn, J.D., & Rock, D.A. (1997). Academic success among students at risk for school failure. Journal of Applied Psychology, 82, 221-234. https://psycnet.apa.org/record/1997-03393-002

Gamlath, S. (2021). Peer learning and the undergraduate journey: A framework for student success. Higher Education Research & Development, 41(3). https://www.tandfonline.com/doi/full/10.1080/07294360.2021.1877625.

Gilbert, J.K. (2004). *Models and Modelling: Routes to More Authentic Science Education.* International Journal of Science and Mathematics Education 2(2):115–130. DOI: 10.1007/s10763-004-3186-4.

Gilbreath, B., Kim, T. & Nichols, B. (2011). Person-Environment Fit and Its Effects on University Students: A Response Surface Methodology Study. Research in Higher Education, (pp. 47–62). https://link.springer.com/article/10.1007/s11162-010-9182-3.

Hiester, M., Nordstrom, A. & Swenson, L.M. (2009). Stability and change in parental attachment and adjustment outcomes during the first-semester transition to college life. Journal of College Student Development, 50(5). http://dx.doi.org/10.1353/csd.0.0089.

Huber, C.R., & Kuncel, N.R. (2016). Does College Teach Critical Thinking? A Meta-Analysis. Review of Educational Research, 86(2). https://doi.org/10.3102/0034654315605917.

Iksan, Z.H., Zakaria, E., Meerah, T.S.M., Osman, K., Lian, D.K.C., Mahmud, S.N.D. & Krish, P. (2011). *Communication Skills among University Students. Procedia - Social and Behavioral Sciences, 5.* https://doi.org/10.1016/j.sbspro.2012.09.247.

Johnson, C., Gitay, R., Abdel-Salam, S.G., BenSaid, A., Ismail, R., Naji Al-Tameemi, R.A., Romanowski, M.H., Kazem Al Fakih, B.M. & Hazaa, K.A. (2022). Student support in higher education: Campus service utilisation, impact, and challenges. Heliyon, 8(12). https://pmc.ncbi.nlm.nih.gov/articles/PMC9834745/pdf/main.pdf

Lai, E.R. (2011). Critical thinking: A literature review. Pearson. http://paluchja-zajecia.home.amu.edu.pl/seminarium_fakult/sem_f_krytyczne/Critical%20Thinking%20A%20Literature%20Review.pdf.

Lewin, T., & Mawoyo, M. (2014). Student access and success: Issues and interventions in South African universities. Inyathelo published the report, The South African Institute for Advancement, with the support of The Kresge Foundation. https://kresge.org/resource/student-access-and-success-issues-and-interventions-in-south-african-universities/.

Ma, W.W., & Shea, M. (2019). First-Generation College Students' Perceived Barriers and Career Outcome Expectations: Exploring Contextual and Cognitive Factors. Journal of Career Development, 48(2). file:///Users/user/Desktop/MaShea2019FirstGenCollegeStudentsPerceivedBarriersCareerOutcomes.pdf

Manik, S. (2015). 'As a person you need help every now and then': Accessing students' support needs in a higher education environment—South African Journal of Higher Education Volume 29(3).

Mutsotso, S.N., & Abenga, E.S.B. (2010). Study methods for improving quality learning and performance in higher education. Educational Research and Review 5(12). https://academicjournals.org/journal/ERR/article-full-text-pdf/723D2174219.pdf.

Naidoo, A. & McKay, T.J.M. (2018). Student funding and student success: A case study of a South African university. South African Journal of Higher Education, 32(5). https://www.journals.ac.za/index.php/sajhe/article/view/2565.

Nash, J. (2009). Computer skills of first-year students at a South African university. S.A.C.L.A. '09: Proceedings of the 2009 Annual Conference of the Southern African Computer Lecturers' Association https://dl.acm.org/doi/10.1145/1562741.1562752.

Nnadozie, V., & Khumalo, S. (2023). Self-agency and Academically High-performing Students' Success: Towards a Praxis for Academic Support in one South African University. Journal of University Teaching & Learning Practice, 20(1). https://files.eric.ed.gov/fulltext/EJ1382418.pdf

Pfund, G.N., Bono, T.J. & Hill, P.L. (2020). A Higher Goal During Higher Education: The Power of Purpose in Life During University. *Translational Issues in Psychological Science, 6(2)*. https://www.researchgate.net/publication/341798379_A_higher_goal_during_higher_education_The_power_of_purpose_in_life_during_university

Razali, S.N.A.M., Rusiman, M.S., Gan, W.S., & Arbin, N. (2018). The Impact of Time Management on Students' Academic Achievement. I.O.P. Conf. Series: Journal of Physics: Conference Series, 995. https://iopscience.iop.org/article/10.1088/1742-6596/995/1/012042/pdf

Rossouw, N. & Frick, L. (2023). A conceptual framework for uncovering the hidden curriculum in private higher education. Cogent Education, 10:1, 2191409. https://doi.org/10.1080/2331186X.2023.2191409. DOI:10.1080/2331186X.2023.2191409.

Russo, T., Fallon, M., Zhang, J. & Acevedo, V. (2014). Today's university students and their need to connect. *Brock Education Journal, 23(2)*. https://doi.org/10.26522/brocked.v23i2.391.

Sabbah, S.S., Hallabieh, F. & Hussein, O. (2020). Communication Skills among Undergraduate Students at Al-Quds University. *World Journal of Education*, 10(6). https://files.eric.ed.gov/fulltext/EJ1284411.pdf.

Saud, W.I. (2021). Success Factors at University from Students' Perspective. Technium Social Sciences Journal, 16. https://www.researchgate.net/publication/349223588_Success_factors_at_university_from_students'_perspective.

Sax, L.J. & Weintraub, D.S. (2014). Exploring the parental role in first-year students' emotional well-being: Considerations by gender. Journal of Student Affairs Research and Practice, 51. http://dx.doi.org/10.1515/jsarp-2014-0013.

Schutte, De W. (2006). The dendrogram technique is a tool to develop questionnaires. Journal of Public Administration, 41(3). https://journals.co.za/doi/abs/10.10520/EJC51478.

Sevinc, S., & Gizir, C.A. (2014). Factors negatively affecting university adjustment from the view of first-year university students: The case of Mersin University. Educational Sciences: Theory and Practice, 14(4). https://files.eric.ed.gov/fulltext/EJ1045063.pdf.

Shim, W. J., & Walczak, K. (2012). The impact of faculty teaching practices on the development of students' critical thinking skills. International Journal of Teaching and Learning in Higher Education. https://www.semanticscholar.org/paper/The-Impact-of-Faculty-Teaching-Practices-on-the-of-Shim-Walczak/a7d45701942d8a67293997f4743043037fff0394.

Şimşir, Z., & Dilmaç, B. (2020). Self-Discipline in the Life of University Students: A Qualitative Research. Research on Education and Psychology, 4(2). https://dergipark.org.tr/en/pub/rep/issue/57721/810203.

Stankov, L., Morony, S., & Lee, Y.P. (2014). Confidence: The best non-cognitive predictor of academic achievement? Educational Psychology, 34(1). https://doi.org/10.1080/01443410.2013.814194.

Stewart-Ginsburg, J., Kittelman, A. & Rowe, D.A. (2023). Increasing Community Inclusion for Students With Disabilities. *TEACHING Exceptional Children*. https://doi.org/10.1177/00400599231178600.

Swenson Goguen, L.M., Hiester, M.A. & Nordstrom, A.H. (2011). Associations among peer relationships, academic achievement, and persistence in college. Journal of College Student Retention, 12(3). http://dx.doi.org/10.2190/CS.12.3.d.

Torenbeek, M., Jansen, E., & Hofman, A. (2010). The effect of the fit between secondary and university education on first-year student achievement. *Studies in Higher Education, 35(6)*. http://dx.doi.org/10.1080/03075070903222625.

Van den Berg, M.N. & Hofman, W.H.A. (2005). Student Success in University Education: A Multi-measurement Study of the Impact of Student and Faculty Factors on Study Progress. Higher Education, 50. https://doi.org/10.1007/s10734-004-6361-1

Van der Zanden, P.J., Denessen, E., Cillessen, A.H., & Meijer, P.C. (2018). Domains and predictors of first-year student success: A systematic review. *Educational Research Review, 23*. https://doi.org/10.1016/j.edurev.2018.01.001.

van Rooij, E.C.M., Ellen P. W. A., Jansen, E.P.W.A., Wim, J. C. M. & van de Grift, W.J.M.C. 2018. First-year university students' academic success: The importance of academic adjustment. *European Journal of Psychology of Education, 33.* https://doi.org/10.1007/s10212-017-0347-8.

van Zyl, A., Dampie, G., & Ngwenya, N. (2020). Effective Institutional Intervention Where It Makes the Biggest Difference to Student Success: *The University of Johannesburg (U.J.) Integrated Student Success Initiative (I.S.S.I.). Journal of Student Affairs in Africa, 8(2).* DOI: https://doi.org/10.24085/jsaa.v8i2.4448.

Wang, Y., Cullen, K.L., Yao, X., & Li, Y. (2013). Personality, freshmen proactive social behavior, and college transition: Predictors beyond academic strategies. *Learning and Individual Differences, 23.* http://dx.doi.org/10.1016/j.lindif.2012.09.010.

Weatherton, M., & Schussler, E.E. (2021). Success for All? A Call to Re-examine How Student Success Is Defined in Higher Education. *C.B.E. - Life Science Education, 20(1).* https://www.lifescied.org/doi/full/10.1187/cbe.20-09-0223.

Wrench, A., Garrett, R., & King, S. (2013). Guessing where the goal posts are: Managing health and well-being during the transition to university studies. Journal of Youth Studies, 16(6). http://dx.doi.org/10.1080/13676261.2012.744814.

Xing, B. (2023). A Review of Research on Learning Style. *Open Journal of Modern Linguistics, 13(2).* Doi: 10.4236/ojml.2023.132016.

Yorke, M., & Longden, B. (2004). Retention and student success in higher education. McGraw-Hill Education.

Zakir, S., Khan, S., Siraj, D. (2023). Relationship between Self-Leadership and Academic Performance of Students: Empirical Evidence from Public Sector Universities in AJ&K, *Pakistan Journal of Humanities and Social Sciences 11(4).* https://journals.indexcopernicus.com/api/file/viewByFileId/1925970.

Zhou, Y.-X., Ou, C.-Q., Zhao, Z.-T., Wan, C.-S., Guo, C., Li, L. & Chen, P.-Y. (2015). The impact of self-concept and college involvement on the first-year success of medical students in China. *Advances in Health Sciences Education, 20*. http://dx.doi.org/10.1007/s10459-014-9515-7.

Zimmerman, B.J., & Kitsantas, A. (2014). Comparing Students' Self-Discipline and Self-Regulation Measures and Their Prediction of Academic Achievement. *Contemporary Educational Psychology, 39(2)*. https://www.sciencedirect.com/science/article/pii/S0361476X14000162

AI in Higher Education: IRIS and Turnitin Challenges and Opportunities

Nothando C. Shiba[1], Ilunga Masengo[2] and Linda L. Jewell[1]
[1]Department of Chemical and Materials Engineering, Florida Campus, University of South Africa, Roodepoort 1710, South Africa
[2]Department of Civil Engineering, Florida Campus, University of South Africa, Roodepoort 1710, South Africa

eshibanc@unisa.ac.za

Abstract: The emergence of advanced educational technologies such as Artificial Intelligence (AI) has revolutionised learning and teaching methods. For example, at the University of South Africa (UNISA), IRIS is used for exam invigilation. This tool provides educators assurance of assessment integrity during online and remote assessment. It monitors students' movement during the exam by recording a video of their face, audio, and taking screenshots of their computer screens at regular intervals and reports any alleged misconduct. However, IRIS often does not detect, where AI such as ChatGPT was used to generate answers. Furthermore, the university policies currently allow the use of Grammarly and Quillbot apps, which are increasingly incorporating AI features. These apps generate real time writing suggestions and rephrasing information from the internet to prevent any plagiarism. In addition, the University uses Turnitin's AI detection software that gives false positives if the student has written well in the passive voice. Considering that apps constantly evolve, the university needs to regularly check and mandate their use based on the latest features of the app. ChatGPT is amongst the latest AI writing apps, it enables students to easily access pre-written content without actively engaging in critical thinking and learning, potentially leading to widespread plagiarism, which poses a threat to education. In this paper, we present a concise overview of the use of IRIS and Turnitin invigilation and detection tools for online assessments. In an action study, the co-authors reflect on the implications of the use of these AI apps on the integrity and validity of the assessments. Directions for further research are suggested.

Keywords: Detection of Cheating, AI in Education, AI Detection, Online Invigilation

1. Introduction

Accelerated by the COVID-19 pandemic, artificial intelligence (AI) has opened up new opportunities for educational advancement and innovations (Mphaga, 2024). The urgent need to strengthen the education sector during the pandemic, prompted a widespread use of technology in education. This included moving to online teaching and learning platforms for assessment, leveraging internet access, AI and mobile technology. Open distance e-learning (ODeL) institutions embraced digital integration and technological innovations, while staying ethically grounded (Tsindoli 2025). AI information and communication technology has long been at the forefront of technological advancements in education in the global north (Kuleto et al. 2021), however, African countries like South Africa have not yet fully harnessed its potential.

New technologies are important for lecturers to facilitate and reshape teaching and learning paradigms for online classes in ODeL institutions. ODeL emphasizes independent learning through a facilitator via an acceptable medium or platform to one or a group of learners (Tanyanyiwa and Madobi 2021). Platforms like Microsoft Teams™ (n.d), Zoom™ (n.d.) and Google Meet™ (n.d.) have become important tools to conduct online lessons, with platforms like Moodle™ (n.d.) and Blackboard (n.d.), for course management, student participation, and assessment (Yen et al. 2021, Aswir et al. 2021). AI-based proctoring tools such as IRIS (n.d.), Proctorio (n.d.) and Honorlock (n.d.) are used to monitor student behaviour during exams and online assessments to prevent cheating (Dash et al. 2022). Other widely used tools in ODeL include: Turnitin, Grammarly Premium and Copyscape to check the originality of content in assessment scripts (Bahuguna et al. 2024).

While researchers argue that embracing these technologies can lead to professional growth for lecturers, particularly through the integration of AI applications with traditional teaching methods, AI in education is said to lessen cognitive growth. Lecturers have not been trained to integrate AI into traditional pedagogy and institutions do not have the necessary infrastructure and policies in place. This paper considers staff perceptions of AI detection and the impact of reporting false positives in students' work when using IRIS invigilation and Turnitin (Tii) AI detection software, for online assessments. The authors' reflections suggest that AI detection and monitoring tools are not completely reliable, and that human-based judgement is still required for assessment evaluations.

2. Literature Review

2.1 AI in Education

With the advent of AI in the mid-1950s up to the present day, AI has become smarter, in parallel with growth in knowledge, and has become increasingly relevant in education and training (Owoc et al. 2019). The inevitable development and adoption of AI not only impacts the effect of the far-reaching technological progress such as data storage, microprocessors, and global networking, but also changes in business strategies. While the debate on how AI will change business is at the top of the present-day agenda (Bullock 2019), education is also being challenged to reconceptualize the existing teaching and learning methods by putting AI tools and techniques into service (Garrett et al. 2020).

Intelligent technologies are gradually being implemented in universities, usually as part of the strategy that sets up a framework of priorities for mobile learning (Owoc et al. 2019). This opens up new opportunities to teach and learn anytime and anywhere by providing new methods and systems that aim to stimulate innovative teaching and ultimately improve learning outcomes (Verma et al. 2021). One of the crucial objectives of AI in education is the provision of personalized learning guidance. AI simulates human intelligence to make inferences, judgments, or predictions, to provide personalized support or feedback to students as well as teachers or policymakers (Owoc et al. 2019). According to Hwang et al. (2020) the roles of AI in education include problem solving, serving as an intelligent tutor, learning tool/partner, or policy-making advisor. Verma et al. (2021) reported the four main aspects of using AI in higher education to be learning, management, evaluation, and teaching, with the main objective being to provide a new education model that teaches in innovative ways. This includes overcoming the limitations of the traditional classroom and realizing the free, open, and mixed education and teacher efficiency, avoiding the repetition of simple work.

Recently, higher education institutions and companies in first world countries have embraced and supported the use of AI and machine assisted learning (MAL). Good examples of AI adoption come from the University of Murcia in Spain that began testing an AI-enabled chatbot to answer students' questions about the campus and areas of study. This AI was able to answer more than 38,708 questions, answering correctly more than 91% of the time (Rouhiainen 2019). The University of Derby, in England, introduced a system that could monitor data to predict when students are likely to drop out, to signal timely interventions (Owoc et al. 2019). A high-tech company from Burlington, USA implemented a speech recognition software that can be used both by students and faculty. This application is useful for students with limited mobility or a disability, i.e. struggle with writing, as it can transcribe up to 160 words per minute (Owoc et al. 2019). Teachers can apply this software to prepare homework and schedule recurrent tasks, on average teachers spend about 11 hours preparing a weekly task which could be done in 6 hours using AI assistance (Rouhiainen 2019). These examples confirm that many repetitive tasks and routines could benefit from the assistance of AI-enabled systems, offering teachers more time to focus on educating their students or to engage in research pursuits.

2.2 Challenges of AI in Education

Transformative learning allows learners to use their understanding and the information at their disposal to contribute constructively according to their ability (Khedkar and Nair 2016). AI tools have the potential to enhance pedagogy and promote learning; however, they present significant ethical concerns associated with maintaining academic integrity, including the risk of plagiarism, the stifling of critical thinking, and data privacy (Owoc et al. 2019). To emphasize the current situation at a global level, UNESCO launched global standards for AI ethics in November 2021, which have been endorsed by 193 member states, recognising the dynamic impacts of AI on societies, environment, ecosystems and human lives, including the human mind (UNESCO 2022). The global standards stipulate a universal framework of values for ethics, which provides stakeholder-driven guidelines in adopting AI, but at an individual level, challenges range from critical societal drawbacks such as systemic bias, discrimination, inequality for marginalized groups of students, and xenophobia (Nguyen et al. 2023). Little is known about what ethical principles should guide the design, development, and deployment of ethical and trustworthy AI in education.

The emergence of studies with conflicting ethical ideas regarding the use of AI in the education can be a driving force towards establishing effective and inclusive governance and regulations for the responsible use of AI. For example, Homes et al. (2022) addressed the issue of AI in research, where responses revealed that researchers are not trained to tackle the emerging ethical questions. Fu and Weng (2024) did a cognitive readiness case study for students and teachers and found that many teachers were concerned about their jobs being completely

replaced by AI and how technologies might shape their roles and human interactions. However, ethics is not the only area in which AI poses a threat to, another challenge is fairness and equity, which is further connected to the quality of education. In a study by Jabar et al. (2024) a respondent raised the issue on equity and quality of education in the use of AI systems, stating that "not everyone has access to both the internet and the AI-assisted technology." Furthermore, privacy and security, which mainly refer to the governance of data, including data collection, control, storage, access, and usage. Data storage, security confidentiality and loss of privacy were regarded as the elements most exposed to hackers and those who have criminal intentions in the virtual environment by Nguyen et al. (2022).

Validity is also a challenge in the context of AI enabled assessments. For example, the use of facial-recognition software packages such as IRIS and Talview to prevent cheating or copying during an exam by capturing data based on head and eye movements (Lee and Fanguy 2022, Nurpeisova et al. 2023). Real life data indicate that the software may report false positives and negatives, thus making the results unreliable. Recent research also indicates that facial-recognition software packages performed much worse at identifying the gender of women and people of colour than male, white faces (Castelvecchi, 2020). Also, AI cannot perceive what a teacher can observe: for example, the health of a student. If a student gives a wrong answer, it is recorded as such, but if the teacher notices that the student is not feeling well and still participates in the test, the teacher may consider rescheduling the test. Therefore, when the human component is missing, the results of such assessment can be misinterpreted (Pisica et al. 2023). According to Holmes et al. (2022) AI enabled systems can only detect and score responses which they have been trained to recognize.

Despite the possible advantages of integrating AI into education, both from a pedagogical point of view and for learning analytics and administration, there are substantial obstacles to be overcome (Neo 2025). A significant issue being the high cost of developing and implementing AI technologies, which requires substantial infrastructure, such as robust data management systems and skilled staff. The pace and scope of implementation AI into the core operations of educational institutions vary widely, with recent studies highlighting the potential of AI to revolutionize administrative processes (Aithal and Maiya 2023), generate interactive learning materials and improve educational outcomes (Saxena et al. 2023). However, financial constraints, infrastructure and limited qualified personnel to manage and maintain AI systems remain significant hurdles. The financial aspect introduces another level of complexity, as the cost of maintaining AI systems can be exorbitant for some institutions, potentially limiting accessibility for students and educators (Kaouni et al. 2024).

Educators are continuously exploring new approaches and refining existing systems for effective AI implementation, but limitations arise from the complexity of natural language processing, contextual understanding, and the knowledge domain of AI teachers (Tian 2023). To generate human-like interactions, AI teachers mostly rely on natural language processing (NLP) technologies. NLP algorithms, however, may not correctly decipher ambiguous or sophisticated learner input. AI teachers could give inaccurate answers or misunderstand the intended meaning when presented with regional dialects, slang, or linguistic nuances. This restriction makes it more difficult for the AI LLM to interact and communicate with students in their normal language (Kaouni et al. 2024). Neo (2025) reported concerns about the accuracy of feedback in technical and scientific subjects involving models like GPT-4, i.e. fabricated concepts, such as incorrect physical formulas, which can confuse learners and disrupt their understanding. Furthermore, while advanced NLP models can facilitate mental health support by offering accessible and immediate assistance to students, they cannot be a substitute for human interaction or expert medical counsel as mental health issues are intricate, necessitating tailored treatment strategies that consider the individual's unique circumstances and requirement (Alqahtani et al. 2023).

Infrastructure, which encompasses all the hardware, software entities and an ecosystem of thriving innovators to incorporate and provide training on AI related skills in the educational curricula, is still a challenge (Nguyen et al. 2023). For instance, countries such as Finland, China, USA, and the UK have launched strategic policies of education in order to integrate intelligent technologies into education, providing higher institutions with grants and resources to develop AI learning platforms and train academic staff (Pedro et al. 2019). In the United Arab Emirates (UAE), the Ministry of Education rolled out an advanced data analytics platform with over 1,200 schools and over 70 higher education institutions, totalling over 1.2 million students. This data analytics system contains data on curricula, teachers' professional development, learning resources, financing, operations, performance reports, student and parent feedback (UNESCO 2019, Pedro et al. 2019). But, what about the urgency of introducing AI in developing countries which have financially struggling institutions? This leads to inequality as teachers lack the necessary training to perform their tasks and with the continuous upgrading of software,

universities will constantly face the need to adapt to the ever-changing technological solutions and require more funds to keep up to date.

Education goes beyond imparting knowledge to learners but is also a transformational force capable of shaping individuals into conscious and responsible agents of change (Nguyen et al. 2023). The possibility of AI dehumanisation, causing a digital and social divide, may also lead to lack of critical thinkers and innovators. In addition, there is a need for a global consensus and standard guidelines for the regulation and ethical consensus of these technologies, utilizing their various capabilities in education.

3. Research Methodology

The methodology followed in this article is action research. The main reflective characteristic of action research should be acknowledged since action research allows the lecturers and students, as key players in teaching and learning, to evaluate the instructional teaching methodology to improve the learning process. In this way, online pedagogy can be re-examined to identify areas of strengths and weaknesses. This leads to opportunities in narrowing the latter and enhancing the former. New approaches to assessment and marking were designed in response to changes in the online teaching landscape, specifically the implementation (in 2020) of invigilation for online assessments in the face of the Covid-19 pandemic and then response to the advent of an LLM called Chat GPT in November 2022.

As these new approaches were implemented, lecturers responded by adjusting their assessments and then observations of the results have been recorded and analysed as reflections. The data collected in this study is based on the practices and perceptions of the academics to evaluate the impact of these changes on the effectiveness of the assessments. To guide the action research reflections, each of the three authors (LLJ (scenario 1) and MI (scenario 2) and 2022 and 2025 for NCS (scenario 3)) completed the table and then wrote reflections on which tool had been used with a particular type of assessment, how the assessment was marked, how AI LLM usage was detected, the estimated incidence of this and what action was taken consequently.

Although the community of inquiry (CoI) has been discussed at length in the literature (Swan et al. 2009), aspects related to student misconduct during online examinations has not been dealt with and seems to be almost non-existent in the current literature. This study intends to bridge the gap by using action research, as a methodological approach.

4. Results and Discussion

In 2020, when the Covid-19 pandemic forced the university to move its assessments from traditional venue-based exams with invigilation to online exams, online authentication and monitoring was necessary to ensure the credibility of the assessments and the university's qualifications. The university adopted IRIS® which authenticates the student prior to the exam by using face recognition technology and the student's ID card. It records sound, movement and takes screenshots during the assessment which are uploaded at the end of the examination. These recordings are evaluated, and suspicious activity is flagged.

In November 2022, a large language model (LLM) called Chat GPT was released on the internet. It was immediately obvious that this constituted a monumental disruption in assessment and marking, in particular, for higher education. Initially there were no detection tools, besides the academic who was marking the script. As evidence of the lack of sophistication, we received a couple of handwritten scripts which included general phrases (Scenario 1). Students would copy the "answer" of an LLM without any critical evaluation of the answer. However, the LLMs quickly became more polished and avoided self-revealing phrases. This is a demonstration that students who cheat by copying work from one another will do the same with an AI LLM without applying their minds and unwittingly copying blatant errors.

Lecturers responded by adapting questions to be able to detect the use of LLMs. LLMs cannot answer specific questions, like "Where do you live?" "What is the distance between your home and the chemical facility that you have selected?" A blank answer for such a question is a red flag for the use of an LLM. The other aspect of critical thinking that LLMs are programmed to avoid is firm conclusions. To avoid bigotry, an LLM will fence-sit, "weighing" the options when asked to draw a conclusion. By marking with a rubric, one can allocate a failing mark for scripts with these characteristics, where students are told not to use LLMs. In this case, the question was structured so that students had to use given information to calculate a reactor volume for two different reactor models and compare the two answers, explaining the difference (scenario 1). One of the students did

the calculation part by hand, and since the LLM did not have the gist of the question, it gave a generic answer for the comparison, which was blatantly wrong.

IRIS can only detect the use of an AI if the student opens it on the same device and then re-writes the answers onto the script. Handwritten scripts are an obstacle for the similarity checking tool to detect any form of plagiarism, Scenario 2. A question rises, will computer vision technology advancements be coupled with LLM detection to identify scanned scripts in future? Surprisingly, IRIS did not detect the transfer of an identical screenshot between a few students for the same question; there was no evidence of misconduct in the invigilation report. Human intelligence was necessary to detect this behaviour. Since then, typing of assessments has been enforced. Beyond the use of AI or intelligent tools in education, this situation shows that human judgment still plays a major role. The non-use of Turnitin would make it difficult to detect similarity aspects between projects, unless the class is relatively small or similarities among projects are prominent.

There are a number of instances where students' IRIS reports were acceptable, only to find out that there was clear evidence of cheating in-the recordings, Scenario 3. The use of IRIS in online assessment is double work for lecturers, they must review all the recorded videos to identify unfamiliar or suspicious behaviour. Enormous time is often spent in analysing the performance metrics of the video surveillance, especially when there are hundreds of students for that module, taking extra hours to evaluate each assessment and give feedback, which is a very inefficient and un-economical approach. Some of the recordings show only a black screen due to students' cameras not working. Moreover, students only become aware at the end of the assessment that their recording did not upload and therefore they will be failed. IRIS does not give real time updates and warning to students while they are writing. There is also the issue of the limited internet service or bandwidth, which can interrupt the recording and fail the session. This results in an accessibility issue, since the students in remote rural areas are more likely to experience this problem. Failure to submit the IRIS recording automatically equates to a zero grade. The risk of false accusations using IRIS invigilation raises critical concerns around technical reliability and equity.

In an evaluation of data for 271 students in an online assessment, Judi (2022), concludes that there are the persisting challenges of integrity and security in digital assessment. One of the functionalities of an e-assessment system is to offer secure exams that are void of intrusions (Khalil et al. 2022). IRIS proctoring does not require room checking at the beginning of the test through the webcam in order to ensure security, and this alone brings into question the reliability of the assessment. Employing physical proctors and making it mandatory for the students attend for timed assessments, might still be the most reliable option to ensure the fairness and validity of the assessments. However, this increases the burden and cost on both the teacher/inspector and the student, as well as generally limiting access for distance education and training in remote areas. A more viable solution is to change the assessment design, use context-based questioning, or authentic assessments.

The University responded with Turnitin similarity and AI detection in 2024 for written assessments which must be typed. The Turnitin similarity detection not only detects similarity for published material that is online but also runs similarity against other submissions in the same batch of scripts. However, evaluating these reports is slow, each report takes about 30 seconds to open, Scenario 3. There is no "acceptable" percentage for similarity and AI detection gives a percentage for a particular paragraph which is identified as LLM generated, rather than for the script as a whole. This means that human skill is required to interpret the reports, and each script ends up having to be evaluated twice: once for similarity and AI detection and then again for the assessment criteria. I decided to test the AI detection, by requiring my students to include LLM AI summaries of their references in an Appendix, Scenario 1. I identified three scripts which have acknowledged their summaries as being written by Copilot. The AI detection scores for these scripts are 0%, * and * (below 20%), however, I expected these paragraphs to be identified as 100% AI generated. In conclusion, Turnitin AI detection software may not be good at detecting Copilot summaries of academic articles.

Turnitin is widely used for detecting plagiarism, but it has several limitations that educators should be aware of. In online assessments, we found that Turnitin can flag common phrases, references, and human written work as plagiarised even when properly cited or acknowledged, Scenario 3. This leads to a high percentage of plagiarism thus giving a false positive for that work. Another observation is that Turnitin cannot detect similarity in content that has been paraphrased using AI tools. This raises questions about good practice for academic integrity.

Table 1: Reflections on online assessment by LLJ

Detection/Invigilation Tool	Without IRIS and Tii	IRIS no Tii	Tii no IRIS
Type of assessment	Written and calculations	Calculations	Written
Type of marking (rubric, simple direct grading (SDG)	Calculations: SDG Written: rubric	Calculations: SDG	Written: rubric
How is suspected AI LLM usage detected	Mathematical Errors; Generic, conclusions. Blank answers for easy questions about specifics	Mathematical Errors; Generic, conclusions;	AI detected for certain paragraphs; but false positives and false negatives
Estimated incidence	8 out of 240 used Chat GPT	2 out of 120 used Chat GPT	2 out of 37 used Chat GPT
Action taken (e.g. way questions set up)	Change the way questions are set and marked	Use randomised Cloze or calculation-based questions	Detection is always playing catch-up; uncertainty about accuracy of the tool

Table 2: Reflections on online assessment by MI

Detection/Invigilation Tool	Without IRIS and Tii	IRIS no Tii	Tii no IRIS
Type of assessment	Calculations	Written	Written
Type of marking (rubric, simple direct grading (SDG)	Rubric	SDG	SDG
How is suspected AI LLM detected	Project submitted presented a lot of similarities. Copying from the same source most likely.	IRIS failed to identify such behavior, from the report generated.	No detection was observed. Turn It In failed to detect some scanned parts the assessment.
Estimated incidence	30% of the students submitted project reports with identical literature review and calculations, covering the previous year project scope.	Identical Screenshots for a specific question.	Student scanned the script to avoid Tii detection.
Action taken (e.g. way questions set up)	Students were penalised by a zero mark. This forced them to re-write the assessment. Scope was different from the first opportunity.	Students were penalised by awarding a zero mark for the specific question.	Answer to the specific question was nullified. Students were required to strictly type their assessments.

Table 3: Reflections on online assessment by NCS

Detection/Invigilation Tool	Without IRIS and Tii	IRIS no Tii	Tii no IRIS
Type of assessment	Calculations and written	Written	Written
Type of marking (rubric, simple direct grading (SDG)	Rubric & SDG	SDG	SDG
How is suspected AI LLM detected	Percentage of the class with one generic answer	IRIS cannot detect AI, it is designed to detect suspicious behaviours therefore, detection will have to be manual	Turnitin detection, similarity index percentage.
Estimated incidence	Students submitting the same generic answer, using a certain level of proficiency with a significantly advanced vocabulary,	Similar answers. Students scoring higher marks than usual.	Flagging human written content as AI,

Detection/Invigilation Tool	Without IRIS and Tii	IRIS no Tii	Tii no IRIS
	work that lacks specific personal insights in topics that require subject-specific interpretation, work with no references.		Giving a false positive or false negative such as a student using ChatGPT to generate 30% of the text, add personal reflections and references, the work passes undetected.
Action taken **(e.g. way questions set up)**	Set questions in the context of SA, ask open-end questions: ask questions that require personal or situation-related reflections	Use an AI detector together with IRIS	Ask students to lower the similarity index, rephrase and rewrite their work.

Our study has highlighted that students may find ways to circumvent plagiarism and proctoring tools. Students bypass these tools, by exploring cheating and using unauthorised resources (Lancaster & Clarke, 2016). The authors are of the view that students should not be left outside designing anti-cheating tools rather a co-design process should be adopted, and they should understand how these tools work and express their own opinions freely. In this way, one would get a deep understanding of the anti-cheating mechanisms and make an effort for areas of improvement in the implementation of such tools (Waltzer & Dahl, 2023). Despite the benefits of proctoring systems, some students experienced a sense of violating their privacy by being monitored by electronic devices, as opposed to face-to-face setting they were used to before. This could align with the criticisms for proctoring by Lee and Fanguy (2022). To make the final decision on the assessment script, it should be emphasised that plagiarism and proctoring tools should not be used ultimately as sole deciding mechanisms, rather human experts (academics), should assess critically the outcome of such tools. It should be emphasised one of the limitations of this preliminary study, i.e. the non-inclusion in a narrative way of students' perceptions to enhance/validate some aspects, as this would require the process of acquiring the adequate ethical clearance. To strengthen the validity of the findings of the study, this should be done in future so that the conclusions will be data-driven.

5. Conclusion

This study has demonstrated that the use of AI software and related technologies that are necessary, but not sufficient to prevent unethical student behaviour during online examinations. Students find ways to bypass detection technologies, therefore, lecturers should assess critical thinking in the assessments and revise how they set questions to minimise cheating during online assessments. Nonetheless, the action research approach used in this study sheds light on important aspects. False positives and true positives coexist during detection. However, the proportion of the former compared to the latter is high, too high for lecturers to be confident about prosecuting student cheating via disciplinary processes. Aligning with Ellis et al. (2020), we propose that Turnitin and IRIS should be used as a support tool rather than for decisive verdicts. Educators should always combine the results derived from these two technologies with student engagement and a follow up assessment. Whereas this preliminary study has its merit, it is suggested that opinions of students should be elicited, through surveys (interviews or questionnaires), for triangulation to validate the findings of this study.

Ethics and AI Declaration

Ethical clearance was not required for this research. AI tools were not used in creation of this paper.

References

Aithal, P.S. and Maiya, A.K. (2023). Development of a new conceptual model for improvement of the quality services of higher education institutions in academic, administrative, and research areas. International Journal of Management, Technology, and Social Sciences (IJMTS), 8(4), pp.260-308. https://dx.doi.org/10.2139/ssrn.4770790.

Alqahtani, T. Badreldin, H.A. Alrashed, M. Alshaya, A.I. Alghamdi, S.S. Bin Saleh, K. Alowais, S.A. Alshaya, O.A. Rahman, I. Al Yami, M.S. and Albekairy, A.M. (2023). The emergent role of artificial intelligence, natural learning processing, and large language models in higher education and research. Research in social and administrative pharmacy, 19(8), pp.1236-1242. https://doi.org/10.1016/j.sapharm.2023.05.016.

Aswir, A. Hadi, M.S. and Dewi, F.R. (2021). Google meet application as an online learning media for descriptive text material. Jurnal studi guru dan pembelajaran, 4(1), pp.189-194. doi.org/10.30605/jsgp.4.1.2021.533.

Bahuguna, R. Nainwal, N. Banerjee, S. Saharan, V.A. and Singh, A. (2024). Software and Tools for Plagiarism and English Grammar Check. In Principles of Research Methodology and Ethics in Pharmaceutical Sciences, pp.311-335. CRC Book Press.

Bullock, L. (2019). The Top 6 Ways that Artificial Intelligence will affect your business in the near future. Forbes Magazine.https://www.forbes.com/sites/lilachbullock/2019/02/25/. Accessed05/05/2025.

Castelvecchi, D. (2020). Is facial recognition too biased to be let loose? *Nature*, *587*(7834), pp.347-350. Doi:10.1038/d41586-020-03186-4.

Dash, S. Samadder, S. Srivastava, A. Meena, R. and Ranjan, P. (2022). Review of online teaching platforms in the current period of COVID-19 pandemic. Indian Journal of Surgery, 84, pp.12-17. doi.org/10.1007/s12262-021-02962-4.

Ellis, C. Van Haeringen, K. Harper, R. Bretag, T. Zucker, I. McBride, S. Rozenberg, P. Newton, P. and Saddiqui, S. 2020. Does authentic assessment assure academic integrity? Evidence from contract cheating data. Higher Education Research & Development, 39(3), pp.454-469. https://doi.org/10.1080/07294360.2019.1680956.

Fu, Y. and Weng, Z. (2024). Navigating the ethical terrain of AI in education: A systematic review on framing responsible human-centered AI practices. Computers and Education: Artificial Intelligence, pp.100306. doi.org/10.1016/j.caeai.2024.100306.

Garrett, N. Beard, N. and Fiesler, C. (2020). More than" If Time Allows" the role of ethics in AI education. In Proceedings of the AAAI/ACM Conference on AI, Ethics, and Society, pp.272-278.

Holmes, W. Porayska-Pomsta, K. Holstein, K. Sutherland, E. Baker, T. Shum, S.B. Santos, O.C. Rodrigo, M.T. Cukurova, M. Bittencourt, I.I. and Koedinger, K.R. (2022). Ethics of AI in education: Towards a community-wide framework. International Journal of Artificial Intelligence in Education, pp.1-23. doi.org/10.1007/s40593-021-00239-1.

Hwang, G.J. Xie, H. Wah, B.W. and Gašević, D. (2020). Vision, challenges, roles and research issues of Artificial Intelligence in Education. Computers and Education: Artificial Intelligence, 1, pp.100001. https://doi.org/10.1016/j.caeai.2020.100001.

Jabar, M. Chiong-Javier, E. and Pradubmook Sherer, P. (2024). Qualitative ethical technology assessment of artificial intelligence (AI) and the internet of things (IoT) among Filipino Gen Z members: implications for ethics education in higher learning institutions. Asia Pacific Journal of Education, pp.1-15. doi.org/10.1080/02188791.2024.2303048.

Judi, H.M. (2022). Integrity and security of digital assessment: Experiences in online learning. Global Business and Management Research, 14(1), pp.97-107.

Kaouni, M. Lakrami, F. and Labouidya, O. (2024). The use of Artificial Intelligence and Natural language processing In E-learning Platforms: An Exploration of Potentials and Limitations. International Journal of Information Science and Technology, 8(4), pp.1-9. http://dx.doi.org/10.57675/IMIST.PRSM/ijist-v8i4.258.

Khalil, M. Prinsloo, P. and Slade, S. (2022). In the nexus of integrity and surveillance: Proctoring (re) considered. Journal of Computer Assisted Learning, 38(6), pp.1589-1602. https://doi.org/10.1111/jcal.12713.

Kuleto, V. Ilić, M. Dumangiu, M. Ranković, M. Martins, O.M. Păun, D. and Mihoreanu, L. (2021). Exploring opportunities and challenges of artificial intelligence and machine learning in higher education institutions. Sustainability, 13(18), pp.10424. https://doi.org/10.3390/su131810424.

Rouhiainen, L. 2019. How AI and data could personalize higher education. Harvard Business Review, 14, pp.2-6.

Khedkar, P.D. and Nair, P. (2016). December. Transformative pedagogy: A paradigm shift in higher education. In Proceedings of Third International Conference on Multidisciplinary Research & Practice, pp. 332-337.

Lancaster, T. and Clarke, R. (2016). Contract cheating: The outsourcing of assessed student work. Handbook of academic integrity, pp.639-654.

Lee, K. and Fanguy, M. (2022). Online exam proctoring technologies: Educational innovation or deterioration? British Journal of Educational Technology, 53(3), pp. 475-490. 10.1111/bjet.13182.

Mphaga, J.M. (2024). The significance of media in education and its integration in open distance learning (odel) institutions: the influence of the digital era. Edulearn24 Proceedings, pp.889-898.

Neo, K.K. (2025). Current Limitation of AI in Education. Master's thesis, Rensselaer Polytechnic Institute.

Nguyen, A. Ngo, H.N. Hong, Y. Dang, B. and Nguyen, B.P.T. (2023). Ethical principles for artificial intelligence in education. Education and information technologies, 28(4), pp.4221-4241. doi.org/10.1007/s10639-022-11316-w.

Nurpeisova, A. Shaushenova, A. Mutalova, Z. Ongarbayeva, M. Niyazbekova, S. Bekenova, A. Zhumaliyeva, L. and Zhumasseitova, S. (2023). Research on the development of a proctoring system for conducting online exams in Kazakhstan. Computation, 11(6), pp.120. https://doi.org/10.3390/computation11060120.

Owoc, M.L. Sawicka, A. and Weichbroth, P. (2019), August. Artificial intelligence technologies in education: benefits, challenges and strategies of implementation. In IFIP international workshop on artificial intelligence for knowledge management. Cham: Springer International Publishing, pp. 37-58.

Pisica, A.I. Edu, T. Zaharia, R.M. and Zaharia, R. (2023). Implementing artificial intelligence in higher education: Pros and cons from the perspectives of academics. Societies, 13(5), pp.118. https://doi.org/10.3390/soc13050118.

Pedro, F. Subosa, M. Rivas, A. and Valverde, P. (2019). Artificial intelligence in education: Challenges and opportunities for sustainable development. Minister of Education. Peru. https://hdl.handle.net/20.500.12799/6533.

Saxena, P. Singh, S.K. and Gupta, G. (2023). Achieving effective learning outcomes through the use of analogies in teaching computer science. Mathematics, 11(15), pp.3340. https://doi.org/10.3390/math11153340.

Swan, K. Garrison, D. R. & Richardson, J. C. (2009). A constructivist approach to online learning: The community of inquiry framework. In Information technology and constructivism in higher education: Progressive learning frameworks, pp. 43-57. IGI global.

Tanyanyiwa, V.I. and Madobi, R. (2021). Challenges to the Effective Teaching and Learning of Geography through ODeL at the Zimbabwe Open University. Journal of Learning for Development, 8(2), pp.364-382. https://doi.org/10.56059/jl4d.v8i2.427.

Tian, Y. (2023). Limitations and Advancements of AI Teachers in Classroom Instruction. Education and Teaching Research, 3, pp.66-72.

Tsindoli, S. (2025). Fostering a Conducive Open and Distance E-Learning (ODEL) Environment in the 21st Century in Higher Learning Institutions in East and South Africa. In Artificial Intelligence, Digital Learning, and Leadership: Redefining Higher Education (pp. 147-176). IGI Global.

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2019). Teaching and learning transformative engagement. Scientific and Cultural Organization, 7, place de Fontenoy, 75352 Paris 07 SP, France. https://unesdoc.unesco.org/ark:/48223/pf0000368961. Accessed05/05/2025.

United Nations Educational, Scientific and Cultural Organization (UNESCO) 2021 report. (2022). Recommendation on the Ethics of Artificial Intelligence. Accessed 05 June 2025. https://unesdoc.unesco.org/ark:/48223/pf0000381137. Accessed05/05/2025.

Verma, A. Kumar, Y. and Kohli, R. (2021). Study of AI techniques in quality educations: challenges and recent progress. SN Computer Science, 2(4), p.238. doi.org/10.1007/s42979-021-00635-3.

Waltzer, T. and Dahl, A. (2023). Why do students cheat? Perceptions, evaluations, and motivations. Ethics & Behavior, 33(2), pp.130-150. https://doi.org/10.1080/10508422.2022.2026775.

Yen, T.V.M. and Nhi, N.T.U. (2021). The practice of online English teaching and learning with microsoft teams: From students' view. AsiaCALL Online Journal, 12(2), pp.51-57.

Introducing C++20 Modules in First-Year Computer Science: A Pedagogical Case Study

Siphesihle Sithungu
University of Johannesburg, Johannesburg, South Africa

siphesihles@uj.ac.za

Abstract: This paper presents a case study on introducing C++20 modules into a first-year computer science curriculum to expose students early to modern modular programming. In line with constructivist learning principles, modules were introduced as bonus content in the first semester, allowing students to learn through hands-on practical tasks. The integration faced technical challenges, especially around compiler compatibility, where initial attempts using MSYS, LLVM, and Clang were unsuccessful. Eventually, GCC 14.2.0 was adopted to support C++20 modules. A scaffolding approach was used to support student learning, starting with a virtual programming lab and gradually transitioning to local lab environments. Supplementary resources, including tutorial videos, were developed to help students move from beginner tools like Code::Blocks to more advanced editors such as Visual Studio Code. The study highlights the benefits of project-based and technology-enhanced learning, showing that students responded positively to the modern C++ content. This paper offers insights into the practical implementation of contemporary C++ features in introductory courses and contributes to ongoing discussions about effective programming pedagogy.

Keywords: Modern C++, Curriculum Innovation, Computer Science Education, Technical and Pedagogical Integration, First-Year Curriculum

1. Introduction

C++ is one of the most used programming languages in the history of computer programming due to the expressive ability it provides to computer programmers and software engineers. The applications of C++ span a wide variety of domains, such as systems programming (Chan, 1996), game development (Sutherland, 2014; Mack & Ruud, 2019), back-end development (Reddy, 2011) and compiler construction (Holmes, 1994). Python is an example of programming languages we use daily that were written in C or C++ (Chun, 2001). The C++ language – initially called *C with Classes* – was primarily incepted as an object-oriented take on its predecessor, C, by Stroustroup, and it was first publicly released in 1983 (Stroustrup, 1996). C++ - along with C- is also the language used to write the influential Compute Unified Device Architecture (CUDA) (Li, et al., 2019), designed for programming Graphics Processing Units (GPUs) (Sanders & Kandrot, 2010).

Given the influence and features of C++, it is unsurprising that it is one of the most taught programming languages at universities globally in undergraduate computer science courses. A significant number of universities teach C++ as part of their undergraduate or graduate programs (Tan, et al., 2014), which is a testament to the language's importance in both foundational concepts and advanced technical applications. Our university is no different in its appreciation of the importance of introducing computer science students to core programming principles through C++.

As with most languages, the C++ programming language is continuously evolving to remain a relevant choice for computer programmers. One of the main improvements introduced in C++20 was the ability to achieve modular programming in C++ using modules (Szalay & Porkoláb, 2025), which are expected to replace header files. Modules were introduced to address critical limitations of header files, which include order sensitivity, slow compilation, limited optimisation and exposure to internal details such as macros. It is worth noting that header files have been a building block of C++ programs since the language's inception and they were also a part of C, which made the introduction of C++20 modules a critical turning point in the evolution of the language.

Given the evolutionary significance of modular programming in C++, it is no surprise that none of the major compilers at the time of writing this paper, such as GNU Compiler Collection (GCC), LLVM (Low-Level Virtual Machine) Clang and Microsoft Visual C++ (MSVC) have fully implemented modular programming as prescribed by ISO C++ (Szalay & Porkoláb, 2025). This situation presents an interesting challenge for educational practitioners: ensuring that students remain exposed to the most up-to-date and current developments in C++ in a way that accommodates ongoing compiler support for C++20 modules.

To enable students to build C++ knowledge through modular programming, a constructivist approach to teaching and learning (Von Glasersfeld, 2012) became a natural requirement in order to create a conducive environment for active learning (Felder & Brent, 2009).

This paper presents a case study on the integration of C++ 20 modules into a first-year computer science curriculum, with the main focus being on the pedagogical strategies followed, the technical challenges encountered and student engagement. The main contributions of this paper are as follows:

- The paper presents a real-world case study of how modular programming in C++ can be introduced to first-year computer science students, where modules are offered as bonus content in the first semester and become compulsory in the second semester. This contribution advances the conversation around modernising programming pedagogy in line with the evolving C++ standard.
- The paper documents obstacles encountered in choosing the right tooling for modular programming in C++ within an educational environment. A discussion is provided on navigating real-world compiler ecosystem challenges to provide insights that others can use to implement modern C++ features in constrained environments.
- Finally, the paper reflects on anecdotal indicators of healthy adoption and student engagement with C++20 modules, which contribute to ongoing efforts to modernise programming education.

The rest of the paper is structured as follows: Section 2 describes the general course design, reflecting on the strategies used to teach modular programming in C++, the challenges encountered and solutions that emerged. Section 3 discusses the results of having introduced C++20 modules, focusing on three main aspects: (1) student engagement, (2) impact on learning outcomes, and (3) technical outcomes. Section 4 offers a discussion that reflects on the outcomes of the project by analysing the pedagogical approach, the challenges and lessons learned and student feedback.

2. Course Delivery

This section discusses the pedagogical approaches employed to teach modular programming to first-year, first semester computer science students to provide a clear picture of how the course was designed and delivered. Thereafter, the challenges faced throughout the semester are reflected upon, including how each challenge was addressed. Most challenges experienced were related to tooling and making the content accessible to students of varying abilities.

2.1 Pedagogical Approaches

In order to successfully introduce C++20 modules, it was important to lean towards a constructivist teaching approach, which views learning as an active process requiring students to engage with their surroundings and experiences in order to build knowledge (Von Glasersfeld, 2012). Constructivism discourages passive learning and encourages active learning. Adopting such a philosophy provided benefits in this context given the practical nature of computer programming and the fact that a new way of writing C++ programs was being introduced.

The transition from traditional header file-based C++ programs to modules should not be underestimated given that header files have been the only approach for creating programmer-defined libraries in C++. It was therefore important to encourage as much “hands-on” learning as possible from our students given that a fundamentally different approach to writing programs was being introduced in our course. Being the very first time that modular programming was being taught in the first year meant that our students could not consult course materials from previous years for revision purposes. Therefore, they had to be given as many opportunities as possible to develop hands-on experience in learning how to create libraries using modules.

Following a constructivist approach was not sufficient. We also had to ensure that students were not overwhelmed by the content. This was achieved by gradually introducing concepts through a scaffolding approach (Gibbons, 2002), where the ability to create modular C++ programs was only made available on the department’s Virtual Programming Lab (VPL). The VPL enabled students to create source files, write source code and execute it without knowing how to actually compile it, thus scaffolding away the implementation details of modular programs in C++.

Over time, after determining that students were comfortable with the program structure and knew how to create the appropriate source files, we then transitioned to teaching them how to compile a C++20 program containing modules via the command line interface (CLI). Even more so, to ensure that students were not overwhelmed with new information, the use of modules was only reserved for bonus assessments, allowing them to continue to use header files for the main assessments. This allowed students to engage with C++20 modules at their own pace, while rewarding their attempts with bonus marks.

As mentioned previously, active learning was an essential component of the pedagogical strategy as it enabled students to engage with the material through hands-on coding, debugging and problem-solving. Active learning directly supports the constructivist philosophy adopted for this particular project. The various tools that were made available to students in enabling them to engage with modular programming in C++ supported technology-enhanced learning as they facilitated a modern learning environment. Traditionally, over many years, our course had used CodeBlocks (Soto & Figueroa, 2018) as the official Integrated Development Environment (IDE). However, the introduction of modules introduced the opportunity to shift attention towards the VPL as well as Visual Studio Code (VS Code). Finally, because students had to create solutions to practical assignments, even though they were part of the bonus component of the course, in doing so, it created an environment for project-based learning.

2.2 Challenges and Solutions

The introduction of C++20 modules was met with numerous technical and administrative challenges, both of which will are discussed separately. The challenges faced during the first semester provided invaluable insights into how the delivery of the content could be better structured in the second semester.

2.2.1 Technical Challenges

One of the foremost technical challenges faced was choosing the appropriate compiler that supports the C++20 standard. Various C++ compilers exist, and some are more niche (or specialised) than others. The most mainstream C++ compilers that are used extensively in both academia and industry are the GCC, LLVM and MSVC. Given that the CodeBlocks IDE has always been used for the course, and CodeBlocks ships with GCC by default, GCC has always been the *de-facto* compiler for the course. However, the latest version of CodeBlocks (20.03) supports up to C++17. This meant that students would have had to create source files manually and use the command line interface (CLI) to compile and run their programs. Another alternative would have been to choose a different editor or IDE, such as Visual Studio Code. However, syntax highlighting in VS Code highlights module-related code as erroneous, which would have added frustration to first-year students.

C++20 support began in GCC 13, and it has been on technical specification[1] until now (we are currently on GCC 14.2.0 as of the writing of this paper). This meant that not all of the C++20 standard was supported by GCC and not every feature/functionality specified in ISO C++ would work. Another issue we experienced was that the GCC version installed on the VPL instance was GCC 13, which certainly introduced a layer of complexity given the difference in C++20 support, as described earlier. It would have been risky to create an entirely new VPL instance with GCC 14 installed given that our VPL is not only used by our computer science first-year students, meaning that other courses might have been affected by the migration.

It is also worth noting that we experimented with the other compilers, such as Clang and MSVC, but both of these alternatives also had limited support for C++20 modules. Given that the main part of the course already makes use of GCC, it was sensible to stick to GCC to prevent confusion or frustration for students. Using the same compiler toolchain meant that we did not have to teach a new compiler to students wanting to engage with the bonus content. Our only goal was to explain to them that the current version of GCC does not yet fully support modules and highlight quirks they might encounter when writing modules in C++. This approach eliminated a significant amount of complexity and ensured that the delivery of the content was straightforward.

To summarise, given that the current version of CodeBlocks does not support C++20 modules, our students had two options: (1) use the dedicated VPL coding area for bonus content or (2) use any text editor to write C++20 programs and compile from the CLI. The second option gave students a more solid understand of the C++ compiler ecosystem including the compilation and linking stages.

Another challenge encountered when delivering the bonus content was to decide on an extension for the source file containing a module. Different conventions exist, as is typically the case in the C++ community, depending on the compiler toolchain. It seems to be the consensus within the GCC community to use the .cxx file extension. Although we initially went with .cxx, we eventually settled with .cpp to simplify the compilation process on the VPL. While the literature might suggest otherwise, we found that GCC 14 does not support the use of separate

[1] Technical specification means that the support for modules is still experimental.

interface and implementation units, which further justified the choice of using the .cpp extension prototypes and implementations were written in the same file.

2.2.2 Administrative Challenges

To successfully teach modular development in C++, new learning material needed to be created for the course. Since modules only formed part of the bonus content, only tutorial videos were created and hosted on our department's YouTube channel, and each video tackled a specific concept. Each video was short and objective, addressing a specific aspect of working with modules. The second administrative challenge was incorporating the bonus content into weekly practical assignments and the practical semester test. To maintain consistency, a separate bonus section was added to each practical assignment with a fixed number of marks.

The practical test is the most important assessment students complete during the semester. It is a three-hour closed-book assessment, completed at our practical lab venues in one sitting, and it contributes 65% towards the semester's mark. Given the critical nature of this assessment, it is standard practice to incorporate a bonus section allowing students to earn extra marks to maximise their chances of success. This year, modules were included as part of the bonus content. However, to make the bonus section accessible to a wide variety of students (even those who did not understand modules), the bonus section also included using functional programming concepts in C++ (i.e. lambda expressions, passing functions as parameters to other functions, etc.)

Another administrative challenge encountered was with regards to marking. Given the large number of students enrolled for our course, we need the help of student assistants to mark weekly practical assignments and semester tests. Given that this was the first time C++20 modules were being taught, it meant that our student assistants, who completed the course in the previous years, were not familiar with C++20 modules. To address this challenge, marking assistants were instructed to watch the same tutorial videos provided to students so that they not only familiarised themselves with the concepts, but were also aware how the concepts were taught to the students. This approach ensured that the marking assistants' expectations (when marking) were in line with what was taught.

Other administrative challenges were expected, such as ensuring the availability of bonus coding areas for weekly practical assignments, the practical semester test and final exam. However, some administrative challenges directly manifested from unexpected technical challenges. An example of a quirk that was discovered during the course was when passing a lambda expression as a parameter to a function defined inside a module when using GCC 14. We found that, if a function takes a lambda expression as a value parameter and passes it to another function as a value parameter, the compiler will see the lambda as being defined more than once (which was obviously not the case), resulting in a compile-time error. A workaround here was to have one of the functions accept a lambda expression as a reference (or a const reference to avoid modifications) parameter. Such arising quirks had to be clearly communicated to students.

The administrative challenges arising from the introduction of C++20 modules in our first-year computer science course provided a significant number of valuable lessons, not only about how to teach the most cutting-edge features of a programming language, but also about the evolution of modern C++ itself.

3. Results

The work undertaken to introduce modules in first-year computer science resulted in several outcomes, which are presented in this section. First, a reflection is made on how students engaged with modules as part of bonus content. Engagement was tracked by monitoring activity logs on the VPL as well as directly observing the number of students who attempted the bonus sections of practical assessments. Thereafter, an assessment of the impact of bonus activities on learning outcomes is briefly conducted by investigating how students who attempted bonus activities performed overall in the course.

3.1 Student Engagement and Adoption

To evaluate whether students were engaging with the bonus content, we tracked the number of attempts for the bonus content of practical assignments based on submissions, as well as the activity logs on the VPL. Although only a small fraction of the students were interested in the bonus content, those who were interested consistently attempted bonus questions. Activity logs on the VPL also showed that certain students consistently used the coding area dedicated to bonus questions. Figure 1 is a chart reflecting the usage of the bonus coding area by one of the students.

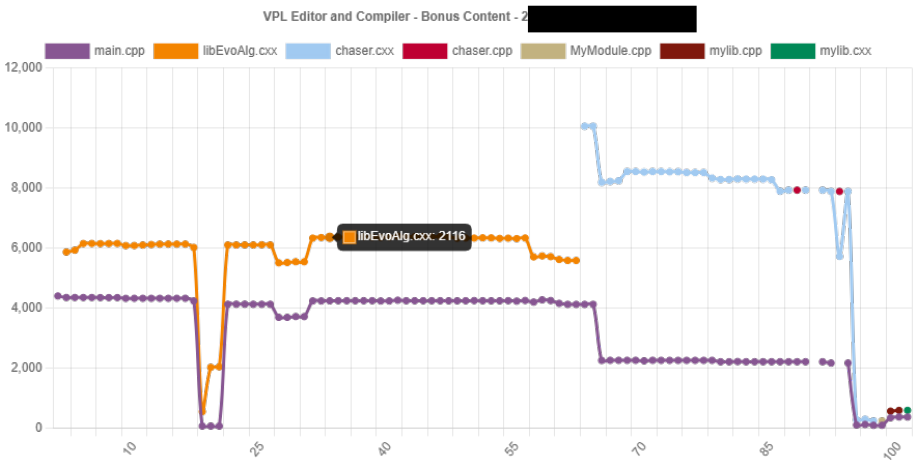


Figure 1: VPL activity log for one student. Student details were removed to preserve anonymity.

The different line colours reflect changes made to corresponding source files (source files are listed at the top of the chart). This type of chart depicts student interaction with the coding area – and therefore – the bonus content. Being able to track engagement in this manner also enabled observing whether students who engaged with bonus content eventually succeeded in the course (and if they did, what their overall performance was). The bar chart shown in Figure 2 shows the total number of hours for which the same student observed in Figure 1 used the bonus coding area. As can be seen from the top of the chart, the student spent a total of 3.2 hours using the bonus coding area.



Figure 2: A bar chart showing a breakdown of the number of hours (y-axis) the student used the bonus coding area per working session (x-axis).

Students received a total of eleven practical assignments throughout the semester and three of those assignments involved the use of C++20 modules as a bonus question. We shall refer to these assignments as P_A, P_B and P_C. The course had a total of 607 registered students, and the number of students who attempted the bonus sections of each of the three assignments was as follows:

- P_A: 85 students (14% of the class)
- P_B: 42 students (7% of the class)
- P_C: 21 students (4% of the class)

The first noticeable pattern here is that the number of students attempting the bonus question decreased by approximately half for each successive practical assignment, which was counterintuitive to what was expected. The expectation was that students would become more confident and attempt more bonus questions as time progressed. A logical conclusion that can be drawn from this observation is that, since practical assignments become increasingly challenging, less and less students had the capacity or time (or even perhaps motivation) to attempt the bonus sections as the course progressed.

The use of modules as a bonus question was also included in the practical semester test, a three-hour long assessment testing on all the content covered during the semester. Only 37 students attempted the bonus question during the practical test. Out of the 35 students who sat for the sick test, none of them attempted the bonus question, which was unsurprising given that, *typically*, students who apply for deferred assessments at university tend to be those who did not prepare well for the main assessment opportunities. Since our practical semester test and the final examination have the same format and are on the same difficulty level, students can get promoted to the second semester without writing the exam if their semester mark is higher than 70%. When a student is promoted, their semester mark becomes their exam and final marks. It should be noted that students have the option to write the final examination even if they are promoted, but students rarely entertain this option.

Out of the 180 students who sat for the final examination (those who did not promote), only 11 students attempted the bonus question. Such a low number of students attempting the bonus question was not surprising since the highly performing students had already been promoted to the second semester and they did not sit for the exam. It should also be noted that most students who attempted the bonus question in the final exam did not perform well on the question.

3.2 Impact on Learning Outcomes

The previous section presented the results of having introduced C++20 modules as bonus content in the course. The results mainly focused on student participation in various assessments, including the final examination. The purpose of this section is to discuss the impact of having introduced modules on overall learning outcomes. It is difficult to quantitatively assess this impact since modules only formed part of the bonus section. However, the most important correlation worth mentioning is that the overwhelming majority (97%) of students who attempted the bonus content in one or more assessments throughout the semester eventually passed the course.

The most logical interpretation of this outcome is twofold: (1) students who had the capacity to attempt bonus questions were those who were already comfortable with mainstream concepts, which makes it unsurprising that they passed. A secondary observation made while marking the practical semester test was that (2) several students who were not particularly excellent in mainstream content were able to significantly boost their practical component mark by learning how to complete the bonus content (C++20 modules) and correctly executing what they had practiced.

A total of 123 (20.3%) students attempted C++20 modules in one or more instances during the semester and 119 of those students passed at the end of the semester. It is worth noting that the four students who failed all attempted bonus questions in only a single instance during the semester (none of the students attempted the bonus two or more times). For example, three of the four students only attempted the bonus when completing P_C (which may be an indication of desperate attempts to boost their practical mark towards the end of the semester) while only one attempted the bonus question in P_A. Figure 3 is a pareto chart showing that most attempts to use C++20 modules came from the students who eventually promoted from the course without having to write the final examination.

The key takeaway from Figure 3 is that most bonus attempts (using C++20 modules) during the semester came from the students who were eventually promoted from the course without having to sit for the final exam. Even more so, more than 95% of bonus attempts throughout the semester came from students who eventually succeeded in the course (either got promoted or passed after having written the final exam). This outcome was not surprising as students who excel at mainstream content often feel confident to engage with bonus concepts.

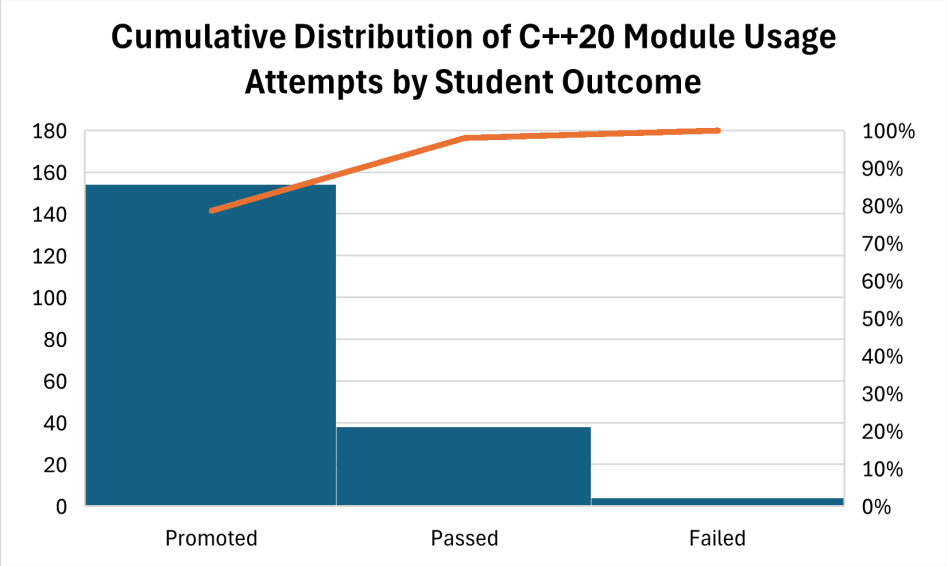


Figure 3: A Pareto analysis of C++20 module usage attempts across various assessments by student outcome.

The above results reflect student interest in engaging with C++20 modules during the first semester of the first-year computer science course. In summary, 123 out of 607 (20%) students engaged with C++20 modules in an official assessment and most of them were high-performing students. The following section reflects on the results as well as lessons learned.

4. Discussion

The introduction of C++20 modules was met with various interesting challenges, such as choosing the right compiler toolchain, creating conducive development and practice environments, and finding innovative ways to teach the bonus content without obstructing the delivery of mainstream content. Based on the level of engagement with C++20 modules in the first semester, modules have been integrated into the course as a mainstream topic in the second semester. This was done because we had verified that GCC can be used as a stable development platform with minimal setup overhead.

Introducing C++20 modules required leaning into constructivism, where students were encouraged to grapple with new concepts (including marking assistants who had to be taught how to mark the bonus sections). It became evident that following a scaffolding approach by first making the VPL the only platform for completing modular programming exercises resulted in a gentle introduction to the concepts. Once students were comfortable with the use of modules from a programming language perspective, they were then taught how to use the compiler to compile programs that make use of modules. This technology-enhanced approach to active learning resulted in a quantifiable interest in C++20 modules: students exhibited proactive learning behaviours and went on to seek additional cognitive challenge by repeatedly interacting with the bonus content.

The challenges and lessons learned from choosing to right compiler for our course as well as finding the right IDE resulted in the abandonment of Codeblocks in the second semester. The official programming platforms prescribed to students in the second semester were Notepad++ and the VPL. These two platforms were chosen specifically for the exposure they provide to the implementation details of C++ programs. Students who are not yet comfortable directly interacting with the compiler can use the VPL, which abstracts away the compilation process and allows students to focus only on coding. On the other hand, more advanced students who are willing to explore compilation from the ground up can use Notepad++ to write their programs and create batch files to compile the required executables. This approach is expected to provide the right level of engagement for both advanced and less experienced students.

5. Conclusion

This paper reported on a real-world case study where C++20 modules were introduced as a new and modern way of building programmer-defined libraries in a first-year computer science course. Modules were only introduced as part of the bonus topic of the course in the first semester, with the goal of making them

compulsory in the second semester (thus doing away with traditional header files). Based on the engagement with C++20 modules (20.3%) as part of the bonus content, the endeavour is viewed as a success because students are not forced to engage with bonus topics. Therefore, it is reasonable to say that 123 out of 607 students, who decided on their own to explore the topic, is a positive outcome.

In the second semester, when the topic becomes compulsory, 123 students will already have a degree of familiarity with it. It is also worth believing that the constructivist and project-based learning approach will further benefit the students who explored the topic in the first semester as they transition into the second semester due to the practical nature of the content delivery. When C++20 modules are explored theoretically in lectures, the students who already grappled with the practically are expected to have a more nuanced understanding of the concepts.

Future work should focus on addressing the technical challenges faced, such as choosing the best IDE for modern C++ and transitioning away from Codeblocks. Using Notepad++ as the official text editor can further reinforce students' understanding of the compilation process and use of batch files. This case study contributes to the wider educational discussion by giving an honest and detailed account – including quantitative results – on the struggles faced with introducing modern C++ topics to an undergraduate computer science class. The case study also gives light into the current capabilities of modern editors, such as Visual Studio Code to support C++ modular programming. The long-term goal is to continue gradually transitioning into modern C++ for this course as compilers continue to gradually support modern C++. This journey will lead to further exploration of the challenges and success that emerge.

Ethics Declaration

Ethical clearance was not required for this research.

AI Declaration

AI tools were not used to create this paper.

References

Chan, T., 1996. *Unix system programming using C++.* s.l.:Prentice-Hall, Inc..

Chun, W., 2001. *Core python programming.* s.l.:Prentice Hall Professional.

Felder, R. M. & Brent, R., 2009. Active learning: An introduction. *ASQ higher education brief,* Volume 2, p. 1–5.

Gibbons, P., 2002. *Scaffolding language, scaffolding learning.* s.l.:Heinemann Portsmouth, NH.

Holmes, J., 1994. *Building your own compiler with C++.* s.l.:Prentice Hall PTR.

Li, W., Sun, J. & Chen, H., 2019. Detecting Undefined Behaviors in CUDA C. *IEEE Access,* Volume 7, pp. 182559-182572.

Mack, K. & Ruud, R., 2019. *Unreal Engine 4 Virtual Reality Projects: Build Immersive, Real-world VR Applications Using UE4, C++, and Unreal Blueprints.* s.l.:Packt Publishing Ltd.

Reddy, M., 2011. *API Design for C++.* s.l.:Elsevier.

Sanders, J. & Kandrot, E., 2010. *CUDA by example: an introduction to general-purpose GPU programming.* s.l.:Addison-Wesley Professional.

Soto, M. S. & Figueroa, I., 2018. *Heuristic Evaluation of Code::Blocks as a Tool for First Year Programming Courses.* s.l., s.n., pp. 1-8.

Stroustrup, B., 1996. A history of C++ 1979–1991. In: *History of programming languages—II.* s.l.:s.n., p. 699–769.

Sutherland, B., 2014. *Learn C++ for game development.* s.l.:Apress.

Szalay, R. & Porkoláb, Z., 2025. Refactoring to Standard C++ 20 Modules. *Journal of Software: Evolution and Process,* Volume 37, p. e2736.

Tan, J., Guo, X., Zheng, W. & others, 2014. Case-based teaching using the Laboratory Animal System for learning C/C++ programming. *Computers & Education,* Volume 77, p. 39–49.

Von Glasersfeld, E., 2012. A constructivist approach to teaching. In: *Constructivism in education.* s.l.:Routledge, p. 3–15.

Strategic Coherence and AI-Enabled Personalization: Drivers of Motivation in Corporate Learning

Olga Tunkevichus, Arseniy Kovalerchik, and Konstantin Bagrationi
Graduate School of Business, HSE University, Frankfurt am Main, Germany

aikovalerchik@edu.hse.ru
kbagrationi@hse.ru
oagordienko@hse.ru

Abstract: As corporations expand globally, corporate training practices evolve in parallel, raising an urgent question: how can individual development pathways be designed to better align L&D strategy with corporate goals for the benefit of both employees and the organization? Recent bibliometric work on organizational change confirms that the misalignment between strategy and learning remains a critical barrier to sustained innovation readiness. Moreover, L&D managers are not yet able to deal with the lack of time and staff engagement (42% and 41% as the main barriers, respectively). There is a large gap in the study of motivation in corporate learning: most articles consider either learning in schools or universities or the technical aspect of technology implementation in corporate learning. This study investigates four potential drivers of motivation – content personalization, environmental dynamism, AI adoption, and strategic coherence. All these factors affect staff, and some of them relate directly to personalized learning strategies. Artificial-intelligence–enabled tutors and chatbots are already tailoring learning paths in real time, mirroring patterns observed in higher-education AI diffusion. Guided by Self-Determination Theory, we formulate hypotheses linking each driver to specific dimensions of motivation. We will survey employees of large firms who have recently completed corporate training programmes with the help of an author's questionnaire. Our research closes an important gap in understanding employee motivation within corporate learning and provides a springboard for future investigations into additional motivational antecedents. Based on the findings, we will offer actionable recommendations for embedding these drivers in learning and development strategies. When applied effectively, these insights can help organizations optimize training through higher employee motivation.

Keywords: Corporate Learning, Learning and Development Management; Content Personalization, Strategic Coherence

1. Introduction

Individual learning strategies are gaining popularity. Currently, L&D managers are the main developers of individual learning strategies in organizations. Modern L&D managers face serious challenges in staff training. Nowadays, a “skill gap” could be found worldwide in modern companies (Buckley & Castro Jorge, 2024) which leads to lack of staff training (Braun et al., 2024). A less visible but equally powerful obstacle stems from employees’ informal networks that can silently block new initiatives (Aksiutin et al., 2022; Bagrationi et al., 2021, 2022). Nowadays, the effectiveness of staff in the workplace directly depends on the quality of L&D management in an organization, so the question arises of how L&D managers can improve development strategies and develop new approaches to training (Garavan, 2023).

It is worth noting that the functions of L&D managers are not only about learning functions, but also about strategic staff management (Garavan et al., 2020). Due to digital transformation, such managers should be able to react quickly to changes, adapt new technologies, and be able to anticipate labor market movements (Tewari & Pant, 2020). Change-oriented leadership behaviours have proved decisive when entire units transition to strategic autonomy (Diakova et al., 2024), underscoring the human side of L&D governance. Analytical thinking and the ability to work with data are also highly appreciated (Bhatt & Muduli, 2022).

In modern world, there are many factors that influence employee motivation in corporate training, and an L&D manager must take them all into account for training to be beneficial (Garavan et al., 2020). In addition to factors that are not directly related to learning, such as the rapidly changing external environment or organizational stocks in the company, there are technologies that can be used in training (Bisht et al., 2025). This is how L&D managers can use artificial intelligence or content personalization to increase employee motivation during the learning process (Bisht et al., 2025). Scenarios work on corporate universities further shows that content-personalisation pressures intensify as firms compete with external course providers (Zinchenko et al., 2024). Such foresight findings signal that motivation drivers cannot be decoupled from institutional learning formats.

The purpose of the study is to analyze the influence of several factors such as strategic coherence, content personalization, AI technologies, dynamic organizational abilities, etc. on different scales of staff motivation in corporate training, as well as to form recommendations for L&D managers on the implementation of technology in training strategies.

2. Literature Review

Most of the research around personalization of content and AI technologies in corporate training focuses on results and technical aspects. This study will fill a gap in the field of the impact of AI and personalization on employee motivation through the prism of Self-Determination Theory.

Some scientific articles indicate the need for new research to identify the elements of personalized learning strategies and their impact on motivation:

"Future research should consider larger and more diverse samples to further explore the impact of personalization. Additionally, long-term studies that examine the sustainability and effectiveness of personalization in adaptive learning environments would provide valuable insights." (Graf, A., 2023, P. 53)

"… future research should use a more representative sampling strategy and a longitudinal design to track improvements. Expanding the study to include other countries and academic disciplines would help explain AI's effect on intrinsic motivation." (Mohamed et al., 2025, P. 604)

Currently, the influence of AI on motivation is widely studied in various fields. The 2024 study showed that statistically, the introduction of AI into the learning process has a positive effect on student engagement. Thanks to the introduction of ChatGPT, students' motivation has increased, as they can now receive personalized feedback in the educational process (Ahmed et al., 2025). Another study analyzes the impact of AI on the motivation and academic performance of university students (Pertiwi et al., 2024). In addition to the positive association, some risks associated with a decrease in independence and the development of "cognitive laziness" in students were identified (Karamuk, 2025).

Content personalization technologies can include comprehensive user data collection, student profile formation, adaptive recommendation systems, and more. As a rule, all these technologies are integrated into one system: for example, a repository of educational facilities with a built-in adaptation mechanism that creates customized content based on experience (Su et al., 2011). There are also systems that, along with personalization, use elements of ontology and machine learning to account for a larger number of learner parameters (Raj & Renumol, 2022). In corporate training, the introduction of personalization significantly increases the comfort of employees, as it allows them to be flexible: to adjust the convenient time and method of presentation of the material. The combination of content relevance and individual development of point competencies significantly increases the effectiveness of training in an organization (Chunaev & Shikov, 2018).

In addition to AI and personalization of content in training, many studies identify other factors that could potentially be related to employee motivation in corporate training. For example, such a factor as "dynamic and contextual changes" is singled out as promising in the context of corporate training: *"Consideration of the dynamic and contextual influences on trainees provides an avenue for future research aimed at explaining transfer motivation in constantly changing workplaces."* (Gegenfurtner et al., 2009, P. 412)

Another additional factor is the strategic orientation and resources of the organization. The latest research notes: *"Future research should explore the optimal strategies used by industries that have successfully implemented training and development initiatives."* (Lee, Z., 2025, P. 2)

Thus, there are a few factors that could potentially be related to employee motivation in corporate training. Within this article the roles of these factors will be evaluated, thereby filling the existing gap in research by offering a fundamentally new approach based on the Self-Determination Theory (SDT) (Deci & Ryan, 2012).

3. Methodology

SDT was chosen as the methodological framework for the study. This theory primarily focuses on factors influencing employee expectations. SDT is already actively used as a basis for assessing employee motivation (Gagné, M. et al., 2015), as well as in the context of personalized learning strategies (Alamri, H. A., 2019). Due to its use in some studies related to learning, it can be argued that SDT has established itself as a theory that meets the business context, so its use in work is quite relevant.

At the first stage of the work, potential factors that can influence employee motivation in corporate training were found and selected. The scientific literature was studied and the factors for which the connection with motivation is still poorly understood were selected.

To collect data as part of the analysis of the role of factors influencing motivation for corporate training within the framework of the company's strategy, an author's questionnaire was developed to combine existing methods to assess the impact of factors on motivation in corporate training. The questionnaire includes the following factors with subscales, which are represented on Figure 1.

Factor / Scale	Sub-scale	Reference
Strategic Coherence	Vertical fit Horizontal fit Learning alignment	Based on Lusiani & Langley, 2019
Strategic Orientation	Exploration Exploitation Contextual ambidexterity	Based on Lubatkin et al., 2006
Environmental Dynamism	Speed Unpredictability	Based on Green et al., 2008
Slack Resources	Financial resources Operational resources Human resources Time resources	Adapted based on Nohria & Gulati, 1996 and Voss et al., 2008
Dynamic Capabilities	Sensing Seizing Transforming	Based on Kump et al., 2019
Key Financial Indicators	Cash Flow ROE Gross margin Operational income Net profit margin ROI	Covin et al., 1990 Gupta and Govindarajan, 1984
Content Personalization	Differences in learning styles and preferences Consideration of knowledge levels and competence gaps Automatic or intelligent routing of learning Flexibility in content generation (dynamic resource assembly) Content customization based on feedback	Su et al., 2011 Raj & Renumol, 2021 Garrido & Morales, 2014 Türker et al., 2006
AI	Automatic student profile building and individual assistance based on student behavior The dependence of "personalized" systems on average models Adaptive learning using ITS Personalized retrieval practice based on AI tutors Using AI to automatically create personalized microlearning	Schiaffino et al., 2008 Holmes et al, 2019 Ma et al., 2014 Baillifard et al., 2023
WPI Motivation Scale	Intrinsic motivation Extrinsic motivation Job satisfaction Complexity of the work Focus on the external environment Compensation for work	Amabile at al., 1994

Figure 1: Scales and sub-scales for the author's questionnaire, the Likert scale (1-7) was employed.

At the second stage of the work, a survey was conducted among 72 employees of companies in various fields (from IT to retail, Table 1 summarizes the key demographic characteristics of the sample) who have been/are undergoing corporate training over the past year. To compile the questionnaire, the author's questionnaire was compiled, which included factors of AI, content personalization, etc., as well as an adapted questionnaire "Diagnostics of internal and external staff motivation" by T. Amabile (WPI). To confirm the reliability of the questionnaire, the Cronbach's Alpha was calculated and evaluated for each scale.

Table 1: Summary of Participant Demographics (N = 72)

Characteristic	Distribution
Gender	55.6% Female (N = 40); 44.4% Male (N = 32)
Age Group	51.4% aged 18–25; 29.2% aged 26–35; 16.7% aged 36–45; 2.8% aged 46–55
Education Level	University-educated (Bachelor's or higher)
Industry	~26% IT; 24% Banking/Finance; 14% Retail; 8% FMCG; 4% Telecom; 3% Consulting; 3% Manufacturing; 3% Education; 19% other industries (various)
Company Size	Predominantly large enterprises (most > 250 employees; many in well-known large firms)
Training Type	Varied corporate training programs in the last year (technical courses, management training, etc.)

To evaluate the adequacy of the sample size (N=72), a post-hoc power analysis was conducted. This analysis indicated that our sample of 72 participants provides approximately 99,6% power to detect a medium effect size ($f^2 \approx 0.429$) at the $\alpha = 0.05$ significance level. In other words, the study has a high power to detect moderate-sized effects in the data. This indicates that the sample size is sufficient for the initial analysis, as it eliminates the possibility of a type II error due to insufficient sample size. We therefore consider the statistical power acceptable for the scope of this research.

Further, to assess the quality of the data and identify key relationships, a correlation and then regression analysis was performed, which allowed us to evaluate the relationships between variables based on a mathematical model. To identify additional relationships, mediation (intermediary variables) and moderation (variable amplifiers) were analyzed. All models are built using the Jamovi app.

In the final part, recommendations are formed based on the results of the study based on the literature. In addition to the recommendations, an algorithm for the implementation of artificial intelligence technologies in corporate training of companies was proposed, as well as the area of further research was identified.

4. Results

In order to assess how certain factors affect motivation, we will build a linear regression. It will allow us to find out which scales have the strongest influence and to what extent this influence is statistically significant. To assess the strength of the influence, we calculate a standard estimate (β-coefficient), and for statistical significance, a p–value and a 95% confidence interval.

As a result of the regression analysis, the strongest and most statistically significant predictors were identified, which are shown on Figure 2.

Dependent Variable	Predictor	p-value	Stand. Estimate	95% Confidence Interval	
				Lower	Upper
INTR	DC Sensing	0.001	0.6718	0.2742	1.0693
EXTR	ED	0.010	0.4251	0.107	0.743
EXTR	AI Retrieval	0.116	0.5021	-0.129	1.133
ORIENT	ED	0.004	0.4572	0.1577	0.757
ORIENT	AI Retrieval	0.064	0.5595	-0.0343	1.153
COMPLEX	DC Sensing	<.001	0.77926	0.3399	1.2186
COMPLEX	AI Profile	0.050	0.48045	9.88e-4	0.9599

Figure 2: The strongest predictors in the constructed linear regression

Notably, the effect sizes of these key predictors were substantial. Several factors exhibited high β-coefficients (exceeding 0.5), indicating not just statistical significance but also a practically significant impact on motivation outcomes. For instance, the dynamic capability of sensing new opportunities had β ≈ 0.67 in predicting intrinsic motivation – a magnitude that qualifies as a large effect in behavioral research terms. Such a large standardized coefficient suggests that improvements in this predictor variable would translate into meaningful, real-world increases in employees' motivation, rather than trivial changes. Overall, the regression results imply that the identified drivers (e.g., environmental dynamism, dynamic capabilities, etc.) are not only statistically reliable but also practically important influences on corporate learning motivation.

AI Retrieval has high values of the β coefficient, but it is not very significant, so it is impossible to say for sure how accurate this factor is as a predictor for external motivation and orientation to the external environment.

Next analysis will be the analysis of mediation (mediation effects). This analysis answers the question "through which variable does a factor influence a certain component of motivation". In other words, an intermediate variable is identified through which the influence is enhanced/weakened. The Bootstrap method (1000 samples) was chosen as the SE – standard errors estimation method. 1000 random samples will be taken from the data, which is quite relevant for analyzing a relatively small sample without assuming a normal distribution. The relationships will also be evaluated by the value of the coefficient of influence (>0.3 is considered high), and the statistical significance by the p-value and 95% confidence interval. The results of the analysis are shown on Figure 3.

				95% Confidence Interval		
Dependent Variable	Predictor	Mediator	Estimate	Lower	Upper	p-value
COMPLEX	Vertical fit	INTR	0.4542	0.252	0.726	<.001
COMPLEX	Horizontal fit	INTR	0.515	0.2849	0.7712	<.001
COMPLEX	Exploitation	INTR	0.431	0.1979	0.7544	0.002
COMPLEX	DC Sensing	INTR	0.5253	0.343	0.706	<.001
COMPLEX	DC Seizing	INTR	0.329	0.192	0.497	<.001
SAT	DC Sensing	INTR	0.3806	0.247	0.5388	<.001

Figure 3: The strongest mediators in the constructed model

The last analysis that will be conducted is a moderation analysis. The so-called conditional variables that strengthen/weaken the connection will be identified here. In this analysis, the same standard error estimation method (Bootstrap (1000 samples)) will be used, and connections will be evaluated by the value of the interaction coefficient. Its essence is to assess how much influence of some factors on motivation changes when the moderator's level increases by 1 standard deviation. Let's assume that a value >0.2 indicates a strong moderation, and values >0.15 indicate a moderately strong one. The results are shown on Figure 4.

				95% Confidence Interval		
Dependent Variable	Predictor	Moderator	Estimate	Lower	Upper	p-value
EXTR	Exploration	CP Plan	0.2057	0.11571	0.340	<.001
ORIENT	Exploration	CP Plan	0.2473	0.1239	0.412	<.001
SAT	ED	AI Model	0.1655	0.02724	0.294	0.014
ORIENT	DC Transformation	CP Know	0.1516	0.0421	0.292	0.013
ORIENT	Exploitation	CP Plan	0.1590	0.0504	0.270	0.004
ORIENT	Exploration	CP Know	0.1774	0.0544	0.434	0.068
ORIENT	Exploration	CP Feedback	0.1749	0.0100	0.4372	0.099
INTR	ED	CP Feedback	0.1534	-0.01932	0.262	0.025

Figure 4: The strongest moderators in the constructed model

It is worth noting that in all relationships (both strong and moderate), the values of the interaction coefficient are higher than the beta coefficient of direct influence which highlights that all the dedicated moderators strengthen the existing connections.

To summarize, it can be claimed that the presence of content personalization enhances the influence of many factors on many “motivation” scales (mainly related to external motivation). Intrinsic motivation serves as an excellent mediator for many factors (strategic coherence, exploitation orientation, and dynamic abilities). In other words, in the presence of these factors, employees in the organization are motivated to learn (intrinsic motivation), and work tasks are perceived as more complex (COMPLEX), or work pleasure increases (SAT). In general, the dynamism of the environment, the dynamic abilities of the organization, and several artificial intelligence technologies showed the strongest direct links to different components of motivation.

As a result, the scientific novelty of the work was reduced to the formation of a chain of strategic coherence (consistency and ambidextrity), dynamic capabilities of the company and AI/personalization technologies. Such a chain seems to be critically important to transfer employee motivation from the "need" category to the "want" mode. Thus, a synthesis of strategic and technological drivers of motivation is obtained, which makes it possible to expand the theory of SDT and transfer it to the L&D context. This paper closes a gap in recent research (Graf 2023), as it provides real data on the impact of technology on employee motivation, rather than on dry educational outcomes.

5. Discussion and Conclusion

Based on the results of the analysis and modern scientific research, a few recommendations can be proposed to increase employee motivation for corporate training.

To maximize impact, companies should ensure strategic coherence of their training programs. Empirical research underscores that learning initiatives that are tightly integrated with business strategy tend to be significantly more effective than ad hoc or disconnected efforts (Garavan, 2007; Tannenbaum et al., 2010). L&D managers should closely link training programs to the company's business strategy and current objectives. According to Garavan (2020) corporate personnel development programs today often lack correlation with strategic goals, which reduces their effectiveness. For instance, research highlights that aligning learning initiatives with key strategic competencies remains a persistent challenge for many organizations and is cited as a critical success factor for improving learning transfer and organizational performance (Blume et al., 2010; Salas et al., 2012).

Secondly, it is essential to develop the dynamic capabilities of the organization and establish the culture of continuous learning. The results of the study showed that the internal motivation of employees is significantly influenced by the company's ability to discover and master new opportunities (DC Sensing) (β=0.67, $p<0.01$). This, to foster improvement, L&D managers should implement practices that stimulate organizational learning and innovation. These may include knowledge-sharing initiatives, internal innovation hackathons, and cross-functional research projects targeting emerging technologies and best practices (Eisenhardt & Martin, 2000). Empirical studies have shown that organizations encouraging knowledge exchange and employee-driven innovation benefit from increased organizational learning and individual motivation (Vera & Crossan, 2004). This resonates with the bibliometric trend that forward-looking universities – and by analogy, corporate universities – leverage AI to shorten the path from insight to skill (Gordienko & Bagrationi, 2024).

Finally, organizations should personalize the training content to meet the needs of employees. Although in our study, indicators of personalization did not become unambiguous predictors of motivation, numerous studies have noted the positive effect of an individualized approach (Su et al., 2011; Chunaev & Shikov, 2018). . Adaptive learning systems that customize content based on learner profiles have been shown to improve engagement, satisfaction, and learning outcomes (Mirari, 2022).

Research has also shown that artificial intelligence technologies have significant potential to increase motivation and learning effectiveness (Zawacki-Richter et al., 2019). Based on the analysis of literature and practical recommendations of experts, it is possible to identify the stages of the implementation of AI initiatives in the education and development system:

Firstly, it is critical to ensure that the deployment of AI tools aligns with the organization’s strategic priorities and addresses specific skill gaps (Khaustova & Riabokin, 2024). By focusing on business goals (reducing training time, increasing sales through knowledge, etc.), L&D managers ensure the semantic value of the project and receive management support. At the same stage, the following resources are evaluated: financial (budget for

software/development), technical (infrastructure, data for training algorithms) and human (competences of the L&D and IT teams).

Secondly, a suitable AI solution should be selected and tested through a controlled pilot project with a small group of employees. The pilot project allows you to collect feedback, test the effectiveness of the tool and identify potential problems on a small scale. It is critically important at this stage to actively involve employees and managers themselves in the process: explain to them the advantages of the new approach, conduct training on using the AI tool, and address questions and concerns (Bond et al., 2021).

Thirdly, upon demonstrating positive pilot outcomes, the AI tool can be scaled to larger cohorts and integrated with existing learning ecosystems such as Learning Management Systems (LMS) and Human Resource Information Systems (HRIS).

Finally, post-implementation, systematic evaluation should compare pre- and post-AI integration metrics (e.g., learning engagement rates, skill acquisition benchmarks) to assess effectiveness (Baker et al., 2019). Based on the evaluation of the results, a decision is made to correct the strategy: it may be necessary to expand the functionality (for example, add a gamification module to increase motivation), or vice versa, to abandon some functions if they turn out to be unclaimed. It is important that the introduction of AI is not a one–time project, but an ongoing process: technologies are developing rapidly, and L&D managers should monitor new opportunities (for example, generative models for content creation, VR/AR for immersive learning) and test them on a separate group before scaling (Roll & Wylie, 2016; Zawacki-Richter et al., 2019).

Beyond practical recommendations, our findings also help expand Self-Determination Theory (SDT) into the corporate learning field. According to SDT, motivation improves when people feel competent, connected to others, and free to make their own choices (Deci & Ryan, 2012). Our results show that organizational factors — such as how well training aligns with company strategy — can support these needs. For example, when training clearly reflects strategic goals, employees are more likely to see it as meaningful and valuable, which in turn boosts their intrinsic motivation.

We also found that combining strategic elements (like strategic coherence) with personalized, AI-based learning tools helps shift motivation from “I have to learn” toward “I want to learn.” This transition from extrinsic to intrinsic motivation reflects a deeper internalization of learning goals — something SDT highlights as crucial. One example is the strong effect of the company’s ability to sense new opportunities, which showed a high positive link with intrinsic motivation. While personalization alone wasn’t the strongest predictor, it still plays a supporting role by giving learners more control — which helps meet their need for autonomy.

Overall, this study shows that SDT can be applied not only at the individual level but also in organizational settings, where strategic and technological factors shape motivation in meaningful ways.

Finally, the effect sizes we observed were not just statistically significant — they were large enough to matter in practice. Some predictors had beta values around 0.6–0.7, which suggests that acting on these drivers can lead to real improvements in employee motivation. This gives L&D professionals a strong evidence base for investing in strategic coherence when designing training programs.

Ethical Declarations

Ethical clearance was not required for the research

AI Declarations

AI (ChatGPT o3) was used to enhance language quality

References

Ahmed, M., Zaid, N. M., & Abdullah, A. H. B. The Impact of Integration of AI in Statistics Learning on Student Motivation and Learning Engagement in Higher Education Sector *International Journal of Academic Research in Progressive Education and Development*, *14(*1), 426-436.

Aksiutin, A., Bagrationi, K., Morozov, M., Trochin, I. (2022). Non-formal social ties as threat to the implementation of innovations. *European Conference on Innovation and Entrepreneurship*, ECIE, 17(1), 1–7.

Alamri, H. (2019). *Effects of Personalized Learning as an Instructional Approach on Students’ Self-Determination and Learning Engagement in Online Higher Education* (Doctoral dissertation, Purdue University).

Amabile, T. M., Hill, K. G., Hennessey, B. A., & Tighe, E. M. (1994). The Work Preference Inventory: assessing intrinsic and extrinsic motivational orientations. *Journal of personality and social psychology*, *66*(5), 950.

Baker, R., Smith, L., & Educational Endowment Foundation. (2019). *Education technology: Evidence review*. Education Endowment Foundation.

Bagrationi K, Gordienko O. (2024). Dynamics of organisational change: resistance, readiness, and the road ahead. *European Conference on Innovation and Entrepreneurship*, ECIE, 19(1), 81–88.

Bagrationi, K., Thurner, T. W., Gordienko, O. (2021). Resistance to digital transformation and the destruction of social capital. Proceedings of the *European Conference on Innovation and Entrepreneurship*, ECIE (47–53).

Bagrationi, K., Thurner, T. W., & Gordienko, O. (2022, August). Resistance to Digital Transformation: The Role of Middle Management Personal Networks. In *European Conference on Knowledge Management* (Vol. 23, No. 1, pp. 52-59).

Bhatt, P., & Muduli, A. (2023). Artificial intelligence in learning and development: a systematic literature review. *European Journal of Training and Development*, *47*(7/8), 677-694.

Blume, B. D., Ford, J. K., Baldwin, T. T., & Huang, J. L. (2010). Transfer of training: A meta-analytic review. *Journal of Management*, 36(4), 1065–1105.

Bisht, S., Sengupta, S., & Kumar, M. (2025). AI in action: transforming learning environments in tech organizations. *Development and Learning in Organizations: An International Journal*, *39*(3), 26-29.

Bond, M., Zawacki-Richter, O., & Nichols, M. (2021). Revisiting five decades of educational technology research: A content and authorship analysis of the British Journal of Educational Technology. *British Journal of Educational Technology*, 52(2), 601–618.

Braun, G., Bokinge, M., Rosén, B. G., Syberfeldt, A., & Stahre, J. (2024). Mastering Industry's Skill Gap-Matching Employee Needs with New Learning Challenges. In *2024 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)* (pp. 668-672). IEEE.

Buckley, C., & Castro Jorge, M. F. (2024). Upskilling for the Modern Workplace: A Case Study on the Most Effective Training Methods and Tools for Bridging the Skills Gap. *International Journal of Advanced Corporate Learning*, *17*(4).

Chunaev, A., & Shikov, A. (2018). The method of personalized corporate e-learning based on personal traits of employees. *Procedia computer science*, *136*, 511-521.

Covin, J. G., Slevin, D. P., & Covin, T. J. (1990). Content and performance of growth-seeking strategies: A comparison of small firms in high-and low technology industries. *Journal of business venturing*, *5*(6), 391-412.

Deci, E. L., & Ryan, R. M. (2012). Self-determination theory. *Handbook of theories of social psychology*, 1(20), 416-436.

Diakova, A., Bagrationi, K., & Gordienko, O. (2024). Change-oriented Leadership in the Context of Transitioning to Strategic Autonomy. *European Conference on Management, Leadership & Governance*, ECMLG, 114–123.

Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: What are they? *Strategic Management Journal*, 21(10-11), 1105–1121.

Gagné, M., Forest, J., Vansteenkiste, M., Crevier-Braud, L., Van den Broeck, A., Aspeli, A. K., ... & Westbye, C. (2015). The Multidimensional Work Motivation Scale: Validation evidence in seven languages and nine countries. *European Journal of work and organizational psychology*, *24*(2), 178-196.

Garavan, T. N. (2007). A strategic perspective on human resource development. *Advances in Developing Human Resources*, 9(1), 11–30.

Garavan, T. (2023). Learning and development practitioners in organisations: organising, belonging, learning and performing tensions. *Irish Journal of Management*, *42*(2), 88-103.

Garavan, T. N., Heneghan, S., O'Brien, F., Gubbins, C., Lai, Y., Carbery, R., ... & Grant, K. (2020). L&D professionals in organisations: much ambition, unfilled promise. *European Journal of Training and Development*, *44*(1), 1-86.

Gegenfurtner, A., Veermans, K., Festner, D., & Gruber, H. (2009). Integrative literature review: Motivation to transfer training: An integrative literature review. *Human resource development review*, *8*(3), 403-423.

Gordienko, O., Bagrationi, K. (2024). Global integration of artificial intelligence in higher education sector: a bibliometric analysis. *European Conference on Knowledge Management*, ECKM, 25(1), 270–276.

Graf, A. (2023). Exploring the role of personalization in adaptive learning environments. *International Journal Software Engineering and Computer Science (IJSECS)*, *3*(2), 50-56.

Karamuk, E. (2025). The Automation Trap: Unpacking the Consequences of Over-Reliance on AI in Education and Its Hidden Costs. *Pitfalls of AI Integration in Education: Skill Obsolescence, Misuse, and Bias*, 151-174

Khaustova, Y., & Riabokin, T. (2024). Integration of Artificial Intelligence into the Corporate Management System. *Economics, Finance and Management Review*, 4 (20), 68-79.

Kump, B., Engelmann, A., Kessler, A., & Schweiger, C. (2016). Towards a dynamic capabilities scale: Measuring sensing, seizing, and transforming capacities. In *Academy of Management Proceedings* (Vol. 2016, No. 1, p. 13839). Briarcliff Manor, NY 10510: Academy of Management.

Lee, Z. (2025). Overcoming Barriers to Corporate Training: A Strategic Framework for Success. *New Advances in Business, Management and Economics Vol. 6*, 156-173.

Lubatkin, M. H., Simsek, Z., Ling, Y., & Veiga, J. F. (2006). Ambidexterity and performance in small-to medium-sized firms: The pivotal role of top management team behavioral integration. *Journal of management*, *32*(5), 646-672.

Lusiani, M., & Langley, A. (2019). The social construction of strategic coherence: Practices of enabling leadership. *Long Range Planning*, *52*(5), 101840.

Ma, W., Adesope, O. O., Nesbit, J. C., & Liu, Q. (2014). Intelligent tutoring systems and learning outcomes: A meta-analysis. *Journal of educational psychology*, *106*(4), 901.

Mirari, K. (2022). The effectiveness of adaptive learning systems in personalized education. *Journal of Education Review Provision*, *2*(3), 107-115.

Pertiwi, R. W. L., Kulsum, L. U., & Hanifah, I. A. (2024). Evaluating the Impact of Artificial Intelligence-Based Learning Methods on Students' Motivation and Academic Achievement. *International Journal of Post Axial: Futuristic Teaching and Learning*, 49-58.

Nohria, N., & Gulati, R. (1996). Is slack good or bad for innovation?. *Academy of management Journal*, *39*(5), 1245-1264.

Raj, N. S., & Renumol, V. G. (2022). A systematic literature review on adaptive content recommenders in personalized learning environments from 2015 to 2020. *Journal of Computers in Education*, *9*(1), 113-148.

Roll, I., & Wylie, R. (2016). Evolution and revolution in artificial intelligence in education. *International Journal of Artificial Intelligence in Education*, 26(2), 582–599.

Salas, E., Tannenbaum, S. I., Kraiger, K., & Smith-Jentsch, K. A. (2012). The science of training and development in organizations: What matters in practice. *Psychological Science in the Public Interest*, 13(2), 74–101.

Schiaffino, S., Garcia, P., & Amandi, A. (2008). eTeacher: Providing personalized assistance to e-learning students. *Computers & Education*, *51*(4), 1744-1754.

Su, J. M., Tseng, S. S., Lin, H. Y., & Chen, C. H. (2011). A personalized learning content adaptation mechanism to meet diverse user needs in mobile learning environments. *User modeling and user-adapted interaction*, *21*, 5-49

Shan, Z., & Wang, Y. (2024). Strategic talent development in the knowledge economy: a comparative analysis of global practices. *Journal of the Knowledge Economy*, 1-27.

Tannenbaum, S. I., Beard, R. L., McNall, L. A., & Salas, E. (2010). Informal learning and development in organizations. In S. W. J. Kozlowski (Ed.), *The Oxford handbook of organizational psychology*, 1, 303–319.

Tewari, I., & Pant, M. (2020). Artificial intelligence reshaping human resource management: A review. In *2020 IEEE international conference on advent trends in multidisciplinary research and innovation (ICATMRI)* (pp. 1-4). IEEE.

Turker, A., Görgün, İ., & Conlan, O. (2006). The challenge of content creation to facilitate personalized e-learning experiences. *International Journal on E-Learning*, *5*(1), 11-17.

Vera, D., & Crossan, M. (2004). Strategic leadership and organizational learning. *Academy of management review*, *29*(2), 222-240.

Voss, G. B., Sirdeshmukh, D., & Voss, Z. G. (2008). The effects of slack resources and environmentalthreat on product exploration and exploitation. *Academy of Management journal*, *51*(1), 147-164.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–Where are the educators? *International Journal of Educational Technology in Higher Education*, 16(1), 1–27.

Zinchenko, M., Bagrationi, K., & Gordienko, O. (2024). Development of Corporate University Evolution Scenarios. *European Conference on E-Learning*, ECEL, 451–457.

Strategic Coherence under Turbulence: How Corporate Universities Balance Exploration and Exploitation

Olga Tunkevichus, Irina Plaunova and Konstantin Bagrationi
Graduate School of Business, HSE University, Frankfurt am Main, Germany

ivplaunova@edu.hse.ru
kbagrationi@hse.ru
oagordienko@hse.ru

Abstract: Corporate Universities (CUs) play a crucial role in modern businesses, serving as strategic tools that foster individual and organizational learning, knowledge creation, and innovation. Their impact extends beyond mere skill acquisition, influencing organizational outcomes such as sustainable competitive advantage, social innovation, and enhanced knowledge processes. CUs' success relies on a number of contextual circumstances, including the institutional environment, economic situation, and industry-specific norms. Moreover, being integral components of organizational learning systems, CUs align with the concept of organizational ambidexterity. However, their strategic orientation – whether exploratory (innovation-oriented) or exploitative (efficiency-oriented) – remains understudied: while extant literature underlines the role of CUs in organizational ambidexterity, there is little empirical evidence on what determines their orientation. This research bridges these gaps by statistically validating the influence of the most significant factors on CU's strategic orientation. Based on open-source material, such as articles and reports retrieved from large scientifical databases, this study gives the state of the art of corporate education research and identifies strategically important factors for CUs. A survey conducted among the management staff of well-known CUs in large companies supplied comprehensive responses. Hypotheses are tested to examine the effect of external environments, strategic learning practices and technology integration on CU strategic orientation. By integrating ambidexterity theory with organizational learning theories, this research provides a comprehensive framework of CU strategic coherence. The findings contribute to both theoretical and applied domains by (1) contributing to the scant literature on CUs, (2) empirically validating the dynamic influence of various factors in CU orientation, and (3) providing practical lessons for corporate managers and policymakers on how to facilitate long-term CU effectiveness. This research not only addresses a significant gap in comparative CU research but also provides input for strategic decision-making to foster innovation and competitiveness under turbulent economic conditions.

Keywords: Corporate Universities, Strategic Orientation, Strategic Coherence, Corporate Learning, Exploration vs. Exploitation

1. Introduction

CUs are vital strategic tools in modern organizations that promote learning, knowledge creation, and innovation (Allen, 2002). Aside from enhancing personal skills development, they contribute to organizational success by strengthening competitive advantage, innovation, and knowledge management (Scarso, 2017; Rademakers, 2005). They are effective depending on situational factors including industry culture, economic performance, and cultural differences (Shakina et al., 2024; Parshakov & Shakina, 2018; Bogolyubov & Easterby-Smith, 2013). In today's rapidly changing business environment (Meister, 1998), ongoing learning through CUs has become essential, with progressive companies employing them to become successful in knowledge-based markets (Rademakers, 2005).

Despite their potential, many CUs focus on operational training rather than strategic knowledge innovation (Jansink et al., 2005). Recent empirical evidence shows that tightly knit, non-formal social ties – often labelled blat – can silently block the diffusion of novel practices, including digital learning solutions, by shielding employees from strategic directives (Aksiutin et al., 2022). This issue is particularly evident in emerging markets, where institutional, cultural, and economic conditions differ from Western contexts (Bogolyubov & Easterby-Smith, 2013). Much of the existing research centers on Western CUs, creating a gap in understanding those in other regions. Foresight-based scenario studies show how CUs can follow divergent evolutionary paths depending on technology uptake and change-management capability (Zinchenko et al., 2024). Because employee readiness for, and resistance to change vary sharply across institutional settings (Bagrationi & Gordienko, 2024; Bagrationi et al., 2021, 2022), context-sensitive studies of CUs remain indispensable.

As integral components of organizational learning systems, CUs align with the concept of organizational ambidexterity - balancing exploration (innovation) and exploitation (efficiency) strategies (O'Reilly & Tushman, 2008). However, the influences on their strategic orientation from this point of view remain underexplored. So, the following major *research question* is raised: What are the key determinants influencing the ambidextrous strategic orientation of CUs?

2. Theoretical Foundations of the Study

The CU concept originated with a General Electric initiative in the 1950s, though significant development began in the late 1980s (Gould, 2005). This period saw economies shift toward service-oriented and knowledge-based industries, prompting organizations to invest in specialized training. Walton (1999) identified three generations of CUs. The first concentrated on formalized, standardized training. The second centered on the flexibility and autonomy of workers amidst growing competition. Third-generation universities reflect technological advancements and utilize virtual communication modalities for training. In today's organizational landscape, knowledge plays a pivotal role in sustaining competitive advantage. CUs act as agencies in spreading, consolidating, and facilitating knowledge to affect business results (Singh et al, 2020).

Efforts to categorize CUs are generally found on strategic emphasis. Rademakers (2005) proposes three categories, starting with rudimentary training (School) and progressing to strategic innovation (Academy). Paton et al (2017) highlights a networked model of CU encompassing diverse learning strategies as the newest one. The most advanced CUs actively impact corporate strategy, pointing to the critical importance of designing CUs in harmony with organizational goals.

2.1 Strategic Orientation From an Ambidextrous Point of View

The strategic orientation in this article is framed through an ambidextrous approach (Ramachandran et al., 2019). Drawing on March (1991), organizational ambidexterity involves balancing exploration and exploitation. Exploitation refers to refinement, efficiency, and execution, linked to explicit knowledge, while exploration involves experimentation, innovation, and risk-taking, tied to tacit knowledge (Nonaka, 1994; Benner & Tushman, 2003). Together, these enable firms to thrive amid market uncertainty. The knowledge process in companies is strongly related to ambidexterity. For instance, Lin et al (2013) recognizes the ability of learning to facilitate organizational ambidexterity which, in turn, provokes business performance. This term has been applied to education already by numerous scholars (Cabeza-Pulléset al, 2020), but it concerns traditional and not corporate education. Lissillour & Rodriguez-Escobar (2022) were the first to apply it specifically to CUs. This article extends this debate.

2.2 Selecting Potentially Influential Factors

Drawing on existing literature, the factors influencing the strategic orientation of CUs can be examined through an ambidextrous lens. Batra & Dhir's (2022) classification of ambidextrous orientation antecedents in developing economies highlights key elements that lead to the introduction of strategic context factors in this study. Additionally, Chen & Xu's (2022) insights support the role of strategic learning and digitalization. A more detailed analysis is given below.

2.2.1 Strategic Coherence

Rademakers (2005) posits that two features are common to successful CUs: strong top management commitment and a clear mission linked to corporate strategy. Extending this view, recent work on change-oriented leadership under conditions of strategic autonomy demonstrates that leaders who frame evaluation systems as learning opportunities significantly boost employees' willingness to support transformational CU agendas (Diakova et al., 2024). These variables enable the university to effectively exploit and innovate knowledge, resulting in long-term organizational performance. In this paper, strategic coherence is seen as a combination of vertical and horizontal strategic fits. Strategy requires balancing them to achieve both stability and distributed problem-solving creativity. The combination of the two concepts is equivalent to the topic of ambidexter strategic orientation for employee training. Moreover, this approach aligns with the unique challenges of emerging markets (Hoskisson et al, 2000).

Hypothesis 1 (H1): The CU strategic orientation positively follows from the characteristics of the main strategic priorities implemented in the organization.

2.2.2 Strategic Learning Processes

Exploration and exploitation strategies are associated with strategic learning processes, as demonstrated by Sirén et al (2012). Organizational learning addresses the fundamental challenge of maintaining an equilibrium between developing new knowledge and leveraging existing competencies, particularly as organizations naturally tend to favor one over the other (Levinthal & March, 1993). An integrative strategic learning framework (Sirén et al,

2012) encompasses individual, group, and organizational levels, connected by processes like knowledge creation, distribution, interpretation, and implementation. Within this context, Paton et al (2017) highlight the growing importance of CUs as strategic learning mechanisms.

H2: Strategic learning processes significantly influence the adoption of CU strategies, contributing to overall ambidexterity.

2.2.3 Cultural Influences

The effectiveness and efficiency of CUs are context-dependent (Singh et al, 2020). In developing economies, they have an additional challenge to provide training to cover up gaps in public education systems (Kolo et al, 2013). Bogolyubov & Easterby-Smith, 2013 illustrated cross-national variations in organizational learning. For instance, high power distance and uncertainty avoidance negatively impacted adaptability, while individualism and long-term orientation facilitated learning. As such, CUs' operation may be contingent on the special nature of the CU program and where it operates.

Hypothesis 3 (H3): Cultural dimensions influence the choice of CU strategic orientation significantly.

2.2.4 Digital Learning

E-learning concepts are in extensive application in third-generation CUs, which are currently the most common type everywhere (Walton, 1999). In this study, we use digitization as an umbrella term that represents many modern technologies enhancing accessibility, interactivity, and efficiency in education.

According to Singh et al (2020), now technology is a key force shaping CUs. The scientific research shows that IT capabilities have a positive impact on innovation ambidexterity. While IT infrastructure alone may not create a competitive advantage (Kmieciak et al., 2012), IT capabilities can boost both processes, particularly in emerging markets (Soto-Acosta et al., 2018). Based on the AI case as the brightest example of modern technology, the content analysis of global news on AI (Johnson et al, 2022) shows a preference for exploratory use (64%) over exploitative use (5%). This suggests a similar trend may apply to other digital technologies.

Hypothesis 4 (H4): The introduction of modern technologies in CUs has a greater impact on the adoption of an exploration strategy than an exploitation one.

As illustrated in Figure 1, the conceptual model posits that several antecedent factors – including strategic coherence, strategic learning processes, cultural context, and digital capabilities – influence a CU's strategic orientation toward exploration (innovation-focused) or exploitation (efficiency-focused). The arrows in Figure 1 represent the hypothesized direction of each influence, indicating how each factor is expected to drive either an exploratory or exploitative orientation.

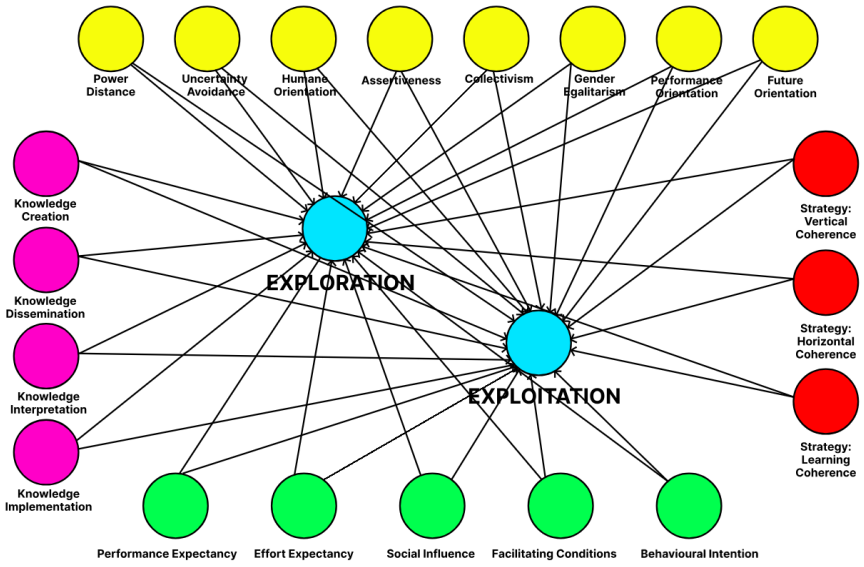


Figure 1: The generalized conceptual framework of the study

3. Data and Methodology

The literature review identified several factors that may influence CU's strategic direction, but these had not been studied thoroughly. To address this gap, the study developed a questionnaire to test the proposed hypotheses using rigorous statistical methods. The conceptual model was a prerequisite for SEM, which relates measurement items to their respective latent variables. Data analysis began with descriptive statistics and confirmatory factor analysis (CFA) to assess construct validity, followed by PLS-SEM with a bootstrapping procedure (5,000 resamples) to evaluate the significance of each hypothesized path (Hair et al., 2019). This approach was chosen to accommodate the sample size and non-normal data, and to robustly test the proposed relationships.

3.1 Questionnaire Development

The questionnaire utilized 7-point Likert scales to provide more accurate responses (Joshi et al, 2015). It measured CU's strategic orientation, technological innovation, strategic learning processes, and regional cultural influences, and consisted of 91 items. To enhance content validity, the questionnaire was reviewed by two subject-matter experts. Their feedback led to minor wording adjustments, ensuring that all items were clear and relevant. All key constructs were measured with multiple items, and each scale demonstrated high internal consistency (composite reliability > 0.85) and acceptable convergent validity (average variance extracted > 0.50), indicating a robust measurement instrument (Hair et al., 2019).

Scales for exploration and exploitation items were constructed by the authors using theoretical anchors and empirical measures available from the literature on innovation and organizational learning (He & Wong, 2004; March, 1991). The strategic coherence measurement was also author-constructed. A key strength was the inclusion of six learning alignment items, which assessed how well training initiatives aligned with strategic priorities. The strategic learning items were adapted from Sirén (2012). A modified version of the GLOBE research program's questionnaire (House et al., 2004) was used to assess cultural dimensions. Leadership-related items were removed from Form Alpha of the 2006 GLOBE survey, as they were outside the scope of the study. The UTAUT framework (Venkatesh et al., 2003) was used to examine technology adoption.

3.2 Sample and Procedure

The selection of CUs for the study followed criteria set by Paton et al. (2017): they must be centralized initiatives in large organizations aimed at generating enterprise-wide value, maintain strategic coherence through adaptable programs, and enhance learning outcomes via partnerships and technology. Accordingly, CUs were selected from large companies (1000+ employees) across various industries.

The study targeted managers in strategic divisions of selected CUs. Out of 23 companies from emerging markets invited, 5 participated. The survey did not collect personal data in any form, and therefore, ethical or data protection approval was not mandatory. Overall, the CUs that took part in the survey belonged to the development, telecommunications, FMCG, and consulting industries. The final sample consisted of 67 mostly young, female, and well-educated managers, reflecting a modern, tech-oriented CU leadership in the region, though with a gender imbalance. The survey was administered via an online questionnaire distributed to the selected CUs, ensuring convenience and anonymity for participants. Out of 23 CUs invited, five provided responses (approximately a 22% participation rate at the organization level). The final sample of 67 managers reflects a modern, tech-oriented CU leadership demographic.

3.3 Primary Data Analysis

The items were grouped by construct and averaged to create composite scores. This process ensured that all constructs were standardized and ready for further statistical analysis, including correlation and regression.

For analysis purposes, we used SmartPLS 4 and Python statistical software. Variance Inflation Factor (VIF) values were calculated to check for multicollinearity. No significant multicollinearity was detected in the dataset (inner-VIF < 3). Descriptive statistics showed high mean scores, moderate standard deviations, and near-normal univariate distributions based on skewness, kurtosis, and the Shapiro-Wilk test. However, the data did not follow a multivariate normality. Given the novel nature of this research, partially custom-developed indicators, and a small (N=67) sample with non-normal multivariate distribution (confirmed by the Mardia test, $p<0.05$), PLS-SEM was an appropriate choice. It effectively handles limited sample sizes, non-normal data, and new measurement scales, while offering strong predictive power suited to the exploratory aim of identifying key influencing factors (Hair et al., 2019; Jannoo et al., 2014).

3.4 Analyzing Construct Validity

As the measurement model was established, CFA was conducted to account for construct differences. Items with non-significant p-values were removed. The measurement model showed an acceptable fit to the data based on several fit indices. The Comparative Fit Index (CFI) was 0.942, above the recommended threshold of 0.90, indicating a good fit. The Tucker-Lewis Index (TLI) was 0.875, slightly below the ideal cutoff but still acceptable. The Root Mean Square Error of Approximation (RMSEA) was 0.0687, with a 90% confidence interval from 0.0258 to 0.101, and fell below the 0.08 threshold, suggesting a reasonable fit. The Standardized Root Mean Square Residual (SRMR) was 0.0675, also under the recommended threshold of 0.08. All preserved factor loadings were positive and mostly substantial with many exceeding 0.7, indicating strong relationships between indicators and their factors. Out of 91 questions, 79 remained.

4. Results

In this study, results are reported at the p≤0.1 significance level, which is considered marginally significant. This approach is appropriate given that the research is exploratory in nature and based on a small sample size. For comparative purposes, findings at the more conventional 0.05 significance level are also indicated where applicable. Unlike CB-SEM, PLS-SEM does not rely on traditional model fit indices like chi-square or SRMR due to differences in algorithmic foundations (Hair et al., 2019). The model-fit indices requirements were met (high indicator loadings, AVE ≥ 0.5, HTMT ratio < 0.9, VIF < 5). Figure 2 presents the estimated structural equation model with all hypothesized paths and their standardized coefficients. As shown in the figure, the model explains approximately 70% of the variance in the exploration orientation and about 80% of the variance in the exploitation orientation of CUs (indicated by R^2 values), highlighting the model's substantial explanatory power.

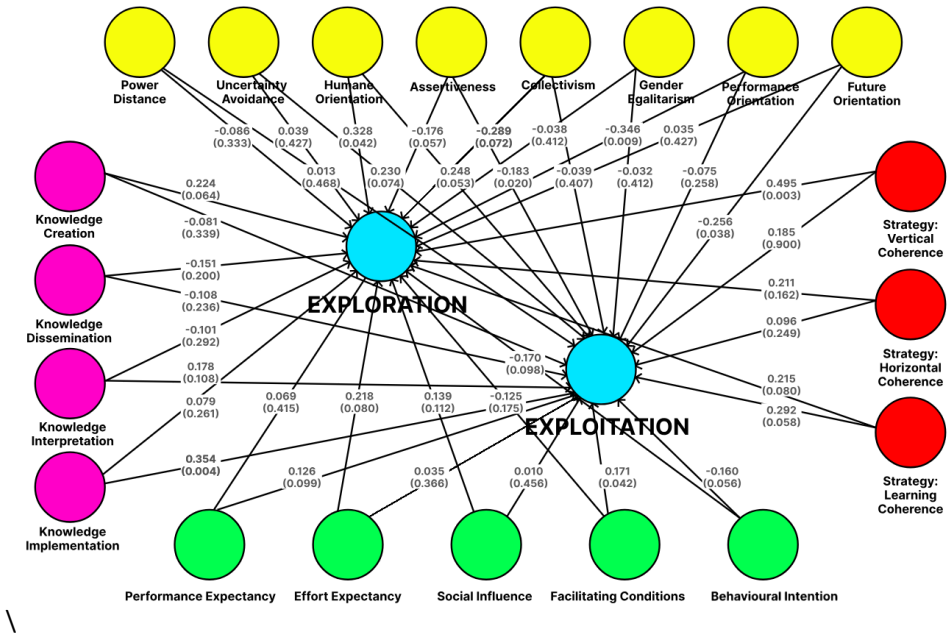


Figure 2: The estimated structural equation model

4.1 Hypotheses Testing

The bootstrapping results with 5000+ iterations are shown in Table 1, which details the results of the hypothesis tests, listing each proposed influence on exploration and exploitation alongside its standardized coefficient, standard deviation and p-value. The table highlights the relative strength of each factor's impact on exploratory versus exploitative orientation, guiding interpretation of the model's findings.

4.1.1 Strategic Coherence

Learning alignment marginally predicts both exploration (β=0.215, p<0.1) and exploitation (β=0.292, p<0.1). Vertical alignment influences exploitation (β=0.185, p<0.1) and significantly predicts exploration (β=0.495, p<0.05), whereas horizontal alignment shows no significant relationships. These findings indicate that vertical

strategic linkages and learning alignment support overall ambidexterity, being in line with Hypothesis 1 and underscoring the role of strategic coherence and vertical integration in enhancing CU effectiveness.

4.1.2 Strategic Learning

Knowledge creation positively predicts exploration (β=0.224, p<0.1). Knowledge implementation significantly drives exploitation (β=0.354, p<0.05). Other learning dimensions show marginal or no relationships. So, the hypothesis that strategic learning processes positively influence ambidexterity is partially supported. Distinct aspects of strategic learning drive different innovation types. Nevertheless, the balanced ambidexterity is not reached.

4.1.3 Cultural Influences

The results provide support for H3. Several cultural dimensions (e.g., assertiveness, collectivism, humane orientation, uncertainty avoidance, future orientation, performance orientation) show significant or marginally significant relationships with either exploitation or exploration. However, not all cultural dimensions demonstrate effects, indicating that while cultural dimensions influence strategic orientation, their impact varies depending on the specific dimension and the type of strategy.

4.1.4 Digital Learning

The results do not fully support H4. While effort expectancy has a marginally significant positive effect on exploration (β=0.218, p<0.1), facilitating conditions (β=0.171, p<0.05) and performance expectancy (β=0.126, p<0.1) have significant positive effects on exploitation with no effect on exploration. Behavioral intention is negatively connected to both strategies. This suggests that technologies may have a greater impact on exploitation rather than exploration, contrary to H4. However, while most factors had some impact on exploitation, fewer influenced exploration, though their effect was stronger in that area.

Table 1: Hypothesis testing

		Original sample (O)	Standard deviation (STDEV)	P values
Cultural Influences	*Assertiveness -> EXPLOITATION*	-0.183	0.089	0.020
	Assertiveness -> EXPLORATION	-0.176	0.112	0.057
	Collectivism -> EXPLOITATION	-0.039	0.168	0.407
	Collectivism -> EXPLORATION	-0.289	0.197	0.072
	Humane Orientation -> EXPLOITATION	0.248	0.153	0.053
	Humane Orientation -> EXPLORATION	0.328	0.189	0.042
	Power Distance -> EXPLOITATION	0.013	0.156	0.468
	Power Distance -> EXPLORATION	-0.086	0.200	0.333
	Gender Egalitarism -> EXPLOITATION	0.032	0.142	0.412
	Gender Egalitarism -> EXPLORATION	-0.038	0.170	0.412
	Uncertainty Avoidance -> EXPLOITATION	0.230	0.159	0.074
	Uncertainty Avoidance -> EXPLORATION	0.039	0.212	0.427
	Future Orientation -> EXPLOITATION	-0.256	0.144	0.038
	Future Orientation -> EXPLORATION	0.035	0.193	0.427
	Performance Orientation -> EXPLOITATION	-0.075	0.115	0.258
	Performance Orientation -> EXPLORATION	-0.346	0.145	0.009
Digital Learning	Effort Expectancy -> EXPLOITATION	0.035	0.103	0.366
	Effort Expectancy -> EXPLORATION	0.218	0.153	0.080
	Facilitating Conditions -> EXPLOITATION	0.171	0.099	0.042
	Facilitating Conditions -> EXPLORATION	-0.125	0.134	0.175
	Behavioral Intention -> EXPLORATION	-0.170	0.132	0.098
	Behavioral Intention -> EXPLOITATION	-0.160	0.100	0.056
	Performance Expectancy -> EXPLOITATION	0.126	0.098	0.099
	Performance Expectancy -> EXPLORATION	0.069	0.124	0.415
	Social Influence -> EXPLOITATION	0.010	0.087	0.456
	Social Influence -> EXPLORATION	0.139	0.114	0.112
Strategic learning	Knowledge Creation -> EXPLORATION	0.224	0.147	0.064
	Knowledge Creation -> EXPLOITATION	-0.081	0.194	0.339
	Knowledge Dissemination -> EXPLOITATION	-0.108	0.150	0.236
	Knowledge Dissemination -> EXPLORATION	-0.151	0.180	0.200
	Knowledge Implementation -> EXPLORATION	0.079	0.123	0.261
	Knowledge Implementation -> EXPLOITATION	0.354	0.131	0.004
	Knowledge Interpretation -> EXPLOITATION	0.178	0.143	0.108
	Knowledge Interpretation -> EXPLORATION	-0.101	0.185	0.292
Strategic alignment	Strategy: Learning Alignment -> EXPLOITATION	0.292	0.185	0.058
	Strategy: Learning Alignment -> EXPLORATION	0.215	0.153	0.080
	Strategy: Horizontal Alignment -> EXPLOITATION	0.096	0.141	0.249
	Strategy: Horizontal Alignment -> EXPLORATION	0.211	0.214	0.162
	Strategy: Vertical Alignment -> EXPLOITATION	0.185	0.138	0.090
	Strategy: Vertical Alignment -> EXPLORATION	0.495	0.182	0.003

To sum up, the data provided statistical evidence in favor of Hypotheses 1 and 3, while other hypotheses showed mixed results.

5. Discussion

Overall, the research on strategic orientation in CUs within emerging economies, viewed through the lens of ambidexterity, highlights key findings (Fig. 2). Strategic coherence and strategic learning emerge as the strongest predictors (based on β-estimates) of success for either exploration or exploitation strategies. Strategic learning alignment shows the greatest positive impact on both, underscoring the importance of shared understanding, knowledge sharing, and adaptive learning cultures central to CUs' mission (Garzón Castrillon, 2019). Vertical Alignment also significantly supports ambidexterity, particularly in markets where hierarchical structures often hinder implementation (Hoskisson et al, 2000). These insights align with prior studies stressing structured knowledge processes and strategic consistency for balancing exploration and exploitation (Crossan & Berdrow, 2003; Sirén et al, 2012; Rademakers, 2005; Batra & Dhir, 2022). However, the results indicate that different dimensions of learning have distinct impacts on strategic orientation. Knowledge creation and implementation emerge as key drivers of organizational ambidexterity, supporting Kat'kalo and Shumkova (2024), who found that CUs in emerging country primarily focus on knowledge creation activities such as education (100%) and interaction with universities (62%), which are closely linked to exploration. High involvement in personnel assessment (81%) further highlights a strong emphasis on knowledge implementation, aligning with exploitative strategies. In contrast, limited engagement in knowledge distribution (e.g., publishing, conferences – 9%) and interpretation suggests these processes are either embedded within broader practices or less critical, exerting minimal influence on ambidexterity.

Cultural dimensions significantly influence strategic orientation. In contexts with high power distance and uncertainty avoidance, organizations tend to prioritize efficiency over experimentation. However, this study found no significant impact of power distance, contrary to earlier studies by Pelagio Rodriguez & Hechanova (2014) and Bogolyubov & Easterby-Smith (2013). Pandey and Sharma (2009) suggested that high uncertainty avoidance cultures favored exploitation over exploration, which was supported here. Humane orientation was found to support a people-centered environment that encourages exploration and strengthens exploitation. However, collectivism was found to be negatively related to exploration only, suggesting that highly cohesive or group-oriented environments might limit the diversity of perspectives or autonomy needed for exploratory activities. Future orientation was negatively related to exploitation, aligning with long-term flexibility. Assertiveness hindered both exploration and exploitation, suggesting competitive cultures may stifle innovation. Performance orientation also limited exploration, indicating achievement-driven environments may reduce creativity and risk-taking.

The digital perspective did not support the research hypothesis that new technologies contribute more to exploration than exploitation. Exploitation was more broadly driven by technological enablers. However, leading UTAUT constructs exhibited different patterns: effort expectancy was indeed positively related to exploration, meaning that the convenience of use in technology inspired people more toward new and risky activities. Concurrently, facilitating conditions and performance expectancy mainly facilitated exploitation, suggesting a focus on efficiency when job performance and organizational support were experienced. Therefore, although most digital tools enhance operational efficiency, the newest ones such as AI and adaptive technologies may have supported exploration if intentionally designed for it (Gastaldi et al., 2022; Johnson et al., 2022), underscoring the need for targeted strategies that go beyond intentions to foster innovation in digital environments. A recent bibliometric synthesis confirms this trajectory, revealing six fast-growing AI research streams in higher education – ranging from generative tutoring systems to blockchain-backed credentialing –that jointly enlarge the exploratory space available to learning organisations (Gordienko & Bagrationi, 2024).

6. Conclusion

The findings indicated that the alignment of CUs with broader organizational goals is crucial in shaping their strategic orientation, underscoring their role as key platforms for knowledge integration. Strategic learning processes were found to positively influence both exploration and exploitation, though with varying intensity and focus. Additionally, cultural dynamics in emerging economies were shown to significantly influence strategic decision-making, while technological capabilities predominantly fueled exploitation efforts.

This study has several limitations. The small sample size (67 CU managers) limited statistical power and generalizability, particularly beyond emerging markets. Moreover, CFA required modifying or removing

constructs, thus simplifying the model. The marginal significance level assessment is also a limitation and requires further research.

Based on the findings of this study, several practical lessons can be drawn for corporate managers and policymakers aiming to enhance the effectiveness of CUs. First, it is essential to foster strategic congruence between CUs and organizational goals, particularly through strong vertical integration and learning congruence that support exploratory and exploitative approaches (i.e., balanced ambidexterity). This sets CUs in a leading position for influencing long-term organizational performance. Second, promoting strategic learning processes can significantly enhance a CU's ability to balance exploration and exploitation, though different dimensions of learning may require targeted interventions depending on the desired strategic orientation. Third, understanding and sensitivity to cultural and technological forces in emerging markets are required, as certain dimensions can facilitate or hinder innovation and efficiency. Policymakers should complement their efforts by crafting mechanisms that encourage investment in strategic CU initiatives and build innovation-supportive environments and conditions for continuous learning. Fourth, organizations should institute mechanisms for knowledge retention to preserve intellectual capital when employees depart. CUs can play a pivotal role in capturing and codifying the tacit know-how of experienced staff – for instance through structured knowledge-transfer programs, mentorship, or documented best practices – so that valuable expertise remains within the company (Nonaka, 1994; Scarso, 2017). By converting individual know-how into organizational memory and intellectual property, firms reinforce the exploitation side of ambidexterity, ensuring that accumulated knowledge continues to be leveraged for efficiency and competitive advantage even as personnel change.

Ethical Declarations

Ethical clearance was not required for the research.

AI Declarations

AI (ChatGPT o3) was used to enhance language quality.

References

Aksiutin, A., Bagrationi, K., Morozov, M., Trochin, I. (2022). Non-formal social ties as threat to the implementation of innovations. European Conference on Innovation and Entrepreneurship, ECIE, 17(1), 1–7.

Allen, M. (2002). The corporate university handbook: designing, managing, and growing a successful program. New York: Amacom.

Bagrationi K, Gordienko O. (2024). Dynamics of organisational change: resistance, readiness, and the road ahead. European Conference on Innovation and Entrepreneurship, ECIE, 19(1), 81–88.

Bagrationi, K., Thurner, T. W., Gordienko, O. (2021). Resistance to digital transformation and the destruction of social capital. Proceedings of the European Conference on Innovation and Entrepreneurship, ECIE (47–53).

Bagrationi, K., Thurner, T. W., & Gordienko, O. (2022, August). Resistance to Digital Transformation: The Role of Middle Management Personal Networks. In European Conference on Knowledge Management (Vol. 23, No. 1, pp. 52-59).

Batra, I., P, P. and Dhir, S. (2022). Organizational ambidexterity from the emerging market perspective: A review and research agenda. Thunderbird International Business Review.

Benner, M.J. and Tushman, M.L. (2003). Exploitation, Exploration, and Process Management: The Productivity Dilemma Revisited. The Academy of Management Review, [online] 28(2), p.238.

Blut, M., Chong, A.Y.L., Tsigna, Z. and Venkatesh, V. (2022). Meta-Analysis of the Unified Theory of Acceptance and Use of Technology (UTAUT): Challenging its Validity and Charting a Research Agenda in the Red Ocean. Journal of the Association for Information Systems, 23(1), pp.13–95.

Cabeza-Pullés, D., Fernández-Pérez, V. and Roldán-Bravo, M.I. (2020). Internal networking and innovation ambidexterity: The mediating role of knowledge management processes in university research. European Management Journal, 38(3), pp.450–461.

Crossan, M.M. and Berdrow, I. (2003). Organizational learning and strategic renewal. Strategic Management Journal, 24(11), pp.1087–1105.

Diakova, A., Bagrationi, K., & Gordienko, O. (2024). Change-oriented Leadership in the Context of Transitioning to Strategic Autonomy. European Conference on Management, Leadership & Governance, ECMLG, 114–123.

Garzón Castrillon, M.A. (2019). Proposed model of corporate University. Visión de Futuro, (23, No 1 (Enero - Junio)), pp.24–41.

Gastaldi, L., Lessanibahri, S., Tedaldi, G. and Miragliotta, G. (2022). Companies' adoption of Smart Technologies to achieve structural ambidexterity: an analysis with SEM. Technological Forecasting and Social Change, 174, p.121187.

Gordienko, O., Bagrationi, K. (2024). Global integration of artificial intelligence in higher education sector: a bibliometric analysis. European Conference on Knowledge Management, ECKM, 25(1), 270–276.

Gould, K.E. (2005). The Corporate University. Behavior Modification, 29(3), pp.508–520
Hair, J.F., Risher, J.J., Sarstedt, M. and Ringle, C.M. (2019). When to use and how to report the results of PLS-SEM. European Business Review, 31(1), pp.2–24.
He, Z.L. and Wong, P.K. (2004). Exploration vs. Exploitation: An Empirical Test of the Ambidexterity Hypothesis. Organization Science, 15(4), pp.481–494.
Hoskisson, R.E., Eden, L., Lau, C.M. and Wright, M. (2000). Strategy in Emerging Economies. Academy of Management Journal, 43(3), pp.249–267.
Jansink, F., Kwakman, K. and Streumer, J. (2005). The knowledge-productive corporate university. Journal of European Industrial Training, 29(1), pp.40–57.
Johnson, P.C., Laurell, C., Ots, M. and Sandström, C. (2022). Digital innovation and the effects of artificial intelligence on firms' research and development – Automation or augmentation, exploration or exploitation? Technological Forecasting and Social Change, [online] 179(179), p.121636.
Joshi, A., Kale, S., Chandel, S. and Pal, D.K. (2015). Likert Scale: Explored and Explained. British Journal of Applied Science & Technology, [online] 7(4), pp.396–403.
Kat'kalo, V. and Shumkova, N., 2024. Korporativnye Universitety Rossii – 2024. Izdatelskiy Dom NIU VShE.
Kmieciak, R., Michna, A. and Meczynska, A. (2012). Innovativeness, empowerment and IT capability: evidence from SMEs. Industrial Management & Data Systems, 112(5), pp.707–728.
Kolo P, Strack R, Cavat P, Torres R, Bhalla V. (2013). Corporate Universities: an Engine for Human Capital. The Boston Consulting Group (BCG)
Levinthal, D.A. and March, J.G. (1993). The myopia of learning. Strategic Management Journal, 14(S2), pp.95–112.
Lin, H.-E., McDonough, E.F., Lin, S.-J. and Lin, C.Y.-Y. (2012). Managing the Exploitation/Exploration Paradox: The Role of a Learning Capability and Innovation Ambidexterity. Journal of Product Innovation Management, 30(2), pp.262–278.
Lissillour, R. and Rodriguez-Escobar, J.A. (2022). Organizational ambidexterity and the learning organization: the strategic role of a corporate university. The Learning Organization.
March, J.G. (1991). Exploration and Exploitation in Organizational Learning. Organization Science, 2(1), pp.71–87.
Meister, J.C. (1998). Extending the Short Shelf Life of Knowledge. Training & Development, 52(6).
Nonaka, I. (1994). A Dynamic Theory of Organizational Knowledge Creation. Organization Science, 5(1), pp.14–37.
O'Reilly, C.A. and Tushman, M. (2007). Ambidexterity as a Dynamic Capability: Resolving the Innovator's Dilemma. SSRN Electronic Journal.
Rademakers, M. (2005). Corporate universities: driving force of knowledge innovation. Journal of Workplace Learning, 17(1/2), pp.130–136.
Ramachandran, I., Lengnick-Hall, C.A. and Badrinarayanan, V. (2019). Enabling and leveraging ambidexterity: influence of strategic orientations and knowledge stock. Journal of Knowledge Management, 23(6), pp.1136–1156.
Scarso, E. (2017). Corporate universities as knowledge management tools. VINE Journal of Information and Knowledge Management Systems, 47(4), pp.538–554.
Shakina, E., Barajas, Á. and Patricio, S.-F. (2024). Revisiting the corporate university phenomenon: quasi-experiment in telecom. Heliyon, pp.e34314–e34314.
Singh, V., Verma, S. and Chaurasia, S.S. (2019). Mapping the themes and intellectual structure of corporate university: co-citation and cluster analyses. Scientometrics, 122(3), pp.1275–1302.
Sirén, C.A. (2012). Unmasking the capability of strategic learning: a validation study. The Learning Organization, 19(6), pp.497–517.
Sirén, C.A., Kohtamäki, M. and Kuckertz, A. (2012). Exploration and exploitation strategies, profit performance, and the mediating role of strategic learning: Escaping the exploitation trap. Strategic Entrepreneurship Journal, 6(1), pp.18–41.
Soto-Acosta, P., Popa, S. and Martinez-Conesa, I. (2018). Information technology, knowledge management and environmental dynamism as drivers of innovation ambidexterity: a study in SMEs. Journal of Knowledge Management, 22(4), pp.824–849.
Venkatesh, V., Morris, M.G., Davis, G.B. and Davis, F.D. (2003). User Acceptance of Information technology: toward a Unified View. MIS Quarterly, [online] 27(3), pp.425–478.
Walton, J., 1999. Human resource development and the corporate university. In: J. Walton, ed., Strategic human resource development. Harlow: FT Prentice Hall, pp. 412–437.
Zinchenko, M., Bagrationi, K., & Gordienko, O. (2024). Development of Corporate University Evolution Scenarios. European Conference on E-Learning, ECEL, 451–457.

An Automated Feedback System for Written Exams

Stefan Ullmann and Mareike Schoop
University of Hohenheim, Stuttgart, Germany

Stefan.Ullmann@uni-hohenheim.de
Schoop@uni-hohenheim.de

Abstract: Summative assessments, particularly exams, are the dominant method for evaluating student performance in higher education. Although feedback is the single most influential factor in promoting learning, exams are often excluded from the good practices highlighted in literature. The gap stems from challenges such as time constraints, large student numbers, and institutional policies. While automation could improve feedback processes, most current automated feedback systems (AFS) are teacher-centred and do not align with good feedback practices. The present paper uses a design science research approach to develop a student-centred AFS for exams in different domains. The system provides a structured setup process to guide lecturers in providing high-quality feedback. We utilise expert knowledge in the form of Bloom's taxonomy and task types, as well as student data such as points, to generate feedback for each student providing a performance overview and suggestions how to improve their exam performance and learning strategies. In addition, the system delivers detailed feedback on topics on which the student performed poorly. In an initial evaluation of the student-centred AFS, three lecturers successfully used the AFS to generate feedback reports to 1323 students from two large-scale bachelor courses. Survey results indicate that the student-centred AFS delivers high-quality, timely, and personalised feedback at scale, helping students to adapt learning strategies and to identify deficits. The present work thus contributes to solving the challenges of feedback in higher education in general and to solving the exam-specific feedback gap. Additionally, our AFS that is easy to adapt for non-experts. We demonstrate the various design features required for such an AFS, including an adaptable domain model utilising Bloom's taxonomy and customisable task types, to ensure applicability across diverse educational domains.

Keywords: Constructive Feedback, Assessment Feedback, Automated Feedback System

1. Introduction

Assessment is of vital importance for learning and teaching in higher education (Mekonen and Fitiavana, 2021; O'Donovan, Rust and Price, 2016). Apart from suggestions to replace traditional assessment methods, summative assessments are still the most common assessment method (Alquraan, 2012; Rawlusyk, 2018; Ray et al., 2018).

The process of assessment using exam, consists of setting a learning task for the student to perform followed by grading the performance and providing the student with their mark. Assessment feedback is an effective means for students to improve their performance and future learning (O'Donovan, Rust and Price, 2016). However, feedback practices, contextual constraints and individual challenges can be challenging (Henderson, Ryan and Phillips, 2019).

From the students' perspective, quality of the comments is often problematic in *feedback practices*. Students ask for more and specific feedback and suggestions for improvement. Lecturers are concerned *with contextual constraints* including time constraints and the scalability of feedback practices especially for large courses which leads to students not receiving well-crafted and personalised feedback. *Individual challenges* include the lecturers' expertise and understanding of the student. There are also some specific challenges regarding written exams (Henderson, Ryan and Phillips, 2019; Scoles, Huxham and McArthur, 2013). The distribution of marked exams as feedback prevents their re-use. Furthermore, students could receive assessment content from previous students, limiting their own revision of the material (Halinen et al., 2014; Medina and Yuet, 2013; Ray et al., 2018).

The feedback process could benefit from technological innovations (Haughney, Wakeman and Hart, 2020). Automating some forms of feedback could save time for lecturers and thus decrease their workload (Debuse, Lawley and Shibl, 2008). Many of the current automated feedback technologies are teacher-oriented whereas students would potentially profit from a more student-oriented approach adaptable to their needs (Deeva et al., 2021).

The overall goal of the present paper is to develop and evaluate a student-centred automated feedback system for exam feedback which overcomes the challenges.

2. Theoretical Background

The relevant theoretical background in learning, assessment and feedback will now be discussed.

2.1 Bloom's Taxonomy

Bloom's taxonomy classifies mental learning and skills into six cognitive levels, as shown in figure 1, (Bloom et al., 1956; Scott, 2003) which we use to categorise exam questions in a hierarchy of complexity (Anderson and Krathwohl, 2001; Omar et al., 2012).

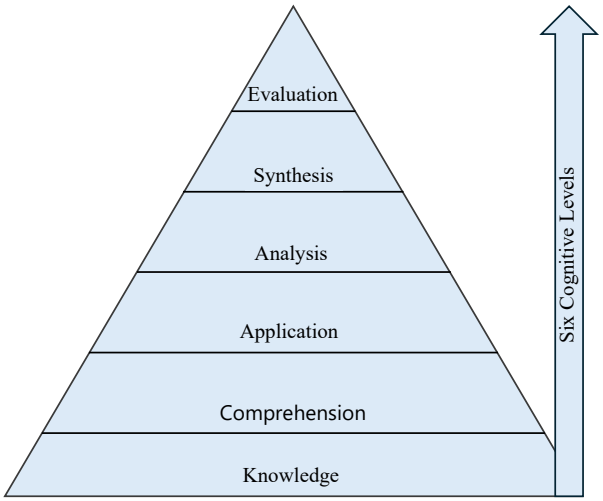


Figure 1: Six cognitive levels based on Bloom at al. 1956

The *knowledge* level refers to the memorisation. *Comprehension* refers to the meaning of information and explaining, classifying or interpreting. The *application* of concepts to specific scenarios means students understand and apply a concept. *Analysis* refers to breaking down information into simpler parts and analysing them including inferring relationships. *Synthesis* is about integrating and combining ideas or concepts into a new whole. E*valuation* alludes to rating and judging the values of ideas for given purposes (Bloom et al., 1956; Omar et al., 2012; Scott, 2003; Starr, Manaris and Stalvey, 2008).

2.2 Assessment and Feedback

Assessments are performed by lecturers to collect information about a student's performance and achievements (Gronlund, 1998). Formative assessments are carried out continuously throughout a course (Jacoby et al., 2014; Sambell, McDowell and Montgomery, 2012), whereas summative assessments evaluate a student's performance at the end of a course, e.g. in written exams (Gibson and Shaw, 2011; Gronlund, 1998). Summative assessments can be combined with supportive feedback and can thus work formatively (Carless, Joughin and Liu, 2006).

Good feedback needs to answer three questions to be effective for the learner: "Where am I going?" (clarifying the intended goal or task), "How am I going?" (informing about the performance in relation to the learning goal) and "Where to next?" (promoting continuous learning and improvement of performance) (Daka et al., 2021; Hattie and Timperley, 2007); it should provide useful information, be specific and personalised (Higgins, Hartley and Skelton, 2002), address the unique needs and contexts of the learner, be timely (James, McInnis and Devlin, 2002), consistent (Holmes and Smith, 2003), legible and detailed (Nicol, 2010) to foster understanding and facilitate improvement (Higgins, Hartley and Skelton, 2002).

3. Related Research

Automated feedback systems (AFSs) can both grade assessments and generate feedback automatically. However, most AFSs focus on the grading. Therefore, they mainly decrease the workload of lecturers. A typical AFS deduces the feedback from a domain model, expert knowledge and student data. This is done using a feedback generation model, which specifies the type and recipient of the feedback by using student data and/or expert knowledge. Most AFSs use feedback generation models that are data-driven (32.1%) or expert-driven

(48.6%); only 21% use a mixed approach. The domain model is a structured representation of the domain knowledge (Deeva et al., 2021).

AFSs can be open (allowing lecturers to set key parameters e.g. feedback information) or closed (preventing the change of parameters or process). Complex systems may require considerable technical expertise to adapt or modify the AFS. If an AFS can be adapted by the lecturer, options exist to adapt the feedback to the requirements of the circumstances and students (Shum et al., 2023).

Types of AFSs include learning management systems, recommender systems and intelligent tutoring systems (Schipper, Feskens and Keuning, 2021; Shum et al., 2023). Most AFSs are domain-specific; only 6% are non-domain-specific and therefore usable universally (Deeva et al., 2021). These non-domain-specific AFSs are designed for providing feedback in online assessments (Del Sánchez-Vera et al., 2012) , for providing formative feedback in large classes (Schaffer et al., 2017), and for use as part of a learning system for students (Tass Grigoriou, Christopher Cheong, and France Cheong, 2015). However, none of them is designed for providing feedback on written exams.

Generative AI can be used to generate feedback (McGowan, Anderson and Smith, 2024; Morales-Chan et al., 2024; Park, 2023) but lecturers need to review AI feedback and adjust it if necessary (McGowan, Anderson and Smith, 2024).

4. Research Goal and Methodology

The state-of-the-art shows that most AFSs are not student-centred, focusing primarily on automated grading and reducing lecturers' workloads; they require lecturers to possess technical expertise; they are domain-specific, which can limit their applicability (Deeva et al., 2021; Shum et al., 2023). Consequently, AFSs should support lecturers in implementing feedback element; AFSs should be applicable to exams in different subject areas; AFSs must fulfil the unique requirements of exam feedback, such as ensuring exams are not leaked during the feedback process. To this end, the following research questions are addressed:

- RQ1: Which properties does a student-centred AFS require to provide high-quality scalable feedback across different educational domains?
- RQ2: How can such an AFS be implemented?
- RQ3: How do students assess the clarity and actionable quality of the exam feedback generated by the AFS?

To answer these research questions, we follow a design science approach as shown in figure 2 (Hevner et al., 2004; Hevner, 2007; Peffers et al., 2020). The following chapters provide a detailed description of all the steps necessary to answer the RQs.

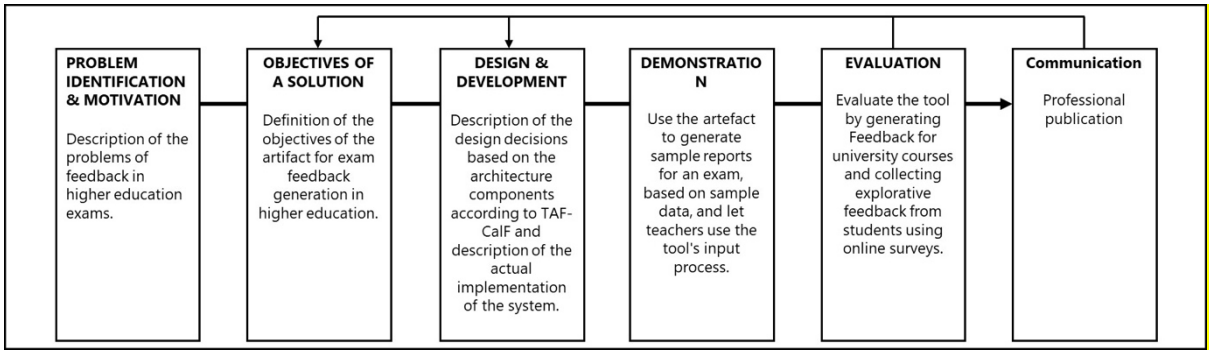


Figure 2: Design Science Process

5. Problem Identification and Objective Derivation

5.1 Problem Identification

A *detailed problem identification* is necessary to derive the objectives and justify the solution; it helps to understand the problem, which is vital for understanding the argumentation presented (Peffers et al., 2020). To this end, a case study in a German university with mostly paper-based exams was conducted. The problem

analysis is based on literature, the authors' teaching experience and interviews with three experienced lecturers. The derived problems are numbered as P1 to P6.

Students receive their grade digitally following the grading of the exam and are offered an exam inspection on-site. Such events might take place much later than the publication of grades. Therefore, receiving timely feedback cannot be guaranteed (P1) but timeliness is an important factor for good feedback (Henderson, Ryan and Phillips, 2019; Li and Luca, 2014). As exam reviews are handled by experienced lecturers who can provide good feedback and advice on how to improve the student's learning strategy, this could close the previously described feedback gap. However, only a small number of students take advantage of the exam reviews and a small proportion of attending students ask questions about specific tasks or ways to improve. Furthermore, detailed face-to-face feedback in exam reviews is not feasible for large student groups (P2). Taken together, most students do not receive feedback that goes beyond the grade which is a general problem in higher education (P3) (Scoles, Huxham and McArthur, 2013).

Another important aspect concerns the distribution of graded exams to students which poses a potential threat to the integrity of subsequent exams, as there is a risk that students will not fully engage with the content, resulting in a narrow focus on marks rather than a broad understanding. Effective lecturers often reuse existing test questions (Appelhaus et al., 2023) due to a high workload which is also one of the most frequently cited challenges to good feedback (Henderson, Ryan and Phillips, 2019). Furthermore, there is a need to archive exams for several years depending on relevant legal regulations. Therefore, it is not possible to hand out the original exams as part of the feedback (P4).

AFSs are mostly designed for a specific domain (P5) (Deeva et al., 2021) and can thus not provide domain-independent exam feedback. AFSs are often lecturer-oriented rather than primarily addressing the quality of feedback given to students (P6) (Deeva et al., 2021).

5.2 Objectives of a Solution

Figure 3 summarises which *objectives* (called O1-O8) were derived from which problems. The problem analysis shows the need for a student-centred (O1) AFS usable in various domains (O2) that can provide high-quality feedback to a large number of students in a scalable and timely manner (O3) without the need of exam publication (O4). Such AFS needs to be easily adaptable to different exams (O5) and usable for a wide range of lecturers (O6). As the need for large data sets can make it difficult to use the system for different exams (Keuning, Jeuring and Heeren, 2019), the system should keep the required data simple (O7), to ensure good usability for various lecturers. The primary focus of student-centred AFSs should be the production of high-quality feedback for students (Deeva et al., 2021). Therefore, the AFS needs to ensure that effective feedback is provided addressing the intended goals and the students' performance in relation to these goals. Additionally, the feedback should provide instructions and suggestions on how students can further improve their learning and performance (O8).

Table 1: Mapping of Problems to Objectives

Problems	Objectives
P1: No timely feedback	O3: Scalable, timely feedback
P2: No practical solution for large groups	O3: Scalable, timely feedback
P3: Only exam feedback are often marks	O5: Usable for different exams, O6: Usable different lecturers, O7: Keeping required data simple, O8: High-Quality feedback
P4: No distribution of old exams	O4: No exam publication needed
P5: AFS domain specific	O2: Domain-independent usability
P6: lecturer-oriented/ feedback quality	O1: Student-centred AFS, O8: High-Quality feedback

6. Design and Development

In the following subsections, steps three and four of the design science research process are conducted.

6.1 Conceptual Design

The *conceptual design* is derived from the objectives (cf. section 5.2). The architecture component of the TAF-ClaF with its five essential AFS elements is used as a reference (Deeva et al., 2021). (1) The domain model is a structured representation of the domain knowledge (Deeva et al., 2021). Such model for the described tool must be easily adaptable for different domains. Bloom's taxonomy as an established method for classifying exam tasks in various domains (Rawat, Kumar and Singh Samant, 2023) is thus a good foundation for an easy-to-use and widely applicable AFS. To support lecturers in classification tasks, the AFS offers task types that can be defined by the lecturer (e.g. multiple-choice vs. free-response questions). The tool is thus able to provide feedback with suggestions for further improvement based on the individual student's ability to answer questions with different levels of thinking skills required or based on different task types. The feedback can, therefore, be personalised for each topic and for each student. (2) The expert knowledge used to derive rules for mapping the domain knowledge to student input can be provided by lecturers or educational theories. We use both to give students information for improving their learning strategies. (3) The student data required for feedback generation (Deeva et al., 2021) are the achieved points in each (sub)tasks. (4) The feedback generation model is a set of rules the system provides that uses data, expert knowledge or both to generate the feedback (Deeva et al., 2021). We use the achieved points in the different tasks and subtasks of an exam, combined with the knowledge of different levels of required thinking skills. The general exam feedback informs students of their performance on tasks of a specific thinking skill or specific task types and issues hints about what kind of preparation is important to improve. These hints are general in nature and can be used for all types of exams. At the task level, a description of the learning objectives for each task is provided. The subtasks are grouped according to the levels of thinking skills required or their different task types. A general description of the objectives for each subtask group is provided. Finally, the students are shown their achieved points in each task and subtask in relation to the set points. The lecturers are guided in providing feedback, ensuring that essential information is included. (5) The system must be easy to use. Once set up, our system is able to generate and send a structured feedback report attached to an email to each individual. The system can work offline and does not need to be integrated into a learning system. Figure 4 shows which objectives are fulfilled by which essential element design decisions.

6.2 Development

We *implemented* our AFS using Excel to organise information across several spreadsheets for ease of use. The AFS backend uses decision mechanisms and an algorithm to calculate and rank the relative and absolute point losses for the whole exam and for each task in relation to the classified thinking skill or the type of task, by analysing the points lost by a student in each individual subtask. The length of the feedback report can be customised by specifying the percentage of points that must be achieved in a task to receive task-specific feedback. For each exam, general exam information (e.g., date, title) as well as a threshold for task-specific feedback are provided by the lecturer. Based on the number of (sub)tasks and their topics, the AFS recommends text blocks for general feedback based on Bloom's thinking skill levels, which can be modified. Task-specific feedback includes goal descriptions and suggestions for improvement. The AFS provides a structured set-up process as shown in figure 5, containing examples, tips and instructions to the lecturer. Once all text blocks are complete, student data is entered, the individualised feedback reports and the emails with the reports attached are generated and sent.

Table 2: Mapping of Objectives to Design Solutions

Objective	Essential Elements	Design Solution
O1: Student-centred AFS	(1), (2), (4)	Blooms taxonomy/ task types, student points and the lecturer knowledge enable generation of personalised feedback
O2: Domain-independent usability	(1), (3)	Blooms taxonomy/ task types and student points are not domain specific, widely used and known from many lecturers
O3: Scalable, timely feedback	(5)	Automated generation and distribution without manual work after setup
O4: No exam publication needed	(1)	The use of task classification makes it possible to generate personalised feedback without a need for task/ exam publication
O5: Usable for different exams	(3), (4)	The adaptable domain model combined with easily available student data makes the tool usable for a wide range of exams
O6: Usable different lecturers	(1), (3), (5)	Domain model and student data are easy to use/ available. The structured, assisted set up process makes it easy usable
O7: Keeping required data simple	(3)	Point of the tasks/ subtasks
O8: High-quality feedback	(1), (2), (3), (5)	The structured and assisted setup process together with the student data and domain model ensure actionable, personalised feedback on the overall exam and on task level

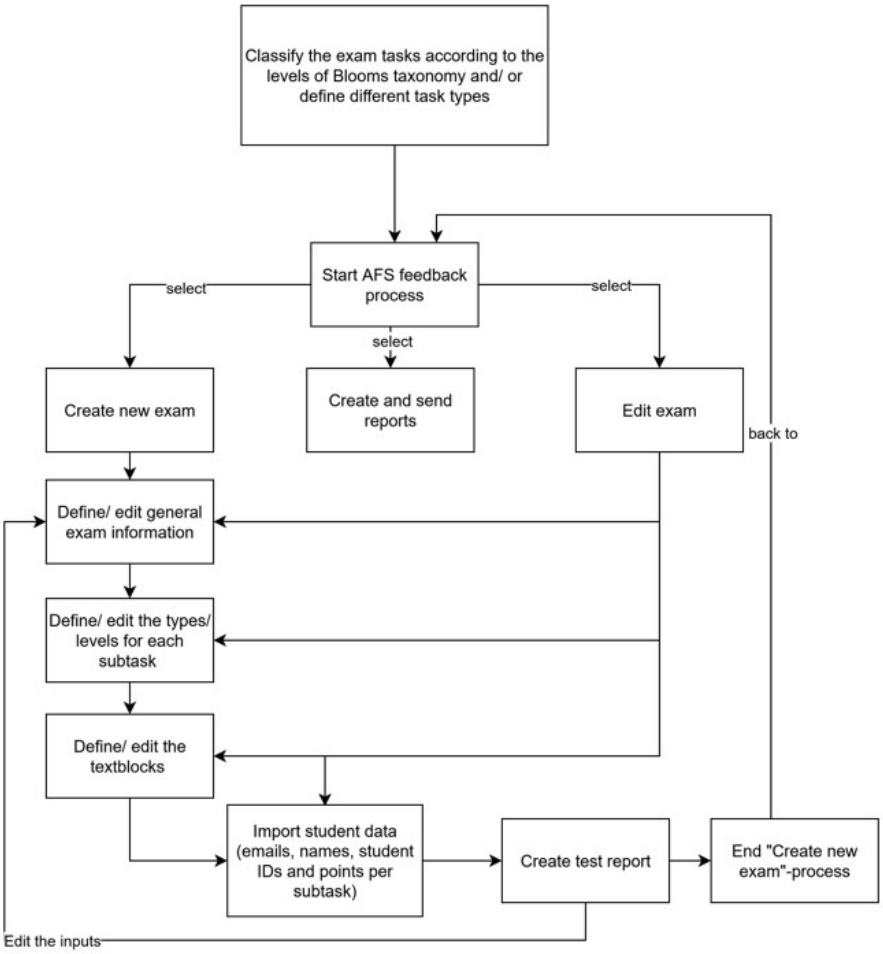
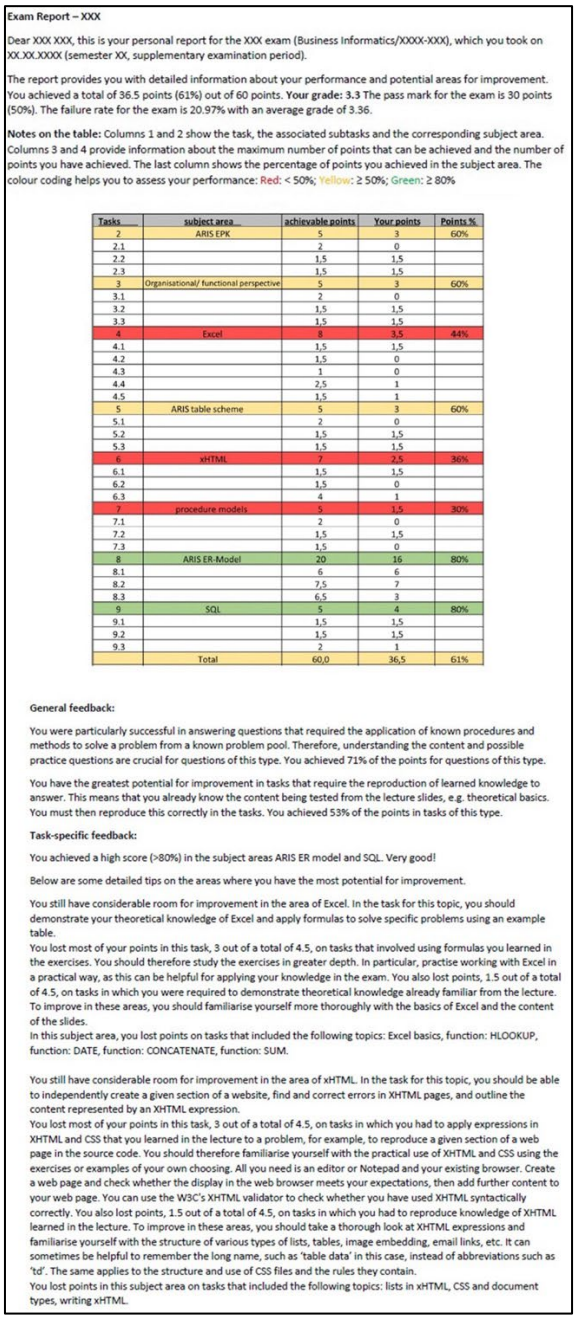


Figure 3: Setup Process Diagram

6.3 Demonstration: Feedback Report

A generated example feedback report is shown in figure 6. The personal address to the student is followed by general information about the exam, details of the grade, the total number of points achieved and the number of points necessary for passing the exam. The exam overview table provides an overview of the task information including the achieved points in relation the set points. The rows of each task are coloured green, yellow and red depending on the percentage of points achieved. This is done to make the report more legible. The second page of the report contains general feedback on the student's performance based on the overall exam performance for the different thinking skill levels or task types. It contains a description of the task type/thinking skill level and hints on how to improve preparation and performance. The feedback includes both general and task-specific comments. Currently, students receive feedback for tasks where less than 80% of the points are achieved; this number can be adapted for each exam. The detailed task-specific feedback contains a general description of the task goal in the exam, followed by descriptions and learning aid for the sub tasks of thinking skills/task types where the student lost points. For tasks with more than 80% of the points, appraisal feedback is provided.



Exam Report – XXX

Dear XXX XXX, this is your personal report for the XXX exam (Business Informatics/XXXX-XXX), which you took on XX.XX.XXXX (semester XX, supplementary examination period).

The report provides you with detailed information about your performance and potential areas for improvement. You achieved a total of 36.5 points (61%) out of 60 points. **Your grade: 3.3** The pass mark for the exam is 30 points (50%). The failure rate for the exam is 20.97% with an average grade of 3.36.

Notes on the table: Columns 1 and 2 show the task, the associated subtasks and the corresponding subject area. Columns 3 and 4 provide information about the maximum number of points that can be achieved and the number of points you have achieved. The last column shows the percentage of points you achieved in the subject area. The colour coding helps you to assess your performance: Red: < 50%; Yellow: ≥ 50%; Green: ≥ 80%

Tasks	subject area	achievable points	Your points	Points %
2	ARIS EPK	5	3	60%
2.1		2	0	
2.2		1,5	1,5	
2.3		1,5	1,5	
3	Organisational/ functional perspective	5	3	60%
3.1		2	0	
3.2		1,5	1,5	
3.3		1,5	1,5	
4	Excel	8	3,5	44%
4.1		1,5	1,5	
4.2		1,5	0	
4.3		1	0	
4.4		2,5	1	
4.5		1,5	1	
5	ARIS table scheme	5	3	60%
5.1		2	0	
5.2		1,5	1,5	
5.3		1,5	1,5	
6	xHTML	7	2,5	36%
6.1		1,5	1,5	
6.2		1,5	0	
6.3		4	1	
7	procedure models	5	1,5	30%
7.1		2	0	
7.2		1,5	1,5	
7.3		1,5	0	
8	ARIS ER-Model	20	16	80%
8.1		6	6	
8.2		7,5	7	
8.3		6,5	3	
9	SQL	5	4	80%
9.1		1,5	1,5	
9.2		1,5	1,5	
9.3		2	1	
	Total	60,0	36,5	61%

General feedback:

You were particularly successful in answering questions that required the application of known procedures and methods to solve a problem from a known problem pool. Therefore, understanding the content and possible practice questions are crucial for questions of this type. You achieved 71% of the points for questions of this type.

You have the greatest potential for improvement in tasks that require the reproduction of learned knowledge to answer. This means that you already know the content being tested from the lecture slides, e.g. theoretical basics. You must then reproduce this correctly in the tasks. You achieved 53% of the points in tasks of this type.

Task-specific feedback:

You achieved a high score (>80%) in the subject areas ARIS ER model and SQL. Very good!

Below are some detailed tips on the areas where you have the most potential for improvement.

You still have considerable room for improvement in the area of Excel. In the task for this topic, you should demonstrate your theoretical knowledge of Excel and apply formulas to solve specific problems using an example table.
You lost most of your points in this task, 3 out of a total of 4.5, on tasks that involved using formulas you learned in the exercises. You should therefore study the exercises in greater depth. In particular, practise working with Excel in a practical way, as this can be helpful for applying your knowledge in the exam. You also lost points, 1.5 out of a total of 4.5, on tasks in which you were required to demonstrate theoretical knowledge already familiar from the lecture. To improve in these areas, you should familiarise yourself more thoroughly with the basics of Excel and the content of the slides.
In this subject area, you lost points on tasks that included the following topics: Excel basics, function: HLOOKUP, function: DATE, function: CONCATENATE, function: SUM.

You still have considerable room for improvement in the area of xHTML. In the task for this topic, you should be able to independently create a given section of a website, find and correct errors in XHTML pages, and outline the content represented by an XHTML expression.
You lost most of your points in this task, 3 out of a total of 4.5, on tasks in which you had to apply expressions in XHTML and CSS that you learned in the lecture to a problem, for example, to reproduce a given section of a web page in the source code. You should therefore familiarise yourself with the practical use of XHTML and CSS using the exercises or examples of your own choosing. All you need is an editor or Notepad and your existing browser. Create a web page and check whether the display in the web browser meets your expectations, then add further content to your web page. You can use the W3C's XHTML validator to check whether you have used XHTML syntactically correctly. You also lost points, 1.5 out of a total of 4.5, on tasks in which you had to reproduce knowledge of XHTML learned in the lecture. To improve in these areas, you should take a thorough look at XHTML expressions and familiarise yourself with the structure of various types of lists, tables, image embedding, email links, etc. It can sometimes be helpful to remember the long name, such as 'table data' in this case, instead of abbreviations such as 'td'. The same applies to the structure and use of CSS files and the rules they contain.
You lost points in this subject area on tasks that included the following topics: lists in xHTML, CSS and document types, writing xHTML.

Figure 4: Example Feedback Report

7. Evaluation and Conclusion

To analyse its usefulness, the AFS needs to be *evaluated*.

7.1 Evaluation and Discussion

The AFS was used to generate feedback for exams of 1323 bachelor students in two different courses. A survey assessing the tool was completed by 65 students, cf. figure 7. Note that not all questions were answered by all of the 65 students. The survey utilised a 7-point Likert scale (ranging from 1 - 'I totally disagree' to 7 - 'I totally agree') and included two yes/no questions.

Table 3: Evaluation results

	n	Mean	Std. Deviation	Median
The design of the report is clear	64	6,4	1,0	7
The report and the information provided are easy to understand	65	6,3	1,2	7
The information in the report is selected sensibly	64	6,2	0,9	6
The information in the points overview table helped me to assess my performance	64	6,3	0,9	7
The task-specific feedback helped me to recognise my learning deficits	60	5,8	1,3	6
The task-specific feedback helped me to adapt my learning strategies for future exams	59	4,8	1,6	5
I would benefit from an exam report in other exams	65	6,4	0,9	7

The students found the design report clear (M=6.4; SD=1.0; Mdn=7), the information understandable (M=6.3; SD=1.2; Mdn=7) and sensibly selected (n=64; M=6.2; SD=0.9; Mdn=6). For 73.8% of the students the report had an adequate length. The remaining students found it too long which might be due to different reports having different lengths, depending on how the student performed (yes/no question). The points overview table helped them to assess their performance (n=64; M=6.3; SD=0.9; Mdn=7); the task-specific feedback helped them to recognise learning deficits (n=60; M=5.8; SD=1.3; Mdn=6). Most of the students agreed at least partially that the feedback report helped them to adapt their learning strategies for future exams (n=59; M=4.8; SD=1.6; Mdn=5). The students replied that they would benefit from such reports in other exams (M=6.4; SD=0.9; Mdn=7). 52,3% of students stated that the report would influence their future exam preparations which is a significant success given the report was the first one they received.

In a first evaluation of the setup process, three lecturers used the AFS for two different exams. All lecturers were able to set the AFS up and to provide high-quality feedback for their large courses and valued the structured process. They mentioned the still time-consuming process of text block definition.

AFSs can use several complex student data and complex techniques to generate feedback (Deeva et al., 2021). To design an AFS that can provide feedback across different educational domains it is important, to use student data that is available in different educational domains and design a system that enables the lecturer to modify the feedback to make it appropriate for their exam. Whilst some existing non-domain specific systems also use Blooms taxonomy (Barker, 2010), we added task types, that can be defined by the lecturer to ensure the AFS suits the needs of the particular exam; furthermore, the AFS is usable even if the lecturer is not familiar with Blooms taxonomy.

Whilst some AFSs need programming skills or technical expertise to be modified (Karkalas et al., 2016; Shum et al., 2023), our system is usable without technical expertise and even supports lecturers during its setup process, as our first evaluation of the setup process shows.

There are several possibilities to implement an AFS, using programming languages like C++ or tools like Rapid Miner (Deeva et al., 2021). We decided to use only tools commonly available in the education field, (namely Microsoft Word, Excel and Outlook), to ensure the AFS is usable for all lecturers.

The evaluation using student surveys as the most common type of evaluation AFSs (Deeva et al., 2021), demonstrates that the generated feedback is clear and understandable. We also show that the students asses the feedback as actionable, with a majority reporting they can adapt their learning strategies and preparations for future exams.

7.2 Conclusion

The evaluation shows that the AFS is able to provide student-centred feedback in a scalable and timely manner to large courses. Therefore, we have contributed to solving the challenges of feedback in higher education in general and to solving the problems of exam-specific feedback in particular. Further we designed an AFS that is easy to adapt for non-experts. We have shown different design aspects required for such AFS, e.g. an adaptable domain model utilising Bloom's taxonomy and customisable task types to ensure applicability across educational domains. The AFS integrates expert knowledge and available student data to generate personalised, actionable feedback for different types of exams. Additionally, the system provides a scalable, automated implementation to ensure timely, consistent feedback without manual intervention.

Our research faces some limitations. Only 65 of the 1323 students filled in the survey. Therefore, the evaluation is seen as a first indicator that our approach is promising. More extensive evaluations are to follow. The usage of GenAI for the text block generation is a potential way to enhance the efficiency of the setup process of the AFS. Furthermore, we will analyse whether feedback via chatbots can enhance the student experience.

Ethics Declaration

This study used anonymised data only. No personally identifiable information was collected, stored, or analysed. Therefore, no ethical approval was required.

AI Declaration

AI-based tools were used solely for language improvement.

References

Alquraan, M. F. (2012) "Methods of assessing students' learning in higher education", *Education, Business and Society: Contemporary Middle Eastern Issues*, Vol. 5, No. 2, pp 124–133.

Anderson, L. W. and Krathwohl, D. R. (2001) *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*, New York, Munich, Longman.

Appelhaus, S., Werner, S., Grosse, P. and Kämmer, J. E. (2023) "Feedback, fairness, and validity: effects of disclosing and reusing multiple-choice questions in medical schools", *Medical education online*, Vol. 28, No. 1, pp 1–7.

Barker, T. (2010) "An Automated Feedback System Based on Adaptive Testing: Extending the Model", *International Journal of Emerging Technologies in Learning (iJET)*, Vol. 5, No. 2, p. 11.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. and Krathwohl, D. R. (1956) *Taxonomy of Educational Objectives*, New York, Longmans, Green & Co.

Carless, D., Joughin, G. and Liu, N.-F. (2006) *How assessment supports learning: Learning-oriented assessment in action*, Hong Kong, London, Hong Kong University Press; Eurospan distributor.

Daka, H., Mulenga-Hagane, M. L., Mukalula-Kalumbi Mwansa and Lisulo, S. (2021) "Making Summative Assessment Effective", *European Modern Studies Journal 5(4)*, pp 224–237.

Debuse, J. C. W., Lawley, M. and Shibl, R. (2008) "Educators' perceptions of automated feedback systems", *Educational Technology 24(4)*, pp 374–386.

Deeva, G., Bogdanova, D., Serral, E., Snoeck, M. and Weerdt, J. de (2021) "A review of automated feedback systems for learners: Classification framework, challenges and opportunities", *Computers & Education*, Vol. 162, p. 104094.

Del Sánchez-Vera, M. M., Fernández-Breis, J. T., Castellanos-Nieves, D., Frutos-Morales, F. and Prendes-Espinosa, M. P. (2012) "Semantic Web technologies for generating feedback in online assessment environments", *Knowledge-Based Systems*, Vol. 33, pp 152–165.

Gibson, K. and Shaw, C. M. (2011) "Assessment of Active Learning", in *Oxford Research Encyclopedia of International Studies*.

Gronlund, N. E. (1998) *Assessment of studies achievement*, 6th edn, Boston, Allyn and Bacon.

Halinen, K., Ruohoniemi, M., Katajavuori, N. and Virtanen, V. (2014) "Life science teachers' discourse on assessment: a valuable insight into the variable conceptions of assessment in higher education", *Journal of Biological Education*, Vol. 48, No. 1, pp 16–22.

Hattie, J. and Timperley, H. (2007) "The Power of Feedback", *Review of Educational Research*, Vol. 77, No. 1, pp 81–112.

Haughney, K., Wakeman, S. and Hart, L. (2020) "Quality of Feedback in Higher Education: A Review of Literature", *Education Sciences*, Vol. 10, No. 3, p. 60.

Henderson, M., Ryan, T. and Phillips, M. (2019) "The challenges of feedback in higher education", *Assessment & Evaluation in Higher Education*, Vol. 44, No. 8, pp 1237–1252.

Hevner, A. R. (2007) "A Three Cycle View of Design Science Research", *Scandinavian journal of information systems 19(2)*, pp 87–92.

Hevner, A. R., March, S. T., Ram, S. and Park, J. (2004) "Design Science in Information Systems Research", *MIS quarterly*, pp 75–105.

Higgins, R., Hartley, P. and Skelton, A. (2002) "The Conscientious Consumer: Reconsidering the role of assessment feedback in student learning", *Studies in Higher Education*, Vol. 27, No. 1, pp 53–64.

Holmes, L. E. and Smith, L. J. (2003) "Student Evaluations of Faculty Grading Methods", *Journal of Education for Business*, Vol. 78, No. 6, pp 318–323.

Jacoby, J. C., Heugh, S., Bax, C. and Branford-White, C. (2014) "Enhancing Learning through Formative Assessment", *Innovations in Education and Teaching International*, Vol. 51, No. 1, pp 72–83.

James, R., McInnis, C. and Devlin, M. (2002) *Assessing learning in Australian universities: Ideas, strategies and resources for quality in student assessment*.

Karkalas, S., Mavrikis, M., Xenos, M. and Kynigos, C. (2016) "Feedback Authoring for Exploratory Activities. The Case of a Logo-Based 3D Microworld_AAM".

Keuning, H., Jeuring, J. and Heeren, B. (2019) "A Systematic Literature Review of Automated Feedback Generation for Programming Exercises", *ACM Transactions on Computing Education*, Vol. 19, No. 1, pp 1–43.

Li, J. and Luca, R. de (2014) "Review of assessment feedback", *Studies in Higher Education*, Vol. 39, No. 2, pp 378–393.

McGowan, A., Anderson, N. and Smith, C. (2024) "The use of ChatGPT to generate Summative Feedback in Programming Assessments that is Consistent, Prompt, without Bias and Scalable", *Proceedings of the Cognitive Models and Artificial Intelligence Conference,* 25.05.2024. New York, USA, ACM, pp 39–43.

Medina, M. S. and Yuet, W. C. (2013) "Promoting academic integrity among health care students", *American journal of health-system pharmacy*, Vol. 70, No. 9, pp 754–757.

Mekonen, K. Y. and Fitiavana, A. R. (2021) "Assessment of Learning Outcomes in Higher Education: Review of literature", *International Journal of Research Publications*, Vol. 71, No. 1.

Morales-Chan, M., Amado-Salvatierra, H. R., Medina, J. A., Barchino, R., Hernández-Rizzardini, R. and Teixeira, A. M. (2024) "Personalized Feedback in Massive Open Online Courses: Harnessing the Power of LangChain and OpenAI API", *Electronics*, Vol. 13, No. 10, p. 1960.

Nicol, D. (2010) "From monologue to dialogue: improving written feedback processes in mass higher education", *Assessment & Evaluation in Higher Education*, Vol. 35, No. 5, pp 501–517.

O'Donovan, B., Rust, C. and Price, M. (2016) "A scholarly approach to solving the feedback dilemma in practice", *Assessment & Evaluation in Higher Education*, Vol. 41, No. 6, pp 938–949.

Omar, N., Haris, S. S., Hassan, R., Arshad, H., Rahmat, M., Zainal, N. F. A. and Zulkifli, R. (2012) "Automated Analysis of Exam Questions According to Bloom's Taxonomy", *Procedia - Social and Behavioral Sciences*, Vol. 59, pp 297–303.

Park, J. (2023) "Medical students' patterns of using ChatGPT as a feedback tool and perceptions of ChatGPT in a Leadership and Communication course in Korea: a cross-sectional study", *Journal of educational evaluation for health professions*, Vol. 20, p. 29.

Peffers, K., Tuunanen, T., Gengler, C. E., Rossi, M., Hui, W., Virtanen, V. and Bragge, J. (2020) *Design Science Research Process: A Model for Producing and Presenting Information Systems Research*.

Rawat, A., Kumar, S. and Singh Samant, S. (2023) "A Systematic Review of Question Classification Techniques Based on Bloom's Taxonomy", *2023 14th International Conference on Computing Communication and Networking Technologies (ICCCNT).* Delhi, India, 06.07.2023 - 08.07.2023, IEEE, pp 1–7.

Rawlusyk, P. E. (2018) "Assessment in Higher Education and Student Learning", *Journal of Instructional Pedagogies 21*.

Ray, E. M., Daugherty, K. K., Lebovitz, L., Rudolph, M. J., Shuford, V. P. and DiVall, M. V. (2018) "Best Practices on Examination Construction, Administration, and Feedback", *American journal of pharmaceutical education*, pp 1127–1133.

Sambell, K., McDowell, L. and Montgomery, C. (2012) *Assessment for learning in higher education*, Abingdon, Oxon, Routledge.

Schaffer, H. E., Young, K. R., Ligon, E. W. and Chapman, D. D. (2017) "Automating Individualized Formative Feedback in Large Classes Based on a Directed Concept Graph", *Frontiers in psychology*, Vol. 8, p. 260.

Schipper, E. de, Feskens, R. and Keuning, J. (2021) "Personalized and Automated Feedback in Summative Assessment Using Recommender Systems", *Frontiers in Education*, Vol. 6.

Scoles, J., Huxham, M. and McArthur, J. (2013) "No longer exempt from good practice: using exemplars to close the feedback gap for exams", *Assessment & Evaluation in Higher Education*, Vol. 38, No. 6, pp 631–645.

Scott, T. (2003) "Bloom's taxonomy applied to testing in computer science classes".

Shum, S. B., Lim, L.-A., Boud, D., Bearman, M. and Dawson, P. (2023) "A comparative analysis of the skilled use of automated feedback tools through the lens of teacher feedback literacy", *International Journal of Educational Technology in Higher Education*, Vol. 20, No. 1, pp 1–42.

Starr, C. W., Manaris, B. and Stalvey, R. H. (2008) "Bloom's taxonomy revisited", *ACM SIGCSE Bulletin*, Vol. 40, No. 1, pp 261–265.

Tass Grigoriou, Christopher Cheong, and France Cheong (2015) "Improving Quality of Feedback Using a Technology-Supported Learning System", *PACIS 2015 Proceedings*.

Leveraging Scientific Research for Business Improvement: A PRISMA Review

Jaani Väisänen
LAB University of Applied Technology, Lappeenranta, Finland

jaani.vaisanen@lab.fi

Abstract: University-Industry Collaboration (UIC) is a crucial driver of knowledge exchange, traditionally framed by the triple, quadruple, and quintuple helix models. While these models emphasize synergistic collaboration and mutual benefits stemming from strong relationships, a key aspect often overlooked is industry's capacity to utilize existing scientific knowledge, such as research articles. Universities consistently generate new scientific insights, offering a vast, underutilized resource for knowledge transfer beyond conventional UIC frameworks, particularly for Small and Medium-sized Enterprises (SMEs). This paper addresses this gap through a comprehensive systematic literature review. Following PRISMA methodology, we identified a foundational set of 616 articles from diverse scientific databases using a three-tiered core concept approach: 1) SMEs, 2) scientific research results, and 3) business improvement. A semantic search program, leveraging a pre-trained sentence-embedding model, then pinpointed relevant case studies. After rigorous threshold fine-tuning, 18 articles were selected for in-depth qualitative analysis. Preliminary automated analysis revealed thematic categories for Access challenges, Impact assessment, Research focus, and Utilization strategies. The in-depth analysis further explores the interplay within these themes, focusing on identifying research gaps within the literature. The insights derived will contribute to furthering the understanding of knowledge transfer dynamics in UIC and SME innovation, highlighting practical avenues for facilitating SME engagement with scientific knowledge.

Keywords: Literature Review, University-Industry Collaboration, SMEs, Research Utilization

1. Introduction

Universities and other Higher Education Institutions (HEIs) are key in preparing business professionals and entrepreneurs with up-to-date knowledge. Heavily funded by governments, HEIs drive research that supports local and national innovation and business growth. When public funding declines, universities must seek alternative sources and engage more directly in business value creation. University-Industry Collaboration (UIC) is a widely used open innovation model that facilitates this knowledge and technology transfer between academia and industry (El-Ferik and Al-Naser 2021). The Triple Helix model captures the interconnected roles of universities, governments, and industries (Etzkowitz and Leydesdorff 2000), with later versions further refining these relationships (Cai and Etzkowitz 2020).

To meet these challenges, universities increasingly commercialize academic knowledge through collaborations with businesses and government, such as licensing, incubators, and start-up programs (O'Shea, Chugh and Allen 2008; Phan, Siegel and Wright 2005). Success in commercialization requires close, long-term commitment from both academic and external partners (Cirella and Murphy 2022). The impact of innovation efforts varies depending on UIC involvement. For instance, "made in academia" innovations attract less attention than those from industry (Bikard 2018), and discoveries with industry ties yield more scientific publications but fewer follow-on patents than those without (Bikard, Vakili, and Teodiridis 2019).

Dynamic capabilities theory explains how firms adapt and succeed in changing environments by integrating, building, and reconfiguring competencies (Teece, Pisano and Shuen 1997). This approach emphasizes strategic renewal over static resources. Firms with strong dynamic capabilities can generate new ideas, develop products and services, and renew business models, especially when they collaborate closely with institutions (Gölgeci et al 2019; Bloedon & Stokes, 1994).

Research shows that UIC is vital for knowledge transfer, innovation, and improved performance. The Triple Helix model (Etzkowitz & Leydesdorff 2000) and dynamic capabilities theory (Teece, Pisano and Shuen 1997) help explain how firms—especially resource-constrained SMEs—can use external knowledge for competitive advantage. However, how knowledge transfer from academia to SMEs works in practice is still not fully understood.

Most research focuses on formal UIC channels, like joint research, incubators, and licensing (Tereschenko et al 2024), but often ignores informal knowledge acquisition. Formal collaborations can be costly and time-consuming, making them difficult for many SMEs. Micro SMEs, in particular, need clear, practical justifications for knowledge transfer (Väisänen 2024).

This research posits that SMEs can enhance their dynamic capabilities and drive innovation by utilizing academic research without engaging in these formal, structured collaborations. This more independent form of knowledge transfer, where SMEs access and apply publicly available scientific research (e.g., from research papers, reports, and open-access databases) to their operations, represents a distinct and under-researched phenomenon. The SMEs' own absorptive capacity drives it and is not contingent on direct, formal, and often long-term partnerships with universities. Thus, this study aims to systematically review the available literature to investigate how SMEs are utilizing publicly available scientific research results in their operations, contributing to the literature by providing a structured overview of a previously underexplored phenomenon.

2. Methodology

To ensure a transparent and replicable review of the literature, this study uses the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Moher et al 2009). The PRISMA statement provides a robust evidence-based foundation for reporting systematic reviews. The four phases—Identification, Screening, Eligibility, and Inclusion—guide the researcher through literature collection, selection, and final inclusion in the qualitative synthesis.

2.1 Document Identification

Since the Screening process relies on automated document retrieval, the Identification phase was set to include a document repository as large as possible. The researcher utilized the LUT Universities' library database, which gives access to the most common scientific databases:

- Scopus
- SAGE Premier
- ProQuest Databases
- Emerald Journals
- Elsevier
- EBSCO Academic Search Elite
- EBSCO Business Source Elite

The document identification phase involved identifying the following three core concepts from the documents: SMEs, Academic research, and Business Improvement. The following search terms were used for each concept to expand the three core concepts to provide a wide range of results (Table 1).

Table 1: The three core concepts used in the Identification stage.

Core Concept 1 (SME)	Core Concept 2 (Academic Research)	Core Concept 3 (Business Improvement)
SME	academic research	business improvement
small and medium-sized enterprise	university research	competitiveness
small and medium-sized business	knowledge transfer	efficiency
small business	research finding	performance
		value creation
		competitive advantage

All the databases included have differing search functionalities, but all of them allow the user to utilize Boolean logic in their searches. By utilizing the core concepts presented in Table 1, the Boolean pseudo-query for all the databases was as follows:

(sme OR "small business" OR "small and medium-sized enterprise" OR "small and medium-sized business") AND ("academic research" OR "university research" OR "knowledge transfer" OR "research finding") AND ("value creation" OR profitability OR competitiveness OR efficiency OR "competitive advantage" OR "business improvement" OR "performance")

Additionally, the eligibility criteria for inclusion were to have the articles peer-reviewed and openly accessed. As previously mentioned, each platform had its own search functionalities and result classifications. Table 2 presents the classifications for the results along with the number of results identified.

Table 2: The number of results from the Identification phase per database.

Database	Result Classifications	Results
Scopus	Journal + Article + English + Final + Open Access	121
SAGE Premier	Research + Open Access	102
ProQuest Databases	Scholarly journals + Full text + Peer reviewed	150
Emerald Journals	Articles + open access	212
Elsevier	Research + Open Access + English	18
EBSCO Academic Search Elite	Full text + peer reviewed + academic journal	4
EBSCO Business Source Elite	Full text + peer reviewed + academic journal	9

The initial Identification phase of this study yielded a substantial corpus of 616 journal article abstracts sourced from the databases. The subsequent screening phase presented a significant methodological challenge. This phase typically requires the researcher to manually review the title and abstract of every identified record to exclude clearly irrelevant ones. Given the volume of abstracts and the complex nature of the inclusion criteria, a purely manual screening process was deemed susceptible to researcher fatigue, subjectivity, and potential inconsistency over time (Beller et al., 2018). Furthermore, the core inclusion criteria for this review were conceptual rather than keyword-based, requiring the identification of articles that were 1) a case study, and 2) concerned an SME that has utilized university research results. Therefore, a simple keyword search would likely be insufficient to capture the semantic essence of these concepts. Specific challenges would be expected in, e.g., recognizing synonyms (e.g., "small firm" for "SME"), related concepts (e.g., "knowledge transfer" or "technology adoption" for "utilized university research"), and the specific context of their use. Thus, an automated screening tool was proposed to tackle this issue (O'Mara-Eves et al., 2015).

2.2 Screening

A semi-automated screening methodology was developed to address these challenges while upholding the systematic principles of PRISMA. This Python-coded approach leverages modern Natural Language Processing (NLP) techniques to perform a semantic-based pre-screening of the abstracts.

The core of the semi-automated methodology was implementing a semantic search protocol. Unlike traditional search methods that match literal text strings, semantic search aims to understand language's intent and contextual meaning, while sustaining adequate computational viability (Pratt-Hartman 2013, pp. 90). This is achieved by converting text into high-dimensional numerical representations, known as "embeddings," where the semantic relationships between texts are reflected in the geometric properties of their vector representations. This approach allowed for the screening of abstracts based on their conceptual similarity to a precisely defined query that encapsulated the full inclusion criteria.

2.3 Data Preparation and Parsing

The initial step involved parsing the source material of the 616 journal abstracts, which underwent the semantic search protocol on a database-by-database basis. A custom Python script was developed to iterate through each list of abstracts, correctly identifying and separating each record. The format of the abstract extraction files differed slightly from database to database, so a slight modification of the Python code was necessary for each database. The semantic engine and inclusion criteria remained unchanged for each database, however. For every record, the script extracted the essential metadata—the paper's title and its corresponding URL—and the full text of the abstract. The abstracts were cleaned of any file-specific prefixes (e.g., "ABSTRACT:") to create a refined corpus consisting solely of the abstract texts, ready for analysis. This automated data extraction ensured consistency and eliminated the potential for manual copy-paste errors.

2.3.1 Model Selection and Semantic Query Definition

The cornerstone of the semantic analysis was a pre-trained sentence embedding model. This study used a Bidirectional Encoder Representations from Transformers (BERT) model, called all-MiniLM-L6-v2, suitable for various NLP tasks (Santander-Cruz et al 2022). This framework fine-tunes such models for generating semantically meaningful sentence embeddings, making them highly suitable for semantic search and similarity

comparison tasks. The choice of model represented a pragmatic balance between high performance and computational efficiency, capable of processing the corpus on standard hardware (SBERT.net 2025).

A precise "semantic query" was then formulated to represent the ideal abstract that this review sought to find: "A case study about a small or medium-sized enterprise (SME) utilizing university research results in its operations." This query serves as the conceptual benchmark against which all abstracts are measured.

2.3.2 Embedding Generation and Similarity Calculation

The semantic query and all 616 abstracts were transformed using the selected model into 384-dimensional vector embeddings. Each vector represents a point in a high-dimensional space, and the semantic content of the source text determines its location. Cosine similarity was employed as the measurement metric to quantify the semantic relationship between the query and each abstract. Cosine similarity calculates the cosine of the angle between two vectors, producing a score between -1 (perfectly opposite meaning) and 1 (identical meaning). A score of 0 indicates orthogonality or a lack of semantic relationship. This metric is particularly well-suited for high-dimensional data as it is sensitive to the vectors' orientation (i.e., the direction or "meaning") rather than their magnitude. The result of this step was a comprehensive list of all abstracts, each paired with a cosine similarity score indicating its relevance to the research query.

2.3.3 Ranking, Filtering, and Final Screening

The abstracts were ranked in descending order based on their cosine similarity scores. This provided a data-driven prioritization of the corpus, with the most conceptually relevant articles at the top. A similarity threshold 0.5 was established to create a binary distinction between "potentially relevant" and "excluded" abstracts. This threshold was determined through an iterative review of the top-ranked results, ensuring that it was sensitive enough to include relevant studies while remaining specific enough to exclude irrelevant ones. Lower thresholds were manually tested.

All abstracts scoring above this threshold were advanced to the next stage of the PRISMA workflow for full-text review. This procedure presented 29 articles. Two of the articles were duplicates, and none of them were illegible or written in any other language besides English, so these two duplicates were the first to be eliminated in the Eligibility stage. The second and final Eligibility stage included manual reading of the articles. While the content of all the articles did revolve around the research topic, the criteria for inclusion were that the research paper would have to be a case study, where an SME (or a group of SMEs) utilized academic research results. Nine articles were dropped from the analysis for not meeting these criteria, meaning the final number of articles in the Inclusion stage was 18.

3. The Results

The extracted documents were analyzed both manually and using the Atlas.ti software. In this context, we are looking for information on how SMEs utilize academic research results, such as research papers and reports, to improve their competitiveness. Atlas.ti software utilizes Intentional AI coding functionality from the OpenAI software company, using its GPT models, allowing the researcher to input their research questions, context, and overall intention of the research. The models then translate this intention into concrete questions and provide the researcher with categorization in the form of separate code categories.

To ensure transparency and replicability, the first step was to document the intention with which the AI codes are created. As the main intention for the model, we input the general research question: “How are SMEs utilizing Academic research results to improve their competitiveness?”. This prompt generated four distinct research questions from the articles, each associated with a specific code category for thematic analysis:

- RQ1: How are SMEs utilizing Academic research results to improve their competitiveness? (Code category: Utilization Strategies)
- RQ2: What specific academic research results are most frequently utilized by SMEs? (Code category: Research focus)
- RQ3: How do SMEs measure the impact of academic research on their competitiveness? (Code category: Impact assessment)
- RQ4: What challenges do SMEs face in accessing and applying academic research? (Code category: Access challenges)

The stability and reliability of the AI-generated framework were verified through multiple runs of the same prompt. This process confirmed the consistency of the generated research questions and code categories, mitigating the risk of model inconsistencies or hallucinations and ensuring a robust foundation for the subsequent analysis.

The articles' content was analyzed in two ways to ensure consistency and transparency. First, the articles were analyzed by automatically finding specific concepts using the Atlas.ti software. This results in a word cloud-like concept cloud. Since the concept cloud utilizes word frequencies along with semantic analysis, some manual deletion of concepts such as “et al”, “authors”, and “pages” was performed. Second, these concepts were cross-checked by the author by manually reading all the articles to gain a deeper understanding of the nuances of the phenomenon. We start the process by examining the concept cloud in Figure 1.



Figure 1: The concept cloud from the 18 articles from the Inclusion stage.

By looking at the most prominent concepts mined from the articles, we can see that “innovation” is the most occurring one, gathering 1756 mentions, or tokens, across the analyzed articles. To simplify the process and to avoid redundancy, we take all concepts with over 1000 tokens into closer examination. Table 3 shows the concepts and attached sub-concepts (general or vague sub-concepts such as “innovations” or “business case” were omitted).

Table 3: The four main concepts and their sub-concepts from the articles.

Concept	Sub-concept
Innovation	Open innovation
	Product innovation
	Business model innovation
Sme	Family sme
	Technology-based sme
	Business models
	Business model innovation
	Family business
Knowledge	Knowledge management
	Knowledge transfer
	Knowledge collaboration

Concept	Sub-concept
	New knowledge
	Knowledge spillover
	Tacit knowledge
Performance	Operational performance
	Innovation performance
	Growth performance
	Financial performance
	Performance measurement

Building upon the code categories established through Intentional AI, the analysis of key concepts using the Atlas.ti "Concepts" tool provides a thematic overview of the literature and offers preliminary insights into the research questions. The concepts—Innovation, SME, Knowledge, and Performance—and their sub-concepts form interconnected thematic clusters that illuminate the dynamics of academic knowledge utilization by SMEs. The following sections are structured around the four primary research questions, demonstrating how the conceptual analysis sheds light on each.

- RQ1. Utilization Strategies

The prominence of knowledge management, knowledge transfer, and knowledge collaboration as sub-concepts within the Knowledge cluster indicates that knowledge utilization is not a passive reception of information. Instead, it is an active endeavor that requires a high degree of organizational engagement. The literature suggests that successful strategies often involve close collaboration and trust with "knowledge brokers" like universities (Audretsch et al 2023; Franco et al 2024).

The articles further specify a number of these strategies, including participation in local science park incubators and communal activities (Bortoluzzi et al 2022; Nowacki and Stanieski 2012; Marom and Lussier 2017), as well as engagement in broader governmental programs (Bouwman et al 2018; Yadewani et al 2024). The findings also reveal a defined division of labor, where academic institutions tend to assume a knowledge facilitator role, while SMEs are positioned as the primary innovators (Lundberg and Öberg 2021). The emphasis on open innovation policies in the literature also points to a key strategy, as collaboration with universities is seen to accelerate SMEs' open innovation capabilities (Audretsch et al 2023).

- RQ2. Research Focus

The sub-concepts within the Innovation and Knowledge clusters point to a strong focus on research that can drive strategic transformation. The high occurrence of open innovation as a sub-concept, especially in the context of I4.0 industries (Parra-Sanchez and Talero 2023; Bortoluzzi et al 2022), suggests that academic work on this topic is highly relevant. Similarly, the focus on business model innovation indicates that SMEs are leveraging academic research not just for incremental operational changes, but as a catalyst for fundamental shifts in their business models and product development as part of the larger open innovation paradigm (Sabando-Vera et al 2022). While these singular findings may point toward a strategic long-term commitment, the few longitudinal studies found did not conclusively confirm this notion.

- RQ3. Impact Assessment

The Performance thematic cluster directly addresses how the impact of utilizing academic research is assessed. The variety of sub-concepts including operational performance, innovation performance, growth performance, and financial performance. The articles show that impact is assessed both in pure financial terms (Yadevani et al 2024; Amoros, Planellas and Batista-Foguet 2007) and more holistically (Manville et al 2018), as well as by metrics such as readiness for change (Chao ang Kang 2022). This suggests that both SMEs and researchers are interested in capturing the full spectrum of benefits, from enhancing efficiency to fostering a more innovative internal culture.

- RQ4. Access Challenges

The analysis of the Knowledge cluster, specifically the sub-concepts of knowledge spillover and tacit knowledge, reinforces the notion that knowledge transfer is not always straightforward. Nowacki et al (2012) further specify financial barriers as a significant obstacle to knowledge transfer. This is particularly relevant when considering

governmental or educational programs aimed at knowledge facilitation, as the emergence of tacit knowledge emphasizes their importance in improving SME performance (O'Connor & Kelly 2017).

The SME cluster also contributes to understanding challenges and the factors that help overcome them. The literature suggests that the specific type of SME (e.g., family SME vs. technology-based SME) may influence their challenges and strategies. An entrepreneurial mindset, for example, was identified as a positive indicator for SME performance (Issau, Soni and Acquah 2022; Marinelli et al 2023; Marom and Lussier 2017), suggesting that firm-level attitudes are key to overcoming access barriers. Additionally, power relationships between actors can also be an obstacle (O'Connor & Kelly 2017), indicating that smaller firms might be at a disadvantage.

4. Reflection

Literature on University-Industry collaboration in and of itself is abundant (see e.g. Tereshenko et al 2024). This literature review was conducted to gain insight into a small subsection of UIC: SMEs utilizing scientific research results to improve their business operations. The criteria for inclusion were that the research paper would have to be a case study, where an SME (or a group of SMEs) was utilizing academic research results. Of all the identified 616 articles, only 18 were included in the final examination. This relatively low number of articles was somewhat surprising, but also points out a research gap, which could warrant closer examination in the future. Future studies should empirically examine the organizational processes and contextual factors that enable SMEs to absorb and apply scientific knowledge, perhaps through in-depth case studies. Longitudinal or comparative studies were also missing in the review. Comparative research on formal versus informal knowledge transfer mechanisms, as well as investigations into sectoral, regional, or firm-size differences, would further enrich our understanding. Methodological limitations of this review must also be acknowledged. The reliance on automated semantic screening, while efficient, may have excluded relevant studies due to model limitations or threshold settings. The small sample size, though partly reflecting a true research gap, also might challenge the generalizability of our findings. The error in this study was mitigated by carefully choosing the language model used for the screening, as it was specifically chosen for its semantic capabilities. Another mitigating factor was that the same model was used separately on all seven databases, and manual inspection of the results lists showed clear thematic consistency across all runs. Future reviews could benefit from combining automated and manual screening approaches, using multiple NLP models, and seeking out unpublished or gray literature.

Besides the topic's novelty, one possible explanation to low article count is that all cases where SMEs utilize scientific results likely never see the light of day. If a research result is publicly available, and an SME decides to utilize it, they most likely don't have the incentive to publish it, as supported by Bikard (2018). In this case, the utilization potential is largely dependent on the SMEs internal absorptive capacity.

This literature review contributes to the academic discourse by establishing a foundational understanding of this under-researched area. The scarcity of literature on SMEs' independent utilization of academic research not only validates the existence of a significant research gap but also highlights the need for a more expansive view of knowledge transfer. This study offers a structured overview of a phenomenon that has previously been overlooked in favor of more formal, institutionalized collaborations, providing a clear direction for future scholarly work. This review demonstrates that SMEs' ability to benefit from academic research hinges on their absorptive capacity—especially in the knowledge transfer domain. Our findings show that knowledge transfer is most effective when SMEs actively engage in knowledge management and collaboration, even outside formal partnerships. Furthermore, the results highlight that dynamic capabilities are essential for SMEs to transform scientific insights into innovation and to assess their impact. Thus, the independent use of academic research by SMEs is not just about access, but about building the organizational capacity to turn knowledge into competitive advantage, while the Universities take on the facilitator role. From a practical perspective, the findings hold substantial value for SMEs and policymakers. The identified patterns of utilizing incubators and business parks should incentivize regional and governmental actors to support these initiatives. Additionally, universities are encouraged to embrace facilitating knowledge transfer in conjunction with these parks, where they can reside close to the local SME community.

Ethics Statement

Ethical clearance was not required in this research.

AI Declaration

Generative Artificial Intelligence tools were used in the generation of this paper the following way: 1) Proofreading and grammatical errors (Grammarly), 2) Refining the overall tone of the text and checking for inconsistencies (Gemini 2.5).

References

Amorós, J. E., Planellas, M., and Batista-Foguet, J. M. (2007) "Does internet technology improve performance in small and medium enterprises? Evidence from selected Mexican firms", *Academia (Consejo Latinoamericano de Escuelas de Administración)*, Vol. 39(39), pp. 71–92.

Audretsch, D. B., Belitski, M., Caiazza, R., and Phan, P. (2023) "Collaboration strategies and SME innovation performance", *Journal of Business Research*, Vol. 164, Article 114018.

Beller, E., Clark, J., Tsafnat, G., Adams, C., Diehl, H., Lund, H., O'Leary, F., McDonald, S., Thavorn, K., van der Kleij, R., and Glasziou, P. (2018) "Making progress with the automation of systematic reviews: A summary of the Cochrane International Colloquium 2017", *Systematic Reviews*, Vol. 7(1), pp. 77.

Bikard, M. (2018). "Made in Academia: The Effect of Institutional Origin on Inventors' Attention to Science" *Organization Science (Providence, R.I.)*, Vol. 29(5), pp. 818–836.

Bikard, M., Vakili, K., and Teodoridis, F. (2019) "When Collaboration Bridges Institutions: The Impact of University–Industry Collaboration on Academic Productivity", *Organization Science (Providence, R.I.)*, Vol. 30(2), pp. 426–445.

Bloedon, R. V., and Stokes, D. R. (1994) "Making University/Industry Collaborative Research Succeed", *Research technology management*, Vol. 37(2), pp. 44–48.

Bortoluzzi, G., Chiarvesio, M., Romanello, R., Tabacco, R., & Veglio, V. (2022) "Servitisation and performance in the business-to-business context: the moderating role of Industry 4.0 technologies", *Journal of Manufacturing Technology Management*, Vol. 33(9), pp. 108–128.

Bouwman, H., Nikou, S., Molina-Castillo, F. J., and de Reuver, M. (2018) "The impact of digitalization on business models", *Info,* Vol. 20(2), pp. 105–124.

Cai, Y., and Etzkowitz, H. (2020) "Theorizing the Triple Helix Model: Past, Present, and Future", Triple Helix, Vol. 7, pp. 189-226.

Chao, Y. and Kang, Y. (2022) "Impact of Dynamic Capability on Enterprise Growth Performance under Environmental Dynamism", *Journal of System and Management Services*, Vol. 12(4), pp. 175-190.

Cirella, S., and Murphy, S. (2022) "Exploring intermediary practices of collaboration in university–industry innovation: A practice theory approach", *Creativity and Innovation Management*, Vol. 31(2), pp. 358–375.

El-Ferik, S., and Al-Naser, M. (2021) "University Industry Collaboration: A Promising Trilateral Co-Innovation Approach", *IEEE access*, Vol 9, pp. 9112761–112769.

Etzkowitz, H., and Leydesdorff, L. (2000) "The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations", *Research policy*, Vol. 29 (2), pp. 109–123.

Franco, M., Sartor, R., and Rodrigues, M. (2025) "Cameron and Quinn's organisational culture traits in the context of university-SME cooperation: A qualitative study", *Industry & Higher Education*, Vol. 39(3), pp. 314–334.

Gölgeci, I., Assadinia, S., Kuivalainen, O., and Larimo, J. (2019) "Emerging-market firms' dynamic capabilities and international performance: The moderating role of institutional development and distance", *International Business Review*, Vol. 28(6), pp. 101593.

Issau, K., Soni, S., and Acquah, I. S. K. (2022) "Ghanaian SMEs' perspective on the interrelationship between market and entrepreneurial orientations", Vol. 29(2), pp. 139–157.

Lundberg, H., and Öberg, C. (2021) "Teachers, researchers, but not innovators? Rethinking university-industry collaboration", *The Journal of Business & Industrial Marketing*, Vol. 36(13), pp. 161–173.

Manville, G., Karakas, F., Polkinghorne, M., and Petford, N. (2018). "Supporting Open Innovation with the use of a Balanced Scorecard Approach: A Study on Deep Smarts and Effective Knowledge Transfer to SMEs Supporting Open Innovation with the use of a Balanced Scorecard Approach: A Study on Deep Smarts and Effective Knowledge Transfer to SMEs", *Production Planning and Control*, Vol. 30.

Marinelli, L., Bartoloni, S., Costa, A., and Pascucci, F. (2023) "Exploring the relationship between entrepreneurial ecosystem inputs and outcomes: the role of digital technology adoption", *European Journal of Innovation Management*, Vol. *26*(7), pp. 635–654.

Marom, S., and Lussier, R. N. (2017) "Developing a Small Business Management Concentration within a Business Degree", *Small Business Institute Journal*, Vol. 13(2), pp. 15–30.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., and The PRISMA Group (2009). "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement", *Physical Therapy*, Vol. 89(9), pp. 873-880.

Nowacki, R., and Staniewski, M. W. (2012) "Innovation in the Management of SMEs in the Service Sector in Poland", *Amfiteatru Economic*, Vol. 14(6), pp. 755–773.

O'Connor, C., and Kelly, S. (2017). "Facilitating knowledge management through filtered big data: SME competitiveness in an agri-food sector", *Journal of Knowledge Management*, Vol. *21*(1), pp. 156–179.

O'Mara-Eves, A., Thomas, J., McNaught, J., Miwa, M., and Ananiadou, S. (2015) "Using text mining for study identification in systematic reviews: A systematic review of current approaches", *Systematic Reviews*, Vol. 4(1), pp. 5.

O'Shea, R. P., Chugh, H., and Allen, T. J. (2008). "Determinants and consequences of university spinoff activity: A conceptual framework", *The Journal of Technology Transfer*, Vol. 33(6), pp. 653–666.

Parra-Sánchez, D. and Talero, L. (2023) "Digital transformation in small and medium enterprises: a scientometric analysis", *Digital Transformation and Society*, Vol. 3(3), pp. 257-276.

Phan, P. H., Siegel, D. S., and Wright, M. (2005) "Science parks and incubators: observations, synthesis and future research", *Journal of Business Venturing*, Vol. 20(2), pp. 165–182.

Pratt-Hartman, I. (2013) "Computational Complexity on Natural Language" In Clark, A., Fox, C., and Lappin, S. (Eds.) *The handbook of computational linguistics and natural language processing (1st ed.)*, Wiley-Blackwell.

Reimers, N., & Gurevych, I. (2019). Sentence-BERT: Sentence Embeddings using Siamese BERT-Networks. Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing. Association for Computational Linguistics.

Sabando-Vera, D., Yonfa-Medranda, M., Montalván-Burbano, N., Albors-Garrigos, J., and Parrales-Guerrero, K. (2022), "Worldwide Research on Open Innovation in SMEs", *Journal of Open Innovation*, Vol. *8*(1), pp. 20-45.

Santander-Cruz, Y., Salazar-Colores, S., Paredes-García, W. J., Guendulain-Arenas, H., and Tovar-Arriaga, S. (2022) "Semantic Feature Extraction Using SBERT for Dementia Detection", *Brain Sciences*, Vol. 12(2), pp. 270-288.

SBERT.net (2025) "Pretrained Models — Sentence Transformers documentation", Availabale at https://www.sbert.net/docs/sentence_transformer/pretrained_models.html. Accessed August 25th, 2015.

Teece, D. J., Pisano, G., and Shuen, A. (1997). "Dynamic capabilities and strategic management", *Strategic Management Journal*, Vol. 18(7), pp. 509-533.

Tereschenko, E., Salmela, E., Melkko, E., Phang, S., and Happonen, A. (2024) "Emerging best strategies and capabilities for University-Industry cooperation: opportunities for MSMSEs and Universities to improve collaboration. A literature review 2000-2023", *Journal of Innovation and Entrepreneurship*, Vol . 13(28).

Väisänen, J. (2024) "Micro vs. Macro: Challenges to Digitalization in Smaller Firms", *NFF 2024 - Nordic Academy of Management Conference*, Reykjavik, Iceland, August 14th-17th, 2024.

Yadewani, D.,Pandi, O., Syafrani, S., Nurofik, A., and Poddar, S. (2024) "Impact Of Government Policies On The Knowledge Base Of Sustainable Small And Medium-Sized Enterprises", *Jurnal Ilmiah Ilmu Terapan Universitas Jambi.* Vol. 8. pp. 251-266.

Research Writing, Ghostwriting and Academic Cheating in the Age of AI: A Scoping Review

Brenda van Wyk and Lesego Makhafola
Department of Information Science (iSchool), University of Pretoria, Pretoria, South Africa

Brenda.vanwyk@up.ac.za
lesego.makhafola@up.ac.za

Abstract: The practice of employing a ghostwriter in writing biographies and political speeches is an accepted practice. It is however not accepted in research and academic writing where originality, validity, and research integrity are paramount in producing credible research output. The pervasiveness of evolving AI-powered writing tools begs the question: could using AI writing assistants be seen as a form of ghostwriting? Traditionally, factors such as a lack of confidence, limited academic acumen, and rigor y enticed emerging scholars to resort to third-party writers. Existing similarity checking tools are effective in identifying possible plagiarism cases, but prove to be limited in detecting academic cheating where a ghostwriter was used. What are the underlying reasons, and how do universities manage this form of academic misconduct in the age of AI? Guided by the PRISMA Extension protocol, this scoping review explored the trends reported in recent studies. Google Scholar, Scopus, and ProQuest databases we searched and 55 recent studies were selected and analysed thematically to identify trends and gaps in current research.

Keywords: Academic Writing, AI-powered Research Writing Tools, Contract Cheating, Ghostwriting, Scoping Review

1. Introduction

Employing a ghostwriter when writing autobiographies, political speeches, and even policies is a common and generally accepted practice. In academic writing where reporting and sharing quality research and academic writing is paramount, this practice is unethical. Young researchers often find academic writing daunting. Using someone's research, knowledge, ideas, or conclusions and passing them off as your own work without the necessary attribution, is still viewed as plagiarism (Kampka *et al*, 2025; Guruge, 2025). Furthermore, academic cheating includes taking, sharing, and receiving prohibited materials or information and circumventing the evaluation procedure (Kampa *et al* 2025). Factors such a lack of academic and research confidence, and limited academic acumen may entice emerging scholars to reach out to third-party writing assistance. These may include sourcing the assistance of AI research writing tools or full contract cheating that involves paying ghostwriters to write and then presenting work as original research. The question is: how prevalent is the use of ghostwriters among postgraduate students? What is reported on the latest trends and research gaps, as well as integrity problems that AI tools and applications present?

Guided by the PRISMA Extension protocol, (PRISMA-ScR) (see Page et al., 2020), this scoping review explored trends, gaps, and reported best practices. Google Scholar, Scopus, and ProQuest were searched, and 55 recent studies we deemed eligible and thematically analysed.

1.1 Academic Contract Cheating and Ghostwriting Practices

It is expected that students produce their own original research output towards. Several studies (including Nayak & Hedge, 2022; Gugge, 2025) warn that there is an alarming increase in consulting web-based commercial agencies or individuals to write their assignments and dissertations. This is an illicit form of ghostwriting availed on the internet, offering readymade work or customised papers to students. This form of contract cheating is different from plagiarism and is more difficult to detect and address. Factors such as an academic immaturity, and a lack of information literacy skills contribute to these practices. Kampa *et al.* (2025) opine that workload, and even a disinterest among lecturers as contributors to this behaviour. New AI technologies offer new and very sophisticated services for academic writing, enabling the dereliction of student responsibilities that could potentially limit their growth and exposure required. Questions are raised around the effectiveness of existing academic policies to manage this rapidly emerging form of contract cheating.

1.2 The use AI Research Writing Tools and Research Assistants

Recent studies (Dergaa *et al*, 2023; Monika *et al*, 2024) indicate that students are increasingly using AI tools such as ChatGPT, Grammarly, and Google Translate as legitimate aids for fact-checking, idea generation, and language editing (Aljuaid, 2024; Chauke *et al*, 2024; Monika, 2024). However, there are many illicit uses of AI. Aljuaid (2024) mentions the use of paraphrasing tools such as Quillbot for automatic paraphrasing, where students

cannot derive meaning from engaging in readings themselves. Unchecked use of AI tools may result in compromised research quality and ethics (Padillaah, 2023). Upholding transparency, honesty, and personal effort is crucial to maintaining ethical standards in academia.

Pertinent to this study is the question: *what are the trends and gaps in recent reported studies around the use of AI in academic research writing? Could using AI writing assistants be seen as a form of ghostwriting?* Studies remind that having plagiarism policies in place is no longer sufficient. A concerted effort must be made to provide the correct support, and inculcate research and writing skills (Aljuaid, 2024). The intersection of research ethics, integrity, and the concept of post-plagiarism reflects how academic norms are evolving in the age of digital content creation, artificial intelligence, and open science.

2. Research Design

Guided by the PRISMA Extension protocol (PRISMA-ScR), (Page *et al*, 2020), this scoping review explored the prevalence of this problem, trends, gaps, as well as reported best practices. The chosen databases provided 55 hits and qualitative thematic analysis was used to identify trends and gaps in current research.

2.1 The Search Strategy

Peer-reviewed articles in English, published between 2019 and 2025, were considered. The following criteria were used to filter the results: (1) the context of the discussion is focused on tertiary academic writing and research; (2) where the discussion includes ethical considerations and how to implement them. Based on the recent escalation AI and GenAI developments (as reported by Floridi, 2019 and others), the study is limited to research reported during the last six years.

The search strategy covers constructs of AI writing assistants, plagiarism and academic cheating, research ethics, quality and integrity, academic writing, research, and academic literacies, AI and AI writing assistance. The databases included in this study are Google Scholar, Scopus and ProQuest. Databases were queried from January 2025 to May 2025.

Keywords included are: ghostwriting OR ghostwriters, AI technology AND research ethics. Websites were searched according to their local search functionality. A combination of the following keywords was used: “Artificial Intelligence”, “ethics”, “Information ethics”, “research quality”, research integrity”, “academic cheating”, “contract cheating”, “academic misconduct” and “plagiarism”, as systematically as possible within the search functionality and capabilities of each website.

2.2 The Selection of Sources of Evidence

These results of each search were filtered according to document type, publication date, and then further refined to look for aspects such as Information or research ethics. A data log of the search strategies and complete results, with links, were recorded in an Excel spreadsheet.

2.3 Inclusion and Exclusion Criteria

Studies included in the literature search met the following inclusion and exclusion criteria:

- *Inclusion criteria:* studies focusing on academic institutions, such as universities or colleges. Studies reported in full-text, peer-reviewed journal articles and conference papers between 2019 and 2025, covering concepts of ghostwriting, and AI-assisted research writing tools in the titles, abstracts, or keywords were identified and included. Only studies in English were considered and selected.
- *Exclusion criteria*: Studies in corporate, industry, and school settings were excluded. Non-peer reviewed sources were excluded. The following document types were excluded: books, book chapters, grey literature, articles with abstracts only, patents, and reports, and duplicate studies found in the databases. Studies in other languages that are not English were excluded.

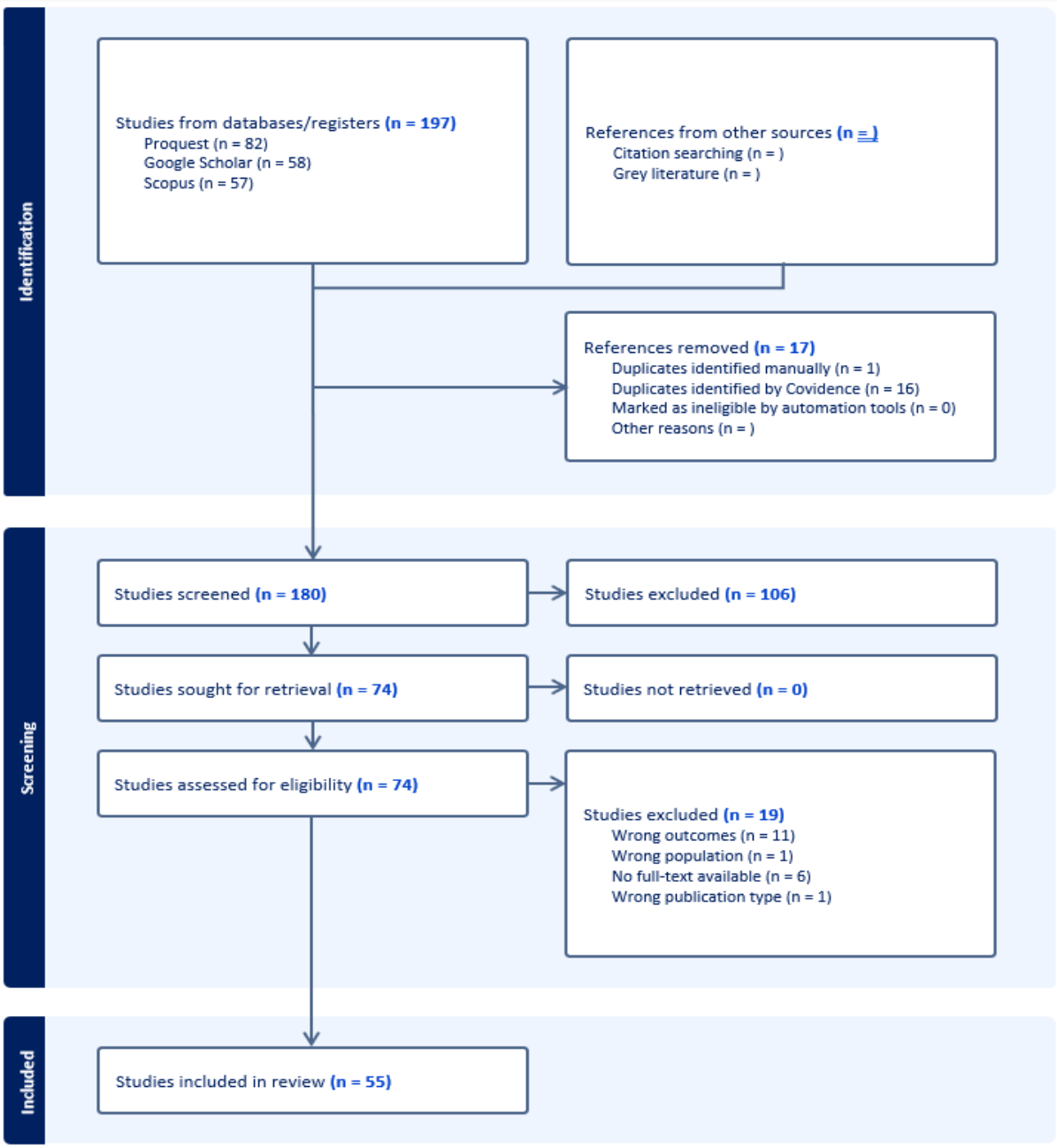


Figure 1: PRISMA flow for screening and extraction in Covidence

2.4 Knowledge Synthesis of Eligible Sources

The PRISMA-ScR flowchart presented in Figure 1 explains the identification, screening, inclusion/exclusion, and extraction for this scoping review. It outlines each step taken, which enhances not only the transparency, but also the reproducibility and rigour of the review process followed.

The review included searches in ProQuest (n=82); Scopus (n=57); and Google Scholar (n=57), totalling 197 records included in the initial abstract screening. Seventeen duplicates were removed, with 16 identified automatically by Covidence and 1 was identified manually. Of the 180 studies screened based on their titles and abstracts, 106 were excluded as they did not meet the inclusion criteria, leaving 74 studies. Full-text reviews followed, and 19 studies were excluded. Reasons included: wrong outcomes (n=11), wrong population (n=1), no full-text available (6), and wrong publication type (n=1). Once the full-text screening was completed, 55 studies were included for extraction. The studies were exported to EndNote and to a Microsoft Excel spreadsheet to commence the thematic data analysis.

3. Presentation and Discussion of Findings

The data extracted from the full-text publications was included in a workbook. The data were then analysed thematically, and the results and discussion of which are presented next.

Table 1: Summary of Results

Publication Years	Research Methods	Themes	Authors
2019 - 2025	• Systematic reviews • Case studies • Quantitative Survey questionnaires • Content analysis • Qualitative interviews	A. Ethics	Bist (2024); Deslauriers. (2025); Rana (2025); Vučković et al. (2023); Vasylyshyna (2024); Skulmowski (2024); Schroter (2020); Kumar, Pratap & Pateria (2022); Andrade-Hidalgo, Mio-Cango & Iparraguirre-Villanueva (2024); Mireku, Dzamesi & Bervell (2023).
		B. Plagiarism	Abdullah(2024); Kampa et al (2025); Rana (2025); Deslauriers (2025); Vučković et al. (2023); Stacy (2022); Kumar, Pratap & Pateria (2022); Jamieson & Howard (2019); Nguyen (2021); Kukali (2022); Sozon, (2024); Eaton (2023); Tarisayi (2023).
		C. Contract cheating,	Ashan, Akbar & Kam (2022); Kampa et al (2025); Sweeny (2022); Vučković et al (2023); Takrimi, (2023); Svirina,& Anand, (2022); Hill, Mason, & Dunn (2021); Liyanagamage et al (2025); Nartgün (2024).
		D. Ghostwriting	Clark et al (2025); DeTora et al (2029); Kampa et al (2025); Svirina & Anand (2022); So (2025); Padillah, (2024); Andrade-Hidalgo (2024); Hamza et al (2022); Lancaster(2019); Xu & Li (2023).
		E. Governance and Policies	Yi (2022); Clark et al (2025); Luo (2024); Goel, & Nelson (2024); Mpolomoka et al. (2025).
		F. Teaching support	Andrade-Hidalgo, Mio-Cango. & Iparraguirre-Villanueva (2024); Kumar, Pratap & Pateria; Gitonga, Gatiti, & Mlingi (2022);Vučković et al (2023); Clark et al (2025); Hamza et al (2022), Costa et al (2024)
		G. Research quality, integrity	Ashford (2021); Nayak, & Hegde (2022);.Vučković et al (2023); Skulmowski (2024); Deslauriers (2025); Hamza et al (2022); Guruge (2025); Hamza et al (2022); Sweeny (2022); Thacker (2022); Nannan Benoit Nemery & Dierickx (2019); Muñoz-Cantero, & Espiñeira-Bellón (2024); Jamieson & Howard (2019).
		H. Authorship	Rana (2025); Skulmowski (2024); Schroter et al, (2020); Hill, Mason & Dunn (2021); Aliuconis, Poškut˙ & Gefenas (2020); Badreldin et al (2021); Pruschak & Hopp (2022); So (2025); Dergaa (2025); Monika, Divyavarsini & Suganthan(2023); Teixeira da Silva (2023); Teixeira et al (2024), Anani et al 2025)
		I. Research misconduct	Vučković (2023); Rana (2025); Deslauriers (2025), Jamieson & Howard (2019); Palla & Singson (2023); Perkins et al (2020); Zhaksylyk (2023).
		J. Consequences	Yi (2020); Deslauriers (2025); Hamza et al (2022); Hutson (2024).

3.1 Coverage by Country

The studies covered in here are from UK, Canada, China. Iran, Montenegro, Poland, Russia, Lithuania, France, South Africa, Ghana, Australia, Saudi Arabia, and USA.

3.2 Research Methods

The research methods used in the articled screened, included systematic reviews, large-scale empirical studies, quantitative survey questionnaires, case studies and content analysis. After analysing the data from the selected sources, ten(10) common and reoccurring themes were identified:

(A) Ethics, (B) Plagiarism and post plagiarism, (C) Contract cheating, (D) Ghostwriting, (E) Governance and Policies, (F) Teaching and Learning, academic support, (G) Research Quality and Integrity (H) Authorship, ownership and AI co-authoring, (I) Research Quality, (J) Consequences

3.2.1 A. Ethics

With the advent of AI and practices such as ghostwriting, contract cheating, and plagiarism, ethics in academic research is particularly challenging. This undermines trust and quality of research. Academic integrity is crucial to ensuring researchers' reputation and upholding ethical standards (Vasylyshyna, 2024). Rana (2025) and Andrade-Hidalgo et al. (2024) note that generative AI add to this concern by blurring the line between ethics and abuse of the technology's capabilities. Skulmowski (2024) refers to the "ghostwriter effect" or silent partner, where the use of AI in their research is not disclosed., which impacts transparency. Kumar *et al*. (2022) mention that institutional credibility is diminished by the failure to act on the academic misbehaviour. Schroter et al. (2020) suggest that guidelines, criteria, and policies for authorship should be clear to improve publication ethics. Training and awareness should take place to help enforce ethics in research.

3.2.2 B. Plagiarism and Post-plagiarism

With the advent of AI research writing tools, plagiarism is no longer just about verbatim copying or poor referencing. Concerns are now around authorship, originality, and attribution in a complex digital environment. Eaton (2023) introduces the concept of post-plagiarism, where advanced AI technologies is part teaching and learning. Rana (2025) mentions that students witnessing unchecked academic dishonesty will believe that this is normal. The blurring of the distinction between what is a student's own work and what is fraudulent, distorts students' perception and erodes academic knowledge gained through legitimate studies.

3.2.3 C. Contract Cheating, Academic Dishonesty

Contract cheating is one of the most serious threats to academic integrity (Ahsan, Akbar & Kam, 2022). Svirina and Ananad (2022) point to plagiarism and contract cheating (ghostwriting) as foremost transgression. Students morally disengage while doing research. Authors see contract cheating as fraud due the commercialisation of higher education, and far more serious than plagiarism. Sweeny (2022) warns that any form of academic conduct is detrimental to academic standards and ethics. It is key in upholding academic and research integrity and credibility higher education.

3.2.4 D. Traditional and AI-assisted Ghostwriting

Author essay and paper mills are widely advertised on the internet. Skulmowski (2024), and Rana (2025) note that using generative AI tools such as ChatGPT can blur the line between ghostwriting and academic support and assistance. Skulmowski (2024) mentioned that AI-generated content is sometimes submitted without the author declaring their use of the AI tool, which in effect, can be considered ghostwriting. Svirina and Ananad (2022) articular targeting students with limited English language acumen. This raises concerns around the role of AI in academic authorship. (Andrade-Hidalgo, 2024). The term ghost-authorship has surfaced in especially bio-medical scholarly, also deemed ethically questionable. Ghost authorship refers to a situation where individuals who have made substantial contributions to research, data analysis, or manuscript writing are not named or disclosed in the author byline or acknowledgments. This is not the same as the concept of honorary or guest authorship, where individuals who made minimal or no contributions are included as authors. Svirina and Anand (2022) laments that ghostwriting practices deter from gaining knowledge first hand, which they describe as the primary value of educational and research.

3.2.5 E. Governance and Policies

Luo (2024) found that universities did not as yet succeed in delivering robust policies on handling AI such as the use of GenAI, and are subsequently ill-equipped to manage the ethical use. Ashan, Akbar and Kam (2022) state universities are responsible for policies and monitoring the implementation of these to not only detect academic dishonesty. These acts would include ghostwriting, plagiarism and contract cheating. Yi (2022) mentions that it is becoming increasingly difficult to detect and enforce transgression committed with the use of AI tools. Authors remind, however, that available tools like Turnitin, PlagScan and Urkund, prove to be in detecting ghostwriting and contract cheating. Ashan, Akbar and Kam (2022) argue that this could be because reports by paid third parties are often well-written and adequately referenced.

3.2.6 F. Teaching and Learning and Academic Support

It is also recommended that educators apply practical approaches that include the integration of the tools identified in this review and AI literacy, foster collaboration between educator and AI experts to design more effective pedagogical strategies, promote the use of controlled environments that allow students to use AI safely, and continuously train educators in the ethical use of technology, all with the goal of ensuring responsible teaching aligned with educational values. Hamza *et al* (2025) found that over 60% of students who did not receive training in academic integrity was unfamiliar with concepts of contract cheating and ghostwriting. They also found that 69% of students never received prior training on integrity.

3.2.7 G. Authorship and Co-authorship

Many AI tools used in academic writing may function more as a co-author (Skulmowski 2024) rather than the copy and pasting seen in plagiarism. Authorship in academic publishing represents a critical aspect of scholarly integrity, establishing who deserves credit and bears responsibility for research contributions. The notion of AI as co-author is not yet interrogated and more clarity and research are needed to inform guiding frameworks.

3.2.8 H. Consequences

Reportedly, there is a real danger of becoming over-reliant on AI assistance in academic writing . Vasylyshyna (2024) warns of a decline in critical thinking, creativity, and independent problem-solving among researchers. Takrimi (2023) adds that trend is evident particularly on PhD level, where the consequences of ethics transgressions could be severe. While AI has the potential to revolutionize the way academic research is conducted, it also raises important questions about ethics, bias, accountability, and the preservation of authentic scholarly work (Vasylyshyna, 2024).

3.2.9 I. Research Misconduct and Research Quality

Research misconduct threatens the quality and credibility of scholarly outputs. It includes acts such as plagiarism, ghostwriting, and unethical co-authorship (Deslauriers, 2025). Such misconduct is not limited to students, but it also involves academic staff and professionals, which undermines trust and academic integrity in institutions. Vučković *et al*. (2023) highlighted the need for comprehensive education on ethical writing and the enforcement of clear institutional guidelines as forms of preventative measures. According to Rana (2025), generative AI creates additional concerns such as inaccuracies, bias, and intellectual contributions that cannot be accounted for (therefore, impacting accountability). Intellectual dishonesty, such as data manipulation and deceptive citation practices (such as self-plagiarism), also impacts research quality (Deslauriers, 2025). In order to maintain good scholarly quality standards, institutions should focus on continually training students on research ethics, create strict peer-review mechanisms, and establish a culture of transparency and accountability.

4. Conclusion

The problem posed by traditional ghostwriting, contract cheating, and new forms of plagiarism enabled by AI tools is a growing concern for researchers and universities alike. Furthermore, the commercialisation of education with essay mills and online ghostwriters coupled with the pervasiveness of AI tools exacerbate this dilemma. Studies indicate a significant increase in the use of AI in research writing that goes undetected. Most authors agree that this phenomenon poses a threat to academic integrity and research quality. In addition, a worrying trend is student's moral disengagement. Xu (2023) add that the supply and demand, albeit underground, sustain this trend. Lancaster (2019) profiled third party academic writers. He calculated that

ghostwriters generated over US$270,000 per annum from essay writing. Universities should address this issue decisively.

Hardly any of the screened articles mention improved information and Ai literacy. This re regrettable, as effective academic-, digital-, AI- and research literacies could alleviate the problem. Implementing simple language policies and guidelines, as well as offering training to both students and academics to help alleviate the challenges of contract writing. Better detection tools and enforcing consequences for academic misconduct must be explored.

As technology evolves, the challenges posing detrimental to academic integrity must be faced decisively. Striking a balance between harnessing AI's potential and preserving the values of education will be critical in shaping an ethical AI-powered educational landscape. Thus, we can ensure that AI becomes a force for good in education, empowering students to be authentic. Transdisciplinary research may be avenue to explore ethical implications of advanced technologies in education.

Ethics Declaration

This paper used secondary data which don't require ethics clearance.

AI Declaration

This paper did not make use of AI to write content; Covidence was used a tool to extract and organise data for thematic analysis.

References

Abdullah, Z. D. 2024. Academic Plagiarism in the Artificial Intelligence Era: The Practices of University Students in Iraq. *International Journal of Social Sciences & Educational Studies*, 11(3), 48-63.

Aliukonis, V., Poškutė, M., & Gefenas, E. 2020. Perish or Publish Dilemma: Challenges to Responsible Authorship. Medicina, 56(3), 123. https://doi.org/10.3390/medicina56030123

Aljuaid, H. 2024. The impact of artificial intelligence tools on academic writing instruction in higher education: A systematic review. *Arab World English Journal (AWEJ) Special Issue on ChatGPT*.

Ahsan, K., Akbar, S., & Kam, B. 2021. Contract cheating in higher education: a systematic literature review and future research agenda. *Assessm*

Anani, G.E., Nyamekye, E. & Bafour-Koduah, D. (2025). Using artificial intelligence for academic writing in higher education: the perspectives of university students in Ghana. *Discov Educ 4, 46 (2025). https://doi-org.uplib.idm.oclc.org/10.1007/s44217-025-00434-5 ent & Evaluation in Higher Education*, *47*(4), 523–539. https://doi.org/10.1080/02602938.2021.1931660

Andrade-Hidalgo, G., Mio-Cango, P. & Iparraguirre-Villanueva, O. 2024. Exploring the Impact of Artificial Intelligence on Research Ethics - A Systematic Review. *J Acad Ethics* (2024). https://doi.org/10.1007/s10805-024-09579-8

Ashford, T. 2021.App-centric Students and Academic Integrity: A Proposal for Assembling Socio-technical Responsibility. J Acad Ethics 19, 35–48 (2021). https://doi.org/10.1007/s10805-020-09387-w

Badreldin H, Aloqayli S, Alqarni R, Alyahya H, Alshehri A, Alzahrani M, Al Tawalbeh A, Ismail WW. 2021. Knowledge and Awareness of Authorship Practices Among Health Science Students: A Cross-Sectional Study. *Adv Med Educ Pract*. 2021;12:383-392, https://doi.org/10.2147/AMEP.S298645

Bist, A. S., Rawat, B., Rahardja, U., Hardini, M., & Kamal, M. 2024. Unveiling Ethical Challenges and Malpractice in Academic Research and Integrity. In 2024 *3rd International Conference on Creative Communication and Innovative Technology (ICCIT*) (pp. 1-6). IEEE

Chauke, T. A., Mkhize, T. R., Methi, L., & Dlamini, N. 2024. Postgraduate students' perceptions on the benefits associated with artificial intelligence tools on academic success: In case of ChatGPT AI tool. Journal of Curriculum Studies Research, 6(1), 44–59. https://doi.org/10.46303/jcsr.2024.4

Clark, D., Nicholas, D., Swigon, M., Abrizah, A., et al (2025). Authors, wordsmiths and ghostwriters: Early career researchers' responses to artificial intelligence. *Learned Publishing*, *38*(1), e1652.

Costa, I. C. P., Nascimento, M. C. D., Treviso, P., Chini, L. T., Roza, B. D. A., Barbosa, S. D. F. F., & Mendes, K. D. S. (2024). Using the Chat Generative Pre-trained Transformer in academic writing in health: a scoping review. Revista Latino-Americana de Enfermagem, 32, e4194

Dergaa, I., Chamari, K., Zmijewski, P., & Saad, H. B. 2023. From human writing to artificial intelligence generated text: examining the prospects and potential threats of ChatGPT in academic writing. *Biology of sport*, *40*(2), 615-622.

Deslauriers, S. 2025. Where Plagiarism Ends, but Intellectual Dishonesty Persists. Journal of Education and Human Development, 14, 113. https://doi.org/10.1080/jehd.v14p1

DeTora, L. M., Carey, M. A., Toroser, D., & Baum, E. Z. 2019. Ghostwriting in biomedicine: a review of the published literature. *Current Medical Research and Opinion*, *35*(9), 1643–1651. https://doi.org/10.1080/03007995.2019.1608101

Eaton, S.E. 2023. Postplagiarism: transdisciplinary ethics and integrity in the age of artificial intelligence and neurotechnology. *Int J Educ Integr* 19, 23 (2023). https://doi.org/10.1007/s40979-023-00144-1

Gitonga, A. N., Gatiti, P. M., & Mlingi, P. E. 2024. A systematic review of academic writing services in low-and middle-income countries. Library Philosophy & Practice.

Goel, R. K., & Nelson, M. A. 2024. Do college anti-plagiarism/cheating policies have teeth in the age of AI? Exploratory evidence from the Internet. *Managerial and Decision Economics*, *45*(4), 2336-2347.

Guruge, D. B., Kadel, R., Shailendra, S., & Sharma, A. 2025. Building Academic Integrity: Evaluating the Effectiveness of a New Framework to Address and Prevent Contract Cheating. *Societies*, *15*(1), 11.

Hamza M.A, Al Assadi F.R, Khojah A.A, AlHanaki R.M, Alotaibi N.T, Kheimi R,M, Salem A.H, Marar S.D. 2022. Contract Cheating and Ghostwriting among University Students in Health Specialties. J Empir Res Hum Res Ethics. 2022 Dec;17(5):536-544. doi: 10.1177/15562646221128418. Epub 2022 Sep 25. PMID: 36154532.

Hill, G., Mason, J. & Dunn, A. 2021. Contract cheating: an increasing challenge for global academic community arising from COVID-19. RPTEL 16, 24 (2021). https://doi.org/10.1186/s41039-021-00166-8

Hutson, J. 2024. Rethinking plagiarism in the era of generative AI. *Journal of Intelligent Communication*, *4*(1).

Imran, M., & Almusharraf, N. 2023. Analyzing the role of ChatGPT as a writing assistant at higher education level: A systematic review of the literature. Contemporary Educational Technology, 15(4), ep464. https://doi.org/10.30935/cedtech/13605

Jamieson, S. & Howard, R. M. 2019. Rethinking the relationship between plagiarism and academic integrity. Revue internationale des technologies en pédagogie universitaire / International Journal of Technologies in Higher Education, 16(2), 69–85. https://doi.org/10.18162/ritpu-2019-v16n2-07

Kampa, R. K., Padhan, D. K., Karna, N., & Gouda, J. 2025. Identifying the factors influencing plagiarism in higher education: An evidence-based review of the literature. *Accountability in Research*, *32*(2), 83-98.

Kukali, A. 2022. Technological Dualism and Plagiarism in Universities: Analysis of Emerging Trends and Implications on Higher Education. Journal of African Interdisciplinary Studies, 6(8), 36-51.

Kumar R, Pratap B, Pateria RK. 2022. An Effect on Academic Integrity Due to Plagiarism: A Review. *Library Progress International*,42(1), 206-219

Lancaster, T. 2019. Profiling the international academic ghost writers who are providing low-cost essays and assignments for the contract cheating industry, *Journal of Information, Communication and Ethics in Society,* Vol. 17 No. 1, pp. 72-86. https://doi.org/10.1108/JICES-04-2018-0040

Liyanagamage, N., Asylguzhina, E., Vel, P., Khan, Z. R., Fernando, M., & Lancaster, T. 2025. Methodological and Ethical Approaches to Studying Contract Cheating: A Systematic Literature Review. *Journal of Academic Ethics*, 1-27.

Luo, J. 2024. A critical review of GenAI policies in higher education assessment: a call to reconsider the "originality" of students' work , *Assessment & Evaluation in Higher Education*, 49:5, 651-664, DOI: 10.1080/02602938.2024.2309963

Mireku, D. O., Dzamesi, P. D., & Bervell, B. 2023. Plagiarism in Higher Education (PLAGiHE) within Sub-Saharan Africa: A systematic review of a decade (2012–2022) literature. *Research Ethics*, 20(2), 156-186. https://doi.org/10.1177/17470161231189646 (Original work published 2024)

Mlitwa, N. B. W., & Ntuli, Z. 2016. Developing research capacity among emerging researchers in a comprehensive university: A case at the University of Zululand. *In INTED2016 Proceedings* (pp. 335-341). IATED.

Monika, M., Divyavarsini, V., & Suganthan, C. 2023. A survey on analyzing the effectiveness of AI tools among research scholars in academic writing and publishing. *International Journal of Advance Research and Innovative Ideas in Education*, *9*(6), 1293-1305.

Mpolomoka, D. L., Luchembe, M., Mushibwe, C., Muvombo, M., Changala, M., Sampa, R. L., & Banda, S. 2025. Artificial intelligence-related plagiarism in education: a systematic review. *European Journal of Education Studies*, 12(4).

Muñoz-Cantero, J. M., & Espiñeira-Bellón, E. M. 2024. Intelligent Plagiarism as a Misconduct in Academic Integrity. *Acta Médica Portuguesa*, *37*(1), 1-2.

Padillah, R. 2024. Ghostwriting: a reflection of academic dishonesty in the artificial intelligence era. *Journal of Public Health*, *46*(1), e193-e194.

Nannan Yi, Benoit Nemery & Kris Dierickx. 2019. Perceptions of research integrity and the Chinese situation: In-depth interviews with Chinese biomedical researchers in Europe, *Accountability in Research*, 26:7, 405-426, DOI: 10.1080/08989621.2019.1652096

Nartgün, Z., & Kennedy, E. 2024. Cheating in Higher Education in the Age of Artifical Intelligence. *International Journal on Lifelong Education and Leadership*, 10(2), 47-53

Nayak, V., & Hegde, K. P. 2022. Students' Perception and Experience of Ghost Writing – Study with Reference to Mangalore City. *Indonesian Journal of Educational Research and Review*, *5*(1), 34–42. https://doi.org/10.23887/ijerr.v5i1.44145

Nguyen, D. T. T. 2021. University students' understandings, attitudes, and experiences on plagiarism. *Cypriot Journal of Educational Science*. 16(4), 1471-1478. https://doi.org/10.18844/cjes.v16i4.6001

Noon, E. J. 2018. Interpretive Phenomenological Analysis: An Appropriate Methodology for Educational Research? *Journal of Perspectives in Applied Academic Practice, 6*(1), 75–83.

Page, M.J., McKenzie, J.E., Bossuyt, P.M. et al. 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Syst Rev* 10, 89 (2021). https://doi.org/10.1186/s13643-021-01626-4

Palla. I.A & Singson. M. 2023. How do researchers perceive research misbehaviors? A case study of Indian researchers, *Accountability in Research*, 30:8, 707-724, DOI: 10.1080/08989621.2022.2078712

Perkins, M., Gezgin, U.B. & Roe, J. 2020. Reducing plagiarism through academic misconduct education. *Int J Educ Integr* **16**, 3 https://doi.org/10.1007/s40979-020-00052-8

Pruschak, G & Hopp, C. 2022 And the credit goes to ...- Ghost and honorary authorship among social scientists. PLoS ONE 17(5): e0267312. https://doi.org/10.1371/journal. pone.0267312

Rana, N. K. 2025. Generative AI and academic research: A review of the policies from selected HEIs. Higher Education for the Future, 12(1), 97-113.

Resnik D.B & Smith E. J. 2023. Should authorship on scientific publications be treated as a right? Med Ethics 2023;49:776–778.

Schroter S, Montagni I, Loder E, et al. 2020. Awareness, usage and perceptions of authorship guidelines: an international survey of biomedical authors. *BMJ Open* 2020;10:e036899. doi:10.1136/ bmjopen-2020-036899

Skulmowski, A. 2024. Placebo or Assistant? Generative AI Between Externalization and Anthropomorphization. Educ Psychol Rev 36, 58. https://doi.org/10.1007/s10648-024-09894-x

Sozon, M., Alkharabsheh, O. H. M., Fong, P. W., & Chuan, S. B. 2024. Cheating and plagiarism in higher education institutions (HEIs): A literature review. F1000Research, 13, 788.

Svirina, A. and Anand, A. 2022. "Dubious or decisive? Digging deeper into the unchartered path of academic ghostwriting", *Journal of Organizational Change Management*, Vol. 35 No. 1, pp. 38-58. https://doi.org/10.1108/JOCM-12-2020-0398

Sweeney, S. 2023. Who wrote this? Essay mills and assessment–Considerations regarding contract cheating and AI in higher education. *The International Journal of Management Education*, *21*(2), 100818.

Takrimi, A., Khojasteh Mehr, R. & Eaton, S.E. 2023. Contract Cheating in Iran: An Overview of Key Issues and a Call to Action. *J Acad Ethics* 21, 323–341 https://doi.org/10.1007/s10805-022-09458-0

Tarisayi, K. S. 2023. Lustre and shadows: unveiling the gaps in South African University plagiarism policies amidst the emergence of AI-generated content. AI and Ethics, 1-7.

Teixeira da Silva, J.A.2023. How are authors' contributions verified in the ICMJE model?. *Plant Cell Rep* 42, 1529–1530 . https://doi.org/10.1007/s00299-023-03022-9

Teixeira da Silva, J. A., Daly, T., Türp, J. C., Sabel, B. A., & Kendall, G. 2024. The undeclared use of third-party service providers in academic publishing is unethical: an epistemic reflection and scoping review. Naunyn-Schmiedeberg's Archives of Pharmacology, 397(12), 9435-9447.

Thacker, E. J. 2022. Contract cheating and academic literacies: Exploring the landscape. (Thesis). Keele University

Vaismoradi, M., Jones, J., Turunen, H., and Snelgrove., S. 2016 Theme development in qualitative content analysis and thematic analysis, Journal of Nursing Education and training, 6(5), 100-110.

Vasylyshyna, N., Skyrda, T., Lazorenko, N., & Kravets, I. 2024. Legal perspective on artificial intelligence and academic integrity within university education process participants research activity: new possibilities along with new limitations. *Scientific Journals of the International Academy of Applied Sciences in Lomza*, *96*(4), 59-82.

Vučković, D., Peković, S., Đoković, R., Blečić, M., & Janinović, J. 2023. Opinions of Montenegrin University Students and Teachers about Plagiarism and its Prevention. *Center for Educational Policy Studies Journal*, *13*(3), 155–183. https://doi.org/10.26529/cepsj.1570

Xu, Y., Li, W. 2023. The Causes and Prevention of Commercial Contract Cheating in the Era of Digital Education: A Systematic & Critical Review. *J Acad Ethics* **21**, 303–321. https://doi.org/10.1007/s10805-022-09457-1

Zhaksylyk, A., Zimba, O., Yessirkepov, M., & Kocyigit, B. F. 2023. Research integrity: where we are and where we are heading. *Journal of Korean medical science*, 38(47).

TalkPro: A Multimodal Language Learning and Evaluation System

Johannes Wirth and René Peinl
Institute for Information Systems at Hof University, Hof, Germany

Johannes.wirth.3@iisys.de
Rene.peinl@iisys.de

Abstract: As universities around the world welcome increasing numbers of international students, there is a growing demand for scalable, objective tools that can support both language learning and applicant selection based on spoken language proficiency. In particular, pronunciation and comprehension remain persistent challenges for non-native speakers and are key factors for communication in academic environments. Traditional methods of assessing these skills are labor-intensive or often rely on surface-level metrics such as transcription accuracy, which do not fully capture a learner's communicative competence. This work introduces TalkPro, a multi-modal system for pronunciation and comprehension assessment as well as language learning, designed to address this need. The system provides continuous, personalized feedback on learners' spoken language, with a specific focus on phoneme-level accuracy as well as articulatory patterns. Instead of relying solely on conventional speech recognition outputs, which are often able to compensate even major pronunciation errors, TalkPro generates detailed acoustic analyses that pinpoint learner-specific difficulties. These include not only phoneme-level errors but also recurring articulatory tendencies, such as misplacement of the tongue, incorrect voicing, or inappropriate manner of articulation. The system also includes a text-to-speech (TTS) engine to generate spoken content adapted to vocabulary gaps, which is then followed by targeted comprehension questions. TTS can also be used to test listening comprehension either word by word in a dictation style or semantically using a large language model (LLM) as a judge. Overall, these components form an integral approach to pronunciation and comprehension training in a blended learning environment and can also be used for automated assessment. Preliminary experiments with incoming students from India to Germany indicate that phoneme-level ASR effectively identifies pronunciation errors, whereas grapheme-level ASR tends to overlook them. Future research will involve a comprehensive evaluation of automated results against human judgment, alongside the expansion of TalkPro's training capabilities with LLM-based reading comprehension modules that prioritize conceptual understanding over traditional verbatim recall.

Keywords: Computer-Aided Pronunciation Training, Second Language (L2), Language Learning, Speech Recognition, Text-to-speech, Large Language Model

1. Introduction

Despite the growing diversity of international students in universities worldwide, tools for assessing and developing spoken language skills in L2 (second language) learners remain underdeveloped. Most automated systems without human expert feedback were not originally developed for and thus are limited in their ability to assist in language learning (Liu et al., 2025), as they often ignore semantics, fail to align with human ratings (Kim et al., 2022) or cannot capture critical phonetic issues: voicing errors, tongue placement, and manner of articulation, that affect intelligibility in spoken communication. Meanwhile, commercial platforms for language learning like Duolingo offer only basic binary pronunciation feedback, which is insensitive to subtle mispronunciations and inconsistently applied. As a result, learners typically make stronger gains in reading and writing, while speaking and listening lag behind (Loewen et al., 2019). These gaps in both assessment and training tools for speaking and listening have concrete consequences: learners may struggle to participate in classroom discussions, lack confidence in presentations, and face communication barriers with native speakers. In today's globalized labor market, where international mobility and global employment opportunities are increasingly important, such limitations hinder academic progression and career prospects.

To bridge these gaps, this work introduces TalkPro, a multimodal platform specifically designed to improve both the assessment and training of spoken language by addressing the limitations outlined above. TalkPro integrates advanced acoustic and articulatory analysis, adaptive content generation, and intelligent comprehension exercises, built on multilingual phoneme- as well as grapheme-based automatic speech recognition (ASR) models, to deliver detailed, actionable feedback on pronunciation and understanding. By focusing on phoneme-level alignment and articulatory patterns, TalkPro identifies the specific challenges learners face, enabling targeted improvement. Its integration of Text-to-Speech (TTS) technology allows for personalized practice and correctional measures regarding pronunciation, while LLM-driven assessment (Large Language Model, LLM) ensures learners develop both accuracy and contextual understanding based on their personal weaknesses. By moving beyond surface-level metrics and focusing on the nuanced aspects of pronunciation and comprehension, TalkPro represents a significant step toward equitable, scalable, and effective language learning as well as assessment.

2. Literature Review

Between 1990 and 2010, CLT emphasized meaning over form (Pennington 2021), but in the last decade pronunciation regained importance with greater acceptance of variation. The primary goal is intelligibility and effective communication, rather than training towards a single, standardized model of perfect pronunciation (ibid). Although it is possible for adults to learn accurate pronunciation of a foreign language according to Flege's Speech Learning Model (SLM) by reorganization to allow for L2 sounds and add new phonetic categories, this is not an easy or quick process, it requires a high quality and quantity of L2 input, as well as sufficient training possibilities for L2 use in communication (Fletcher 1995).

According to Neri et al. (2008), computer-assisted pronunciation training leads to improvements in language learning for 11-year-old children that are on par with a comparison group, that was instructed by a teacher. The study focused on Italian pupils' English word-level pronunciation, using a simple ASR module limited to single-word recognition. The small sample (13 with computers, 15 without) prevented statistically significant results. Other sources like (Lee et al., 2015) suggest that instruction provided by a teacher is more effective than instruction provided on computer.

Pennington and Rogerson-Revell state in 2018, that "limitations of artificial intelligence and speech recognition and synthesis mean that it is hard for a computer to really communicate or negotiate meaning with a human". In 2025, however, this is not the case anymore. The difficulties of ASR in 2019 were dealing with accented,

non-native speech since such variations in pronunciation could not easily be represented in ASR databases. Our phoneme-based ASR highlights deviations directly, unlike earlier systems such as 'Pronunciation Power,' which relied on waveform comparison to a reference speaker (Pennington & Rogerson-Revell 2018).

CAPT systems can be tuned either in favor of falsely accepting incorrect responses (false positives) or falsely rejecting correct ones (false negatives). Since the amount of corrective feedback should be limited to avoid demotivating learners and to prioritize feedback on sounds with a high functional load (Neri et al. 2002), avoiding false negatives should be a priority. Phoneme-based ASR can be combined with grapheme-based ASR in order to prioritize pronunciation errors found with P-ASR according to their relevance for intelligibility judged by G-ASR, as suggested by Liu et al. (2025).

Bashori et al. (2024) investigated the effects of two ASR-based language learning systems, namely ILI and NOVO, on learners' word-level and sentence-level pronunciation of English language. 117 Indonesian high-school students participated in a five-week-long study (52 students used ILI and 65 NOVO). Phonetic edit distances and accentedness as well as comprehensibility ratings were calculated on a pre- and post-reading test. Results showed significant improvements in learners' pronunciation, with NOVO leading to more progress.

Liu et al. (2025) perform a systematic review of ASR use in EFL education and find that the majority of studies adopted a quasi-experimental design, primarily focusing on the pronunciation gains in accuracy. Their findings indicate that ASR is an effective tool in language classrooms but still entails limitations.

Practicing with ASR alone would not be feasible for every learner as some still require assistance to correct pronunciation mistakes (Liu et al. 2025). Therefore, we propose direct feedback from TTS to provide that kind of assistance.

Sentürk (2023) experimented with ChatGPT as a textual help for learning German. He used it for getting explanations of language constructs, example sentences and translations and found it rather helpful, although he found small mistakes in the translation in some cases.

The closest work to ours is (Moxon, 2024), which evaluates a similarly comprehensive computer system for language learning, but again for English language learning. Moxon uses Text-to-Speech, Automatic Speech Recognition, Automatic Pronunciation Assessment, and immediate visual feedback mechanisms from Microsoft Azure services to form "All-Talk". They included instructional videos showing a cut-through view of the mouth while speaking. Although changes in fluency between the pre-test and post-test were not statistically significant, male students improved significantly in overall pronunciation accuracy.

Summed up, computer-based language learning software should (Pennington & Rogerson-Revell 2019)

- be consistent with human feedback;
- be immediate;
- be pertinent and correct;

- be given in a form that students can make use of;
- include information about when goals have been reached
- suggest ways to address errors

3. The Proposed System

3.1 Overview

Our proposed system is Web-based and consists of a phoneme-level ASR, a grapheme-level ASR, a multi-speaker TTS system as well as a large language model (see Figure 1), in order to provide a comprehensive computer-based language learning offering for L2 speakers learning German. The system called TalkPro features both training and assessment functionality for speaking, listening and understanding. Users can listen to spoken text (TTS) and transcribe it to train both listening and writing or choose to provide content-equal text in either German or English (if they are proficient English speakers). Our main target group is bachelor graduates from India that come to Germany for a master study program. The LLM is judging the competence level based on ground truth and given transcript or translation on a 0 to 10 scale. The other way around, users can read German text and get feedback from both ASR systems regarding intelligibility (G-ASR) and pronunciation (P-ASR). Words that are pronounced incorrectly can be replayed with different TTS voices. Differences between recognized and expected pronunciation are highlighted in an International Phonetic Alphabet (IPA) representation. Other words with the same phonemes are displayed in order to show similarities and promote a deeper level of insight.

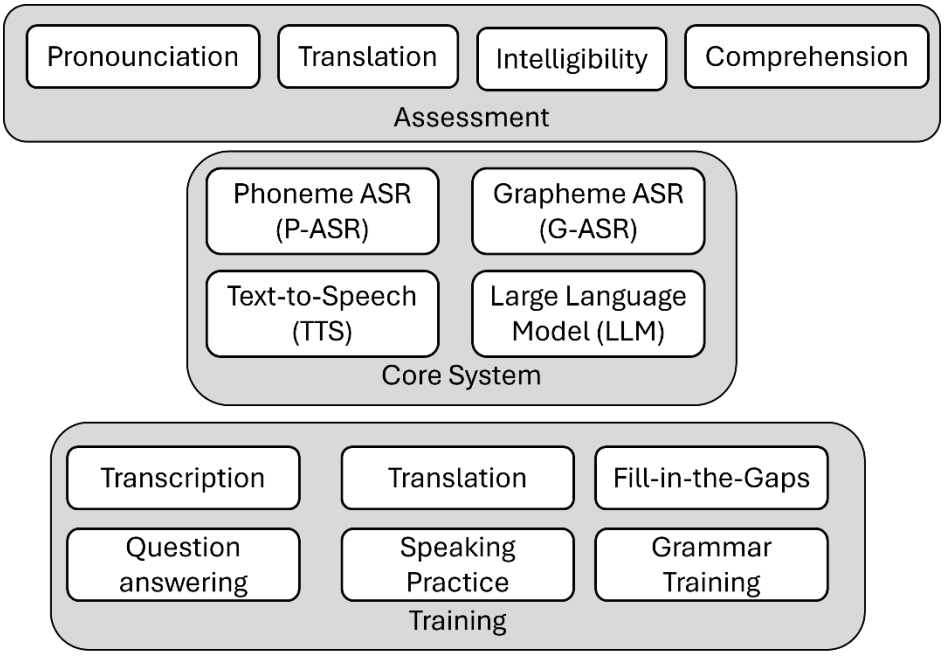


Figure 1: High-Level System Overview including training tasks, assessment possibilities and Modules.

Furthermore, translation on a textual level can be practiced as well as question answering to train text comprehension based on a short paragraph of text in German language (either written or spoken) and questions invented by the LLM.

3.2 ASR Modules

TalkPro incorporates two distinct ASR modules to evaluate and support learners' spoken German: a **phoneme-level ASR (P-ASR)** for pronunciation feedback, and a **grapheme-level ASR (G-ASR)** for intelligibility scoring. These modules enable the system to assess a user's spoken input, highlight errors, and guide improvement in pronunciation, fluency, and speech clarity.

Learners can read German text aloud, and the ASR modules analyze their speech to provide rich, multi-layered feedback:

- The **P-ASR** system performs **phoneme-level alignment and scoring**, identifying mispronunciations and mismatches between the spoken and expected phoneme sequences. Detected issues are

displayed using **IPA notation**, and incorrectly pronounced words can be replayed with alternative TTS voices for comparison.
- The **G-ASR** module estimates **intelligibility**, whether a typical listener would correctly understand the spoken input. It compares the recognized text against the ground truth and supports a **fluency-based scoring mechanism** integrated into the larger assessment workflow.

From a technical perspective, the P-ASR module is based on a Fastconformer-Transducer architecture (Gulati et al., 2020) and trained on a phonemized multilingual corpus comprising approximately 10,000 hours of speech from Common Voice (Ardila et al., 2019), Multilingual LibriSpeech (Pratap et al., 2020), and VoxPopuli (Wang et al., 2021), with data uniformly distributed across English, French, German, and Spanish. Phonemization was performed using OLaPh (Wirth, 2025), a phonemization framework that leverages Wiktionary-derived pronunciation dictionaries, statistical subword modeling based on large text corpora from Wikipedia dumps, and language-aware NLP preprocessing using spaCy (Honnibal et al., 2020). This allows the framework to handle lexical ambiguities (e.g., "wound" as noun vs. verb) and align phonemes appropriately based on sentence context.

For intelligibility estimation, the system uses Canary 1B Flash by Nvidia (Puvvada et al., 2024), a state-of-the-art grapheme-level ASR model, which complements the P-ASR by providing robust transcription and noise tolerance.

3.3 TTS Module

The TTS module provides **auditory input and corrective feedback** that supports both **listening comprehension** and **pronunciation training** for learners of German. It enables interaction with natural-sounding synthetic voices and plays a central role in exercises targeting listening, transcription, and pronunciation modeling.

Learners interact with the TTS module in two primary contexts:

- The system uses TTS to synthesize short text passages that learners transcribe. This supports auditory discrimination, spelling, and familiarity with German prosody. Passages can be predefined or generated by the LLM according to learner level.
- In pronunciation correction workflows, TTS replays the correct version of words or phrases detected as mispronounced by the ASR modules. Learners can choose to hear variations across multiple synthetic voices. Additionally, the system may synthesize phonetically similar words to highlight contrastive sounds and help refine pronunciation.

The component currently integrates five single speaker VITS (Kim et al., 2021) models based on the German datasets HUI (Puchtler et al., 2021) as well as Thorsten Voice (Müller & Kreutz, 2022). These voices vary in speaker characteristics such as gender, tone and speaking rate, enhancing the diversity of input and enabling a richer learning experience.

3.4 LLM Module

The LLM module serves as the system's **core reasoning and evaluation component**, enabling advanced functionality such as **competence scoring**, **question generation**, **translation feedback**, and **instructional adaptation**. It plays a central role in assessing user input, generating dynamic content, and personalizing the learning experience for German language learners.

The LLM is used in several key interaction contexts:

- It evaluates **speaking and writing competence** by comparing user input, whether spoken (ASR transcript) or written (typed) against a ground truth reference. The system then assigns a score between 0 and 10 based on correctness, fluency, and task completion.
- It supports **translation training** by analyzing user-provided German or English equivalents of a source text and offering corrections or stylistic improvements. This allows learners to practice both L1→L2 and L2→L1 translation while receiving feedback beyond simple literal matching.
- For **reading and listening comprehension**, the LLM generates **contextual questions** based on a short German paragraph (either written or spoken by TTS). Learners must answer these questions to demonstrate understanding, and the LLM evaluates the quality and relevance of their responses.
- It provides **instructional scaffolding** by rephrasing content, giving hints, or simplifying/recomplicating tasks depending on the learner's current ability.

Technically, the system can run with any sufficiently advanced LLM. The know-how is in the prompts and the chaining of LLM agents (Chu et al. 2025) to achieve better outcomes as with single-shot prompts. Since multilingual training of LLMs is the standard in the last year and not only US-developed models like Llama are proficient in German language (Peinl & Wirth 2024), but German and other European languages are also standard for Chinese LLMs like Qwen and DeepSeek, there is abundant choice (Phogat et al. 2025). We have used local installations of Llama 3.3 70B and Mistral 3.2 small up to now, besides tests with GPT-4o and Claude 3.7 Sonnet. For the future, an upgrade of our local LLM infrastructure to GLM 4.5 Air or Qwen 3 235B A22 2507 is planned. We did tests with a locally installed Phi-4 reasoning as well but did not get better results compared to Llama.

4. Use Cases

4.1 Speaking Tasks

The system presents the learner with a short text to read out aloud. This text is adjusted to the learning level of the learner (A1..B2) and previous mistakes, so that problematic words occur more frequently than others. The recording is then transcribed using both ASR systems and deviations from the expected result are displayed to the user. **Figure 3** shows example feedback. Please note that the system concentrates on words not understood by G-ASR and ignores the difference in pronunciation for "Waschmaschine". If the WER for G-ASR is zero, the phoneme-level mistakes are also highlighted, except for phonemes from a similarity list.

Ground Truth Grapheme:	meine hose ist schmutzig hast du eine waschmaschine
Recognized Grapheme:	meine hause ist schmierstich hast du eine waschmaschine
Grapheme WER: 25%	Grapheme CER: 17.6%
Ground Truth Phoneme:	ˈmaɪ̯nə ˈhoːzə ɪst ˈʃmʊ͡tsɪk. hast duː ˈaɪ̯nə ˈvaʃmaʃiːnə?
Recognized Phoneme:	ˈmaɪ̯nə ˈhaʊ̯zɐ ɪst ˈʃmjuːʃtɪç hast duː ˈaɪ̯nə ˈvɔʃemaʃiːnə?
Phoneme WER: 37.5%	Phoneme CER: 23.7%

Figure 2: Example of feedback on speaking tasks (all words are lower cased for comparison).

4.2 Listening Tasks

The system presents the learner a short audio file that was produced with our in-house TTS system. The audio files are prerecorded and not generated on demand, so that there is a chance for manual quality assurance. The task can be either to transcribe the audio word by word, or to write down the semantic meaning of the spoken information. In the first case, spelling is scored together with listening comprehension and the system cannot distinguish which kind of mistake was made. Feedback is given regarding the character error rate (CER).

Table 1: Example of feedback on listening and spelling task.

Groundtruth	User input	CER	Time [s]
Ich habe die Milch verschüttet.	Ich habe die mich verschuldet.	13.3%	55.7
400 Euro Miete im Monat sind viel Geld.	400 Euro mitte im Monat sind vier Geld.	4.3%	30.1
Weihnachten ist in Deutschland ein besonderer Feiertag.	weihnachten ist deutschland ein besonderer freitag	11.1%	21.3
Kannst Du mir eine Geschichte vorlesen?	Kannt su mir eine Geschichte vorlesen?	5.3%	23.2
Meine Wohnung hat zwei Zimmer, Küche und Bad.	Am wohnung hatz wer markische im park	48.8%	59.3

In the second case, an LLM is used to score the semantic similarity between the learners' input and the spoken text. It can be prompted to accept input in German only, or to accept single words or whole sentences in different languages. In our primary use case, incoming students from India are e.g. proficient English speakers and therefore we accept English input for the listen and understand task (see **Figure 4**).

Table 2: Example of feedback on listening comprehension tasks (scoring by Llama 3.3 70B).

Groundtruth	User input	Rating [0..10]
400 Euro Miete im Monat sind viel Geld.	Vierhundert Euro Miete pro Monat ist teuer!	9
	400€ Miete im Monat sind viel Geld.	10
	viele hundert euro mieten im Monat viel Geld	6
	Four hundred euros a month for rent is a lot of money.	10
Weihnachten ist in Deutschland ein besonderer Feiertag.	Weihnachten ist ein wichtiger Feiertag in Deutschland.	9
	Weihnachten ist für Deutschland very special.	8
	Weihnachten is in deutsche land bisonde feir	2
	Christmas is a special feast day in Germany	9

4.3 Writing Tasks

In written form, a lot of different training types are possible and many of them are already implemented in our system. The main focus is on creating the training tasks automatically by an LLM instead of manually by a human expert. We use text from websites that provide contents for German children or specifically for German language learners as a basis (e.g. helles-koepfchen.de, or “stories in easy language” by PH Ludwigsburg). We break the text down into single sentences and further filter them according to a list of words that should be known at a certain language level. Based on these texts, the LLM generates different training tasks in a multi-stage pipeline.

For “**fill-in-the-blanks**” kind of tasks, the challenge is to find meaningful words as alternatives for the correct word. These alternatives should not be obviously wrong even for people with low language competency level but should be not too similar so that the correct solution can no longer be determined unambiguously. Tests with Llama 3.3 70B, GPT-4o, and Claude 3.7 Sonnet showed that one-shot solutions were inadequate. Therefore, we developed a pipeline that first generates candidate words and then tests each single one as part of the original sentence and the LLM decides whether it is a valid alternative according to the criteria or not. We repeat up to three times, skipping sentences without sufficient alternatives. We allow up to two blanks per sentence, if the sentence has at least eight words. Otherwise, only a single blank is inserted. Task difficulty can be varied by providing multiple sentences with blanks at once that share a common pool of word candidates.

Grammar training is similar to fill-in-the-blank, but learners receive only the base form and must supply the correct inflection. This is suitable for verbs as well as nouns. To make generation easier, only the basic form is provided in our tasks with no explicit choices.

The insertion of definite articles (“der”, “die”, “das” in German in contrast to “the” in all cases in English) is another slight variation of the task that addresses a common problem for German language learners, since the grammatical gender of a word is often counter-intuitive. It is e.g. “das Mädchen” (the girl) with a neutral article although you would expect a female gender for girl. The other way around, milk has a female gender in German although most other drinkable things are neutral.

Translation tasks are easier to produce. The capabilities of general LLMs in machine translation of high-resource languages is already very good (Kocmi et al. 2024) and the German – English language pair is one of the best (Manakhimova, et al. 2024), only topped by French – English and Spanish – English. As known from other approaches like LLM-as-a-judge (Zheng et al. 2023), the LLMs are even better at judging a given text regarding its correctness than producing a correct text for a given task on their own. This can also be transferred to the machine translation domain. (Treviso et al. 2024) show that LLMs can give qualified feedback to translations. We employ the same principle and let the LLM judge the results from the language learners output for both English to German as well as German to English translation tasks. Especially for the simple sentences of A1 and A2 level, the error rate of this approach is extremely low and can be neglected.

Question answering is another way of practicing a new language and demonstrate language understanding. Since this task is also important for the development of LLMs, it is well studied there for both answering questions as well as generating meaningful questions (Li & Zhang 2024). Although some challenges remain (Al Faraby & Romadhony 2024), a multi-stage pipeline of generation, review and selection of questions for a given text leads to good results and minimizes chances of questions that are not answerable by reading the text alone

or have ambiguous answers. (Biancini, Ferrato, Limongelli 2024) find that even GPT-3.5 can generate meaningful multiple-choice questions within an educational context. Our tests show that both Llama 3.3 70B as well as Mistral 3.2 small are able to generate good questions in a single step, if the prompt is sophisticated enough.

5. Discussion

A preliminary evaluation using only G-ASR was conducted with 24 L2 speakers to assess the feasibility of automated pronunciation assessment. The results highlight the inherent subjectivity in pronunciation judgment, which complicates the creation of a reliable ground truth. The pair-wise inter-rater agreement between three human raters (all German native-speakers) was between 0.71 (rather good) and 0.46 (rather bad). We tested the correlation between both single human raters and several different G-ASR systems and found a significant negative correlation between the average WER or three ASR systems and the average of the human raters (-0.593), with a medium to strong confidence. These results suggest that lower WERs are generally associated with higher human-assessed pronunciation quality, an expected but useful validation of G-ASR-based scoring.

Building on this initial insight, we developed and piloted a more specialized system incorporating P-ASR to address the limitations of G-ASR in capturing detailed articulatory patterns. Although the system has so far only been tested in a small-scale pilot study involving 10 incoming students from India, it has already demonstrated promising usability for assessing competencies in listening and speaking. Each participant completed 15 speaking tasks (see Section 4.1) and 15 listening tasks (see Section 4.2). Their responses were evaluated both automatically by the system (with P-ASR and G-ASR combined) as well as manually by two native-speaking evaluators. While minor discrepancies between automatic and manual scoring remained, incorporating the P-ASR module resulted in a more accurate reflection of learners' speaking abilities compared to the use of G-ASR alone. In some instances, however, P-ASR overcorrected by transcribing mispronounced words as their intended phoneme representations, which suggests possible overfitting to the training data. To address this, earlier model checkpoints should be reviewed to determine whether they produce phoneme transcriptions that more accurately reflect the phoneme representation of the actual speech input. A more extensive evaluation with a larger sample and broader assessment criteria is needed to quantitatively assess the system's effectiveness in productive use. Additionally, while the ASR systems used are state-of-the-art (SOTA), a small risk remains that errors in recognition do not stem from bad pronunciation or other mistakes of the language learner at all, but from errors of the ASR model. However, in quiet environments and under good recording conditions, this error will be minimal, which can be seen from the low WER of LibriSpeech clean (1.5%) and the HUI dataset for German language (1.9%, Wirth & Peinl 2022).

6. Conclusion

In this work, we present TalkPro, a modular, AI-based language learning system designed to support and assess German L2 learners. The system integrates phoneme- and grapheme-level ASR, multi-speaker TTS, and LLM-based components, combining these modules in multiple ways to support training and assessment across key language competencies, including listening, pronunciation, translation, and comprehension.

While the current version already supports most previously described features, it has so far only undergone a limited pilot phase with a small number of users. As part of future work, we plan to conduct a larger-scale evaluation involving incoming Indian students enrolled in master's programs in Germany. This will allow us to assess both the overall effectiveness of the system and the specific contribution of individual modules and exercises. We aim to measure learning outcomes more precisely, explore usage patterns in authentic educational settings, and refine the feedback mechanisms based on empirical data. As part of this refinement, we will also investigate the performance of earlier P-ASR model checkpoints to identify a version that balances phoneme-level sensitivity with tolerance for learner variation, thereby avoiding overcorrection and better representing the actual pronunciation of speech input.

Preliminary experiments with incoming students from India to Germany indicate that phoneme-level ASR effectively identifies pronunciation errors, whereas grapheme-level ASR tends to overlook them.

Future research will involve a comprehensive evaluation of automated results against human judgment, alongside the expansion of TalkPro's training capabilities with LLM-based reading comprehension modules that prioritize conceptual understanding over traditional verbatim recall.

Ethics Declaration

Ethical clearance was not required for the research presented in this work.

AI Declaration

The authors have used generative AI solely for the purpose of rephrasing in a few cases in section 2 and take full responsibility for the content.

References

Al Faraby, S., & Romadhony, A. (2024). Analysis of LLMs for educational question classification and generation. *Computers and Education: Artificial Intelligence*, *7*, 100298.

Ardila, R., Branson, M., Davis, K., Henretty, M., Kohler, M., Meyer, J., ... & Weber, G. (2020). Common Voice: A Massively-Multilingual Speech Corpus. *Proceedings of the 12th Language Resources and Evaluation Conference (pp. 4218-4222)*.

Bashori, M., van Hout, R., Strik, H., & Cucchiarini, C. (2024). I Can Speak: improving English pronunciation through automatic speech recognition-based language learning systems. *Innovation in Language Learning and Teaching*, 18(5), pp. 443–461. Available at: https://doi.org/10.1080/17501229.2024.2315101.

Biancini, G., Ferrato, A., & Limongelli, C. (2024). Multiple-choice question generation using large language models: Methodology and educator insights. *Proceedings of the 32nd ACM Conference on User Modeling, Adaptation and Personalization* (pp. 584-590).

Chu, Z., Wang, S., Xie, J., Zhu, T., Yan, Y., Ye, J., ... & Wen, Q. (2025). LLM Agents for Education: Advances and Applications. arXiv. Available at: https://doi.org/10.48550/arXiv.2503.11733.

Hişmanoğlu, M. (2006) Current perspectives on pronunciation learning and teaching, *Journal of language and linguistic studies*, 2(1), pp. 101–110.

Gulati, A., Qin, J., Chiu, C. C., Parmar, N., Zhang, Y., Yu, J., ... & Pang, R. (2020). Conformer: Convolution-augmented Transformer for Speech Recognition. *Interspeech 2020*.

Honnibal, M. *et al.* (2020) spaCy: Industrial-strength Natural Language Processing in Python. Available at: https://doi.org/10.5281/zenodo.1212303.

Kim, J., Kong, J. & Son, J. (2021). Conditional Variational Autoencoder with Adversarial Learning for End-to-End Text-to-Speech, in M. Meila and T. Zhang (eds) *Proceedings of the 38th International Conference on Machine Learning*. PMLR (Proceedings of Machine Learning Research), pp. 5530–5540.

Kim, S., Le, D., Zheng, W., Singh, T., Arora, A., Zhai, X., ... & Seltzer, M. L. (2021). Evaluating user perception of speech recognition system quality with semantic distance metric. *arXiv preprint arXiv:2110.05376*.

Kocmi, T., Avramidis, E., Bawden, R., Bojar, O., Dvorkovich, A., Federmann, C., ... & Shmatova, M. (2024). Findings of the WMT24 general machine translation shared task: The LLM era is here but MT is not solved yet. In *Proceedings of the Ninth Conference on Machine Translation* (pp. 1-46).

Lee, J., Jang, J. and Plonsky, L. (2015). The Effectiveness of Second Language Pronunciation Instruction: A Meta-Analysis. *Applied Linguistics*, 36(3), pp. 345–366. Available at: https://doi.org/10.1093/applin/amu040.

Li, K. & Zhang, Y. (2024). Planning First, Question Second: An LLM-Guided Method for Controllable Question Generation. in L.-W. Ku, A. Martins, and V. Srikumar (eds) *Findings of the Association for Computational LinguisticsFindings 2024*, Bangkok, Thailand: Association for Computational Linguistics, pp. 4715–4729.

Liu, Y., binti Ab Rahman, F., & binti Mohamad Zain, F. (2025). A systematic literature review of research on automatic speech recognition in EFL pronunciation. *Cogent Education*, *12*(1), 2466288.

Loewen, S., Crowther, D., Isbell, D. R., Kim, K. M., Maloney, J., Miller, Z. F., & Rawal, H. (2019). Mobile-assisted language learning: A Duolingo case study. *ReCALL*, *31*(3), 293-311.

Manakhimova, S., Macketanz, V., Avramidis, E., Lapshinova-Koltunski, E., Bagdasarov, S., & Möller, S. (2024). Investigating the linguistic performance of large language models in machine translation. In *Proceedings of the Ninth Conference on Machine Translation* (pp. 355-371).

Moxon, S. (2024). All-talk: Enhancing EFL pronunciation with Microsoft azure speech services. *Abac Journal*, *44*(4), 139.

Müller, T. & Kreutz, D. (2022). ThorstenVoice Dataset 2022.10. Available at: https://doi.org/10.5281/zenodo.7265581.

Neri, A., Mich, O., Gerosa, M., & Giuliani, D. (2008). The effectiveness of computer assisted pronunciation training for foreign language learning by children. *Computer Assisted Language Learning*, *21*(5), 393-408.

Neri, A., Cucchiarini, C., & Strik, H. (2002). Feedback in computer assisted pronunciation training: When technology meets pedagogy. Available at: https://www.academia.edu/download/40482205/neri.2002.2.pdf

Pennington, M.C. (2021). Teaching Pronunciation: The State of the Art 2021. *RELC Journal*, 52(1), pp. 3–21.

Pennington, M.C. & Rogerson-Revell, P. (2018). English Pronunciation Teaching and Research: Contemporary Perspectives. Palgrave Macmillan.

Pratap, V., Xu, Q., Sriram, A., Synnaeve, G., & Collobert, R. (2020). MLS: A Large-Scale Multilingual Dataset for Speech Research. *Interspeech 2020*.

Puchtler, P., Wirth, J. & Peinl, R. (2021). HUI-Audio-Corpus-German: A high quality TTS dataset. *44th German Conference on Artificial Intelligence (KI2021)*. Berlin, Germany.

Puvvada, K. C., Żelasko, P., Huang, H., Hrinchuk, O., Koluguri, N. R., Dhawan, K., ... & Ginsburg, B. (2024). Less is More: Accurate Speech Recognition & Translation without Web-Scale Data. *Interspeech 2024* (pp. 3964-3968).

Şentürk, R. (2023). Die Rolle Künstlicher Intelligenz beim Deutsch als Fremdsprachenlernen: Eine Untersuchung am Beispiel von ChatGPT. Diyalog Interkulturelle Zeitschrift für Germanistik, 11(2), pp. 405–430.

Wang, C., Riviere, M., Lee, A., Wu, A., Talnikar, C., Haziza, D., ... & Dupoux, E. (2021). VoxPopuli: A Large-Scale Multilingual Speech Corpus for Representation Learning, Semi-Supervised Learning and Interpretation. *11th Intl Joint Conf. on Natural Language Processing*. Association for Computational Linguistics, pp. 993–1003.

Wirth, J. (2025). OLaPh: Optimal Language Phonemizer. Available at: https://doi.org/10.48550/arXiv.2509.20086.

Wirth, J. & Peinl, R. (2022). Automatic Speech Recognition in German: A Detailed Error Analysis. *2022 IEEE International Conference on Omni-layer Intelligent Systems (COINS)*. pp. 1–8

Non Academic Papers

Build-A-Cyber-Attacker: Simulating Attackers to Reflect Myth and Folklore in Cyber Threat Analysis

Tim Pappa
Capitol Technology University, Laurel, Maryland, USA

tpappa@captechu.edu

Abstract: This practitioner's working paper explores the application of simulation exercises in cyber threat analysis, finding that the creative integration of conceptual frameworks like folklore and myth in practical instructional assignments and discussions can familiarize students with the influence of myth and folklore in their analysis. Simulation in this context is concentrated on the process of thinking through a series of events in an exercise, rather than focusing on the outcome. Prior research on simulation found that students were more likely to complete assignments on time and finish course projects with higher grades when they imagined when and how they would study. This practitioner's paper will present a working sample of simulation exercises, including a simulation exercise where graduate intelligence and military students were asked throughout the course to simulate and create the mythos of their own cyber threat attacker group, including their attacker group target portfolio and an outline of how they might respond to threats. These working exercises suggestively demonstrated the complexities of simulating the cultural and operational challenges of cyber threat attacker groups. These students had creative freedom to simulate these cyber threat encounters, even without foundational background or expertise in the countries or cultures they simulate. This exploratory practitioner's working paper suggests simulation can introduce further dimensionality to cyber threat intelligence analysis.

Keywords: Folklore; Myth; Simulation; Cyber Threat Analysis; Cyber Attacker

1. Introduction

This practitioner's working paper demonstrates how conceptual frameworks like folklore and myth can be applied, in a simulation project throughout a course where students create a fictional cyber attack group.

The author structured his original course curriculum with several assignments and discussions related to folklore and myth because of his background in law enforcement and intelligence, where he experienced firsthand what he believed was the influence of folklore and myth in mischaracterizations of cyberterrorism threats (Pappa, 2024). While there has been growing criticism of what at times has appeared to be commodification of characterizing the threat posed by cyber attackers, there has been limited commentary on the influence of folklore and myth on American cyber threat analysts and practitioners who characterize these cyber threats. This paper introduces a potential model for familiarizing students with the influence of folklore and myth, based on students' work in a graduate comparative cyber security course provided asynchronously online. Although the university where students enrolled in this paper is a private university, most of the students in this course are affiliated with the American military or American intelligence community.

Students in this course are immediately introduced to concepts of folklore and myth. To start preparing students for this simulation of creating a fictional cyber attack group, students were asked in the first week to write about their personal experience with cyber threats and what they believe is the biggest danger they face online. The assignment explored students' core beliefs about cyber threats, but additionally and more importantly, the assignment encouraged students to start thinking about why they believe a cyber threat is a danger to them or not. Students generally wrote about fraud and online crime, rather than nation state attackers, which governments and cybersecurity firms tend to warn people the most about.

The author also included additional assignments and reading in this graduate course related to folklore and myth in the initial weeks of the course. As another example, students were asked to select at least one example of a historical cyber threat event or attack and discuss how that event or attack reflected both myth and folklore. This asynchronous graduate course provided considerable reading samples to introduce and familiarize students with these frameworks. Some of those historical events included the *Syrian Electronic Army* and the *Islamic State Hacking Division*, for example. In both cases, these attack collectives were in fact one person or a limited collective in terms of people and threat or capabilities, but significant attention and resources were directed to countering these embellished cyber threats in their time. The assignment also asked students to "characterize the myth and folklore of US government cyber threats". Beyond the reading provided for students, the assignment instructions were limited to allow students to share freer commentary from their own perspective on myth and folklore. This kind of assignment with limited instructions was meant to encourage the students to consider alternative perspectives, such as the folklore and myth of the American government as an enterprise

with cyber attack groups. This assignment may have been most surprising to students, who were asked generally to write about the "real and imagined impressions we form of cyber threats", including if those threats come from their own government.

This practitioner's working paper will introduce some of the related work on the communication of folklore and myth. This paper will then describe additional background on this practice of simulation as an instructional method and how the author structured this assignment throughout the duration of the course. The author will share how two students in this course created fictional cyber attack groups, including samples from their written assignments demonstrating how they applied folklore and myth to the origin story of their fictional cyber attack group and how their fictional cyber attack group responded to false claims of attacks, for example. How a cyber attack group grows or maintains its reputation can be critical to its folklore or myth. This paper will conclude with a discussion of research limitations and future research.

2. Related Work: the "Branding" of Cyber Threats When Communicating Folklore and Myth

Gros (2021) in his longitudinal study of attacker behaviours may have definitionally conflated "myths and misconceptions", but his paper highlighted a fair criticism of cyber threat intelligence practitioners – that we do not necessarily know what kind of attacker we might face, so we generally approximate and sometimes overestimate attackers as "mythical, all-powerful creatures who can do whatever they want…they are treated as an undefined entity that represents every possible type of attacker".

Vigano (2024) encouraged the use of fairy tales and myths to explain cybersecurity or information security more generally to less technical or broader public audiences. Talbot, Frincke, and Bishop (2010) wrote about "demythifying cybersecurity", focusing instead on the common practices derived from so-called beliefs or sayings among practitioners in information security communities, such as "effective security is burdensome security". The author agrees that these perspectives are common in cybersecurity or information security, but the use of myth may be more likened to folklore or how people in those communities talk about it and how they learn about information security from talking about it with people they know in those communities.

The author suggests that this treatment of myth and folklore is a bit trivial, as referring to myth or folklore as an explanation of why people believe some things about cybersecurity, for example, can be useful, but this paper is exploring how folklore and myth as defined in more granular commentaries of that influence in cultures and groups can also influence or even bias our cyber threat analysis. There is some growing recognition of how the "branding" of generally unknown attackers as fearsome and dangerous can be misleading or inaccurate. Shires (2020) wrote that cybersecurity experts continually define or redefine characterizations of attackers. Shires referred to an example of the "Shadow Brokers" who were known for their alleged leak of American intelligence hacking tools and their alleged association with Moscow. Referring to Kumar (2017), Shires wrote that while the Shadow Brokers themselves did not suggest or encourage any prompts for how they should be visualized, "cyber-noir" imagery still emerged, with content such as "dark silhouetted figures in overcoats and fedoras against a red background".

Shires suggested that the "sophisticated cartoon style of graphic novels" and films like *Sin City* have perhaps influenced animations and illustrative representations of dangerous attackers. Shires referred to "Fancy Bear", the codename for a Russian attacker or attack group named by cybersecurity firm Crowdstrike. Fancy Bear appears to have glowing red eyes and a Soviet-style fur hat, he wrote. Shires introduced the term "cyber-noir" when talking about the "branding" he has observed in the cybersecurity industry:

Many emerging companies in the cybersecurity industry deliberately play on the popular perception of cybersecurity as a nether region, a gloomy underworld in which the good guys must resort to unconventional tactics to keep at bay a motley group of threats to the digital safety of unsuspecting individuals, businesses, and governments…These choices are part threat construction, part branding, and part knowing in-jokes, and they are selected just as often by the analysts themselves as they are chosen by marketing departments.

This paper suggests that concepts of folklore or the communication of folklore and even myth may also explain this kind of demonstrated influence or even manipulation of how attackers are characterized as threatening. Ben-Amos (2014) modelled efforts by young anthropologists in the early 1970s who began to grow the definition of folklore, beyond just "orality" or more traditional storytelling. Ben-Amos began characterizing folklore generally as something that is understood only when associated with a structured group of some kind and within a social context of some sort. "Folklore" is first understood in its relationship to and possession by a group of

people. This is just an abstraction for the purpose of using a methodology to examine the phenomena. Examining phenomena as folklore in its cultural context involves observing and characterizing a "communicative process" rather than just identifying an "aggregate of things".

If the cultural mode of communication is the key for definition, he wrote, then all these forms are but different phases within the observed characteristics of a group. Folklore is therefore communication of something that takes place between people. When viewed as a process, folklore can be considered as a form of interaction rather than just a marginal projection or reflection of other social phenomena. This has been called "living folklore" or even "growing folklore" by Soviet folklorists, observing an "ever-growing, changing, living thing". This appears to suggest Shires' characterization of the cybersecurity industry demonstrates this communication of folklore among people with shared interests. Ben-Amos (1971) proposed that folklore was "artistic communication in small groups" *in context*. Meaning again that if we are trying to understand the folklore we are observing, we cannot separate what is being communicated and why from the group of people communicating.

Much of the research literature exploring the difference between folklore and myth has generally characterized myth as something much more sacred. Blout (2017, 2023) has written extensively about the *myth of foreign conspiracy*, examining the narratives of Iranian leaders who propagate attempts by the West to undermine Iran. Many historians have defined myth from a similar perspective – that people can point to actual historical events but then *naturalize* those events and a new myth story with emotion. Suggesting to Iranian audiences a myth of foreign conspiracy such as 'the West wants to overthrow us' is part of a "myth-story" because of events like the 1950s coup attempt in Tehran. This "historical capital" can be represented in state narratives and personal worldviews. Kaser and Halpern (1998) wrote that we could also call this "symbolic capital" because this kind of myth making happens within particularized cultural frameworks. The perception of "sacredness" in a myth unlike some definitions of folklore is often found in narratives associated with the historic fate of a people or a nation. Kaser and Halpern emphasized that these repeated myths never exist in a neutral space, but rather national myths are defined in reference to others. The author suggests these "repeated myths" and communication of folklore happen in offensive and defensive spaces, such as operational squads and analytical units. He has experienced this communication firsthand. These are often "national myths" as well, when considering the branded threats of nation state attackers and cybercriminal attackers who have been or appear to be attacking American critical infrastructure and organizations.

3. Method: Simulation as an Instructional Strategy and a Process of Decision Making

Much of the research literature on cybersecurity education and training has increasingly explored the use of simulation, but primarily from the perspective of simulated cyber ranges and simulated network attack and defence scenarios (Tymoshchuk et al., 2024; Alnajim et al., 2023; Katsantonis et al., 2023; Chowdhury, Katsikas, and Gkioulos, 2021). This paper focuses on simulation as a method for guiding how students think through the creation of their fictional cyber attack group.

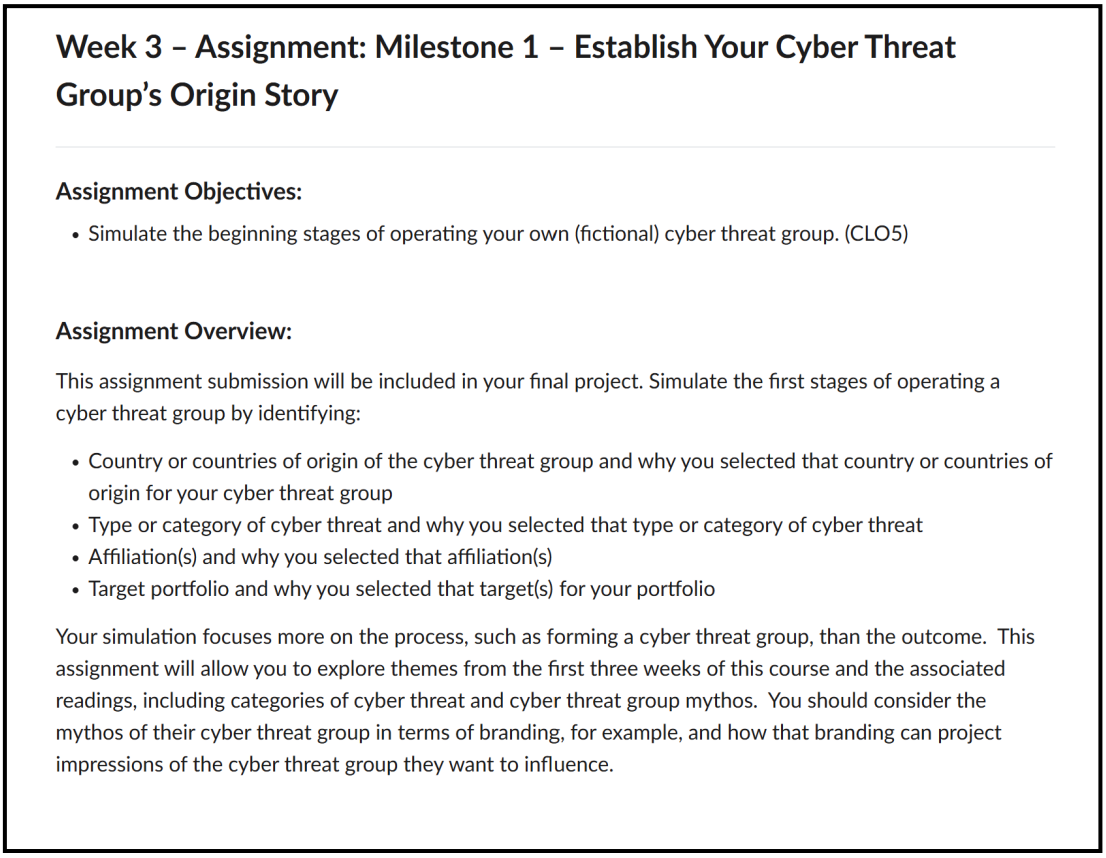
Taylor and Schneider (1989) defined simulation as a "cognitive construction of hypothetical scenarios", where someone thinks through or imagines usually in sequential stages or steps what they might do in a hypothetical or anticipated situation. People tend to think about anticipated events, like a rehearsal of what they think will happen and what they think they will do. Taylor and Schneider noted that simulation can be key for problem solving. Taylor and Schneider referred to Kahneman and Tversky's (1982) description of the heuristic simulation, where someone's availability bias can influence what they determine might be a solution or an approach to an anticipated event or interaction. Kahneman and Tversky characterized the simulation heuristic as a "shortcut" for making predictions or estimating probabilities or assessing causality. Simulations are not necessarily scripts, they wrote. A script is a schema that describes an expected sequence of events in a familiar situation, such as going to a movie or making coffee. Taylor and Schneider, however, wrote that a simulation could be characterized as a "dynamic representation" of a script, although not all simulations require a script. Simulation is a method of planning, rather than focusing on the outcome as most people do.

Unlike many instructional methods, simulation generally concentrates on how people function in a social environment (Jones and Barrett, 2017; Ouahi et al., 2021). Simulation can be adapted to a students' cognitive needs and abilities. Taylor et al. (1998) referred to a study that asked participating students to simulate the steps they would take to study for a future exam, finding that the students focused on the planning phases during their simulation exercises did somewhat better on the exam than students who focused on the outcome. Taylor et al. wrote about the planning fallacy, where people tend to underestimate the resources needed for projects

and overestimate how easily it can be done. Taylor et al. found in a similar study that participating students who simulated the number of hours needed to study for an exam also scored better on an exam than students who simulated the outcome only.

Scherb et al. (2023) resembled some of the approach of this paper, recognizing that users must experience some of the perspective of an attacker to better understand how an attacker might target their organization. Scherb et al. created a rudimentary cyberattack simulation or "serious game" that asked students to demonstrate the role of an attacker crafting phishing and spear phishing emails as if they were attacking their own organization. Students had to essentially simulate the process of researching an organization, finding what they believed might be vulnerabilities, and then crafting an email that may influence a target user to click on a link or respond behaviorally as the attacker intended. The researchers wanted this game or simulation to be as realistic as possible, so students were also required to find fake websites for phishing attacks and simulate the purchase of exploits on a fictional darknet market. In this simulation study, they found that there was marginal improvement in students' ability to understand and detect phishing or spear phishing attempts, in contrast to other user training methods that have generally been viewed as less effective.

The author organized this project so that students would complete assignments developing their fictional cyber attack group three times throughout the course, including in a final assignment where students were presented with several scenarios in which they had to visualize how their cyber attack group would respond. Students read the following objectives and overview for each phase of the assignment:



Week 3 – Assignment: Milestone 1 – Establish Your Cyber Threat Group's Origin Story

Assignment Objectives:

- Simulate the beginning stages of operating your own (fictional) cyber threat group. (CLO5)

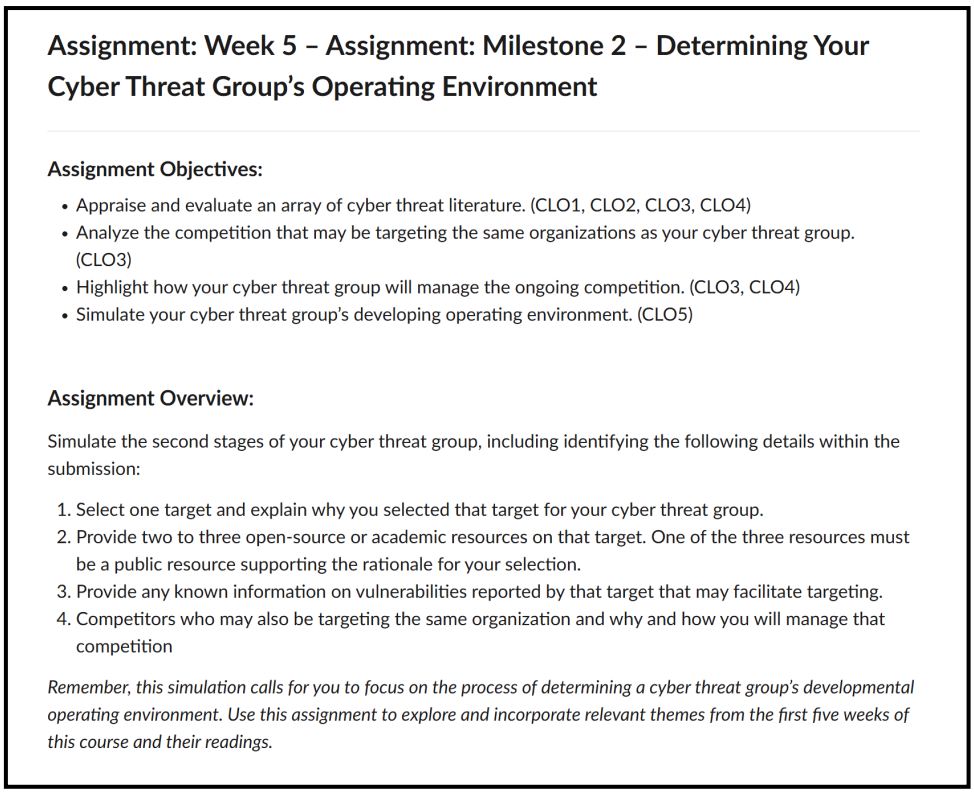
Assignment Overview:

This assignment submission will be included in your final project. Simulate the first stages of operating a cyber threat group by identifying:

- Country or countries of origin of the cyber threat group and why you selected that country or countries of origin for your cyber threat group
- Type or category of cyber threat and why you selected that type or category of cyber threat
- Affiliation(s) and why you selected that affiliation(s)
- Target portfolio and why you selected that target(s) for your portfolio

Your simulation focuses more on the process, such as forming a cyber threat group, than the outcome. This assignment will allow you to explore themes from the first three weeks of this course and the associated readings, including categories of cyber threat and cyber threat group mythos. You should consider the mythos of their cyber threat group in terms of branding, for example, and how that branding can project impressions of the cyber threat group they want to influence.

Figure 1: In week 3 of this course, the author assigned the first step in the students' project creating their own cyber attack group – establishing an origin story. The first two weeks of asynchronous online instruction included reading and writing assignments related to assessing their own impressions of cyber threat and how folklore and myth may have shaped perceptions of historical cyber attacks and cyber attack groups. The assignment overview provided some instruction on completing the first stages of creating a cyber threat group and additional background on simulation.



Assignment: Week 5 – Assignment: Milestone 2 – Determining Your Cyber Threat Group's Operating Environment

Assignment Objectives:

- Appraise and evaluate an array of cyber threat literature. (CLO1, CLO2, CLO3, CLO4)
- Analyze the competition that may be targeting the same organizations as your cyber threat group. (CLO3)
- Highlight how your cyber threat group will manage the ongoing competition. (CLO3, CLO4)
- Simulate your cyber threat group's developing operating environment. (CLO5)

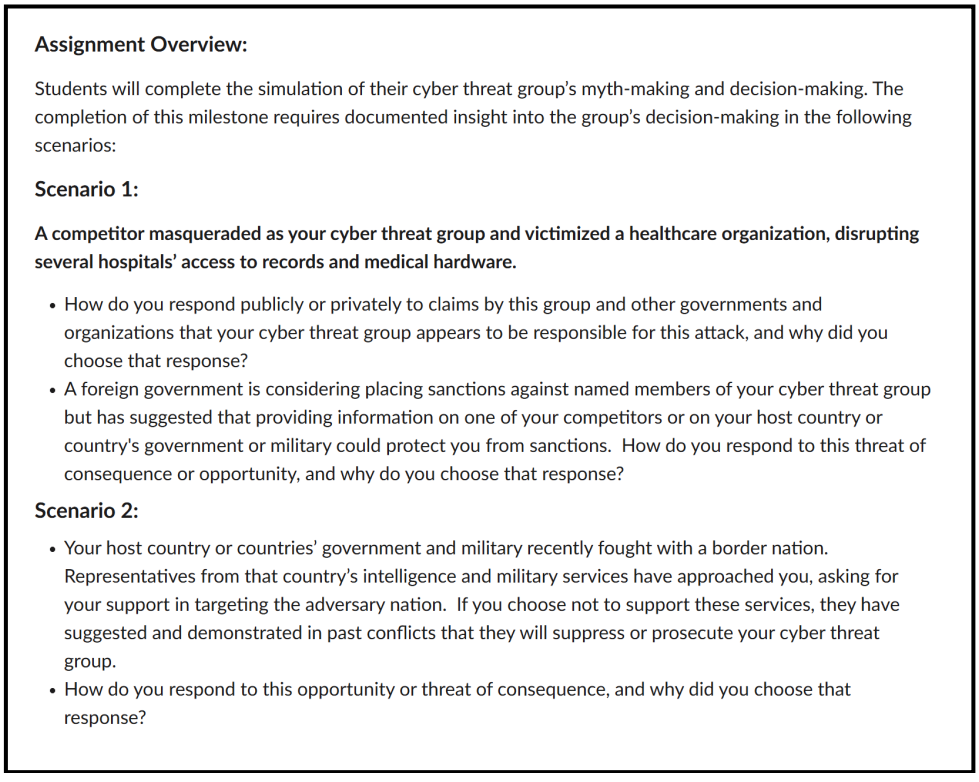
Assignment Overview:

Simulate the second stages of your cyber threat group, including identifying the following details within the submission:

1. Select one target and explain why you selected that target for your cyber threat group.
2. Provide two to three open-source or academic resources on that target. One of the three resources must be a public resource supporting the rationale for your selection.
3. Provide any known information on vulnerabilities reported by that target that may facilitate targeting.
4. Competitors who may also be targeting the same organization and why and how you will manage that competition

Remember, this simulation calls for you to focus on the process of determining a cyber threat group's developmental operating environment. Use this assignment to explore and incorporate relevant themes from the first five weeks of this course and their readings.

Figure 2: In week 5, the author asked students to continue developing their fictional cyber attack group. Students were asked to start creating a target portfolio for their cyber attack group and to provide analysis on the selection of those targets. This exercise was designed to help students think through the challenges and opportunities based on their cyber attack group's chosen operating environment.



Assignment Overview:

Students will complete the simulation of their cyber threat group's myth-making and decision-making. The completion of this milestone requires documented insight into the group's decision-making in the following scenarios:

Scenario 1:

A competitor masqueraded as your cyber threat group and victimized a healthcare organization, disrupting several hospitals' access to records and medical hardware.

- How do you respond publicly or privately to claims by this group and other governments and organizations that your cyber threat group appears to be responsible for this attack, and why did you choose that response?
- A foreign government is considering placing sanctions against named members of your cyber threat group but has suggested that providing information on one of your competitors or on your host country or country's government or military could protect you from sanctions. How do you respond to this threat of consequence or opportunity, and why do you choose that response?

Scenario 2:

- Your host country or countries' government and military recently fought with a border nation. Representatives from that country's intelligence and military services have approached you, asking for your support in targeting the adversary nation. If you choose not to support these services, they have suggested and demonstrated in past conflicts that they will suppress or prosecute your cyber threat group.
- How do you respond to this opportunity or threat of consequence, and why did you choose that response?

Figure 3: In week 8, the final week of the course, students were asked to complete the creation of their fictional cyber attack group by responding to various scenarios that should challenge their cyber attack group's decision making and "mythos".

The following section features samples from two students who completed this simulation.

4. A Simulation of Students' Fictional Cyber Attack Groups

4.1 Establishing Your Cyber Attack Group Origin Story and Target Portfolio

Student 1 named his fictional cyber attack group the "Nguyen Van Ly Alliance" (NVLA), basing his group in Vietnam. He characterized his group as a hacktivist group that formed in response to the growing political dissent online against the government's authoritarian practices. He wrote that the NVLA organized in opposition to the government to "disrupt government bodies from continuously harassing and arresting those who seek to vocalize their desire for a more free and accepting Vietnam".

Student 1 wrote that the NVLA will primarily utilize Distributed-Denial-of-Service (DDoS) attacks against the Vietnamese government, because of how accessible those tools or services are. The student referred to the "underground support" from other activists in Vietnam who oppose the government but want to remain largely private. When the NVLA can showcase local support, it gives the NVLA a "sense of legitimacy". The student also suggested the Vietnamese diaspora who do not support the government could also provide funding. Student 1 described the target portfolio of the NVLA, concentrating primarily on the Ministry of Public Security, because of that agency's state surveillance and censorship. Student 1 wrote that another target will include state-owned enterprises, such as the Vietnam Electricity (EVN) and Viettel Military Industry and Telecoms Group, because they appear to support the Ministry of Public Security in its efforts against Vietnamese communities advocating for human rights and free speech.

Student 1 referred to a real figure when discussing the "mythos" of the NVLA. He wrote that Thadeus Nguyen Van Ly was a Catholic Vietnamese priest who was imprisoned for more than 15 years because of his pro-democracy activism related to human rights. Student 1 wrote that his cyber attack group is named after Van Ly because Vietnamese people who are familiar with Van Ly's human rights activism "will be inspired by the name and actions of the group" in his name. He wrote that the Vietnamese government may also be troubled by a hacktivist group claiming to represent the name and movement of a human rights activist in Vietnam that has challenged the government.

Student 2 characterized his cyber attack group as a Russia-based group focused on ransomware and cyber espionage, operating mostly with cybercriminal gangs and some indirect Russian government support. Student 2 wrote that because of the "safe operational environment" in Russia, his group has more opportunity to recruit talented attackers and to be "ambitious" if his group's objectives appear to align with Moscow. Student 2 appeared to be much more instrumental in explaining his choice of affiliations and group origin; he emphasized more than once that his group is not directly supporting Moscow, but his group needs the safety of operating in Russia to accomplish its goals. He wrote that his group's targets would include critical infrastructure sectors, including healthcare and energy as well as technology and defence firms in Europe and in the United States. He wrote that this approach would "satisfy" his group's financial and strategic motivations. Student 2 explained that healthcare organizations are typically more vulnerable and more willing to pay ransoms to restore their access, and that data stolen from technology and defence firms is more valuable for resale or sharing, including to the Russian government. He wrote that this "careful planning and strategic alignment" would be essential for his cyber operations to be successful.

4.2 Managing Your Operational Environment and Competitors

Student 1 suggested that if the NVLA consistently targeted Vietnamese state telecommunications firms affiliated with security services, the result could be a reduction in customer satisfaction and a reduction in these state firms' revenue. One of these firms also develops weapons systems, so there is the possibility NVLA could disrupt revenue streams to those weapons projects. There is symbolic value in targeting these firms because of their surveillance in support of the government, but also because the government may suffer reputational damage as well if these attacks are publicized.

Student 1 wrote that his two main competitors would likely be China-sponsored cybercriminal collectives or groups and ransomware gangs. He suggested that because China has demonstrated interest in targeting government telecommunications organizations to collect data and enhance their surveillance of that target country and region, China may be targeting the same telecommunications firms in Vietnam. Student 1 suggested his group would avoid "clashing" in any cyber attacks with a China-affiliated cyber attack group but could instead

"piggyback" off any known attack to expose vulnerabilities further. Student 1 recognized that although observers could conclude that NVLA's threat activity was also the same China-affiliated attackers and there would be less suspicion of NVLA by Vietnamese authorities, the public may also assume China was responsible. That affiliation "would impact [NVLA's] mythos in that the public and their target would not effectively receive the NVLA's message of freedom for the Vietnamese public".

Student 2 wrote that he anticipated several rivals when targeting western Europe's energy infrastructure. He wrote that "maintaining flexible operational strategies" could help minimize detection and conflict with competing attackers, including by coordinating with Moscow to gain advantage. While student 2 did not write as much about the folklore or myth of his fictional cyber attack group, he did appear to recognize the folklore and myth of Russian targeting of western European infrastructure and how those disruptions can "create political pressure, influence policy decisions, or sow discord" among allied countries in that region. Student 2 wrote that if his attack group could cause these kinds of disruptions, "they could effectively weaken the collective resilience" of those allied countries and build support for his group from Moscow.

4.3 Cyber Attack Group Decision Making in Various Scenarios

The first scenario for the final phase of Student 1's simulated cyber attack group involved an unknown competitor masquerading as the NVLA while victimizing a Vietnamese healthcare organization. Student 1 wrote that the NVLA would publicly deny responsibility for the attack, noting that targeting a Vietnamese healthcare organization contradicts the NVLA mission. The first scenario also stated that a foreign government suggested it was considering placing sanctions on the NVLA unless the NVLA provided evidence they were not involved in the attack or that someone else was responsible. Student 1 wrote that agreeing to find evidence would provide an "opportunity for ideological progress to gain international awareness and support", much like Anonymous in the past has improved the collective's reputation after assisting in campaigns against dark web sites hosting explicit content, such as images of child sexual abuse. The second scenario involved a recent border conflict between Vietnam and another country. Vietnamese intelligence and military services approached NVLA representatives asking for cyber attack support against the other country involved in the border conflict. Vietnamese services told NVLA they will prosecute or suppress NVLA if the NVLA does not assist them. Student 1 wrote that the NVLA would provide "limited and indirect assistance" because part of their mission includes protecting the freedoms of the Vietnamese people, which would perhaps be disrupted or restricted if a war resulted from this border conflict. The NVLA would attempt to limit any direct cooperation with the Vietnamese government to "retain their ideological integrity to balance their operational goals with public perception within Vietnam".

Student 2 framed the response of his fictional cyber attack group to similar allegations related to an attack on a healthcare organization by detailing a public response and a private response. He wrote that his group would deny involvement and then voluntarily provide material evidence such as time-stamped logs and other operational records that appeared to demonstrate the group was inactive during the timing of the alleged attack. His group would also offer publicly to collaborate with law enforcement. Student 2 wrote that if he could identify the attack group masquerading as his cyber attack group, there may be options for retaliation, such as materially revealing their involvement or exposing their operational infrastructure. He suggested that this approach could discourage future groups from masquerading as them in an attack. Student 2 wrote that in the second scenario, cooperation with Russia would be the only option and that cooperation may strengthen his group's position within Russia's "cyber and geopolitical ecosystem, opening opportunities for resources, intelligence, and operational support". Ultimately, he wrote, the most immediate concern in this scenario is "ensuring the survival of the cyber threat group". Student 2 referenced the enhanced access to tools and information sharing that could result from that support, but much of this decision appeared to benefit the folklore and myth of Russia's attack capabilities and targeting interests and objectives in western Europe, more so than the student's cyber attack group.

5. Limitations and Discussion

The sample of simulated cyber attack groups derived from this graduate course is small. As such, the author considers this working paper to be exploratory because of that limited sample size.

The author could have provided additional instruction in this series of assignments throughout the course, to provide additional commentary on the folklore and myth of their cyber attack group. The author chose not to, so that these students would naturally simulate their fictional cyber attack group.

Student 1 wrote in his conclusion in the final phase of his project that the need for NVLA to blend "ideological purpose with adaptive tactics to persevere" is important especially as global cyber conflicts grow more complicated. Student 2 also appeared to suggest in several of his assignments that there were instrumental motivations for supporting Moscow and targeting similar infrastructure to preserve and grow his attack group. The author would argue these nuanced motivations are rare when compared to much of the commentary on motivations of cybercriminals and cyber attackers who appear to be aligned with nation state enterprises. When there is limited insight into the attribution or affiliation of cyber attackers or cyber attack groups that appear to resemble or be aligned with the interests of a nation state attack enterprise, there often appears to be suggestions of collusion with or support to that nation state enterprise. While that is sometimes the case, both students found that their own cyber attack group objectives only appeared to align with or support the government whenever there was some coercion or some anticipated loss if they did not support them. These kinds of nuances in cyber threat intelligence can significantly impact the analysis of threat and motivation.

Ethics Declaration

Ethics clearance was not required for this research. The author did obtain written permission from both students to sample some of their work in this paper.

AI Declaration

AI tools were not used in the creation of this paper.

References

Alnajim, A.M., Habib, S., Islam, M., AlRawashdeh, H.S. and Wasim, M., 2023. Exploring cybersecurity education and training techniques: a comprehensive review of traditional, virtual reality, and augmented reality approaches. *Symmetry*, *15*(12), p.2175.

Ben-Amos, D., 1971. Toward a definition of folklore in context. *The Journal of American Folklore*, *84*(331), pp.3-15.

Ben-Amos, D., 2014. A definition of folklore: A personal narrative. *Estudis de Literatura Oral Popular/Studies in Oral Folk Literature*, (3), pp.9-28.

Ben Ouahi, M., Lamri, D., Hassouni, T. and Al Ibrahmi, E.M., 2022. Science Teachers' Views on the Use and Effectiveness of Interactive Simulations in Science Teaching and Learning. *International journal of instruction*, *15*(1), pp.277-292.

Blout, E.L., 2017. Soft war: Myth, nationalism, and media in Iran. *The Communication Review*, *20*(3), pp.212-224.

Blout, E.L., 2023. Media and Power in Modern Iran.

Chowdhury, N., Katsikas, S. and Gkioulos, V., 2022. Modeling effective cybersecurity training frameworks: A delphi method-based study. *Computers & Security*, *113*, p.102551.

Groš, S., 2021. Myths and misconceptions about attackers and attacks. *arXiv preprint arXiv:2106.05702*.

Jones, J.D. and Barrett, C.E., 2017. Simulation as a Classroom Teaching Method. *Journal on School Educational Technology*, *12*(4), pp.49-53.

Kaser, K. and Halpern, J.M., 1998. Historical myth and the invention of political folklore in contemporary Serbia. *Anthropology of East Europe Review*, *16*(1), pp.89-107.

Katsantonis, M.N., Manikas, A., Mavridis, I. and Gritzalis, D., 2023. Cyber range design framework for cyber security education and training. *International Journal of Information Security*, *22*(4), pp.1005-1027.

Scherb, C., Heitz, L.B., Grimberg, F., Grieder, H. and Maurer, M., 2023. A cyber attack simulation for teaching cybersecurity. *EPiC Series in Computing*, *93*, pp.129-140.

Shires, J., 2020. Cyber-noir: Cybersecurity and popular culture. *Contemporary Security Policy*, *41*(1), pp.82-107.

Smith, M.W., 1959. The importance of folklore studies to anthropology. *Folklore*, *70*(1), pp.300-312.

Talbot, E.B., Frincke, D. and Bishop, M., 2010. Demythifying cybersecurity. *IEEE Security & Privacy*, *8*(3), pp.56-59.

Taylor, S.E. and Schneider, S.K., 1989. Coping and the simulation of events. *Social cognition*, *7*(2), pp.174-194.

Tymoshchuk, D., Yatskiv, V., Tymoshchuk, V. and Yatskiv, N., 2024. Interactive cybersecurity training system based on simulation environments. *arXiv preprint arXiv:2501.00186*.

Viganò, L., 2024. The cybersecurity of fairy tales. *Journal of Cybersecurity*, *10*(1), p.tyae005.

Work in Progress Papers

Simulation of Postpartum Hemorrhage Maneuvers Using an Educational Biomodel for Low-income Countries

Israel Garnica-Bohórquez, Clara Isabel López-Gualdrón, Adriana Inés González-Quitían, Jesús Alexis Machuca Gelvez, Silvia Isabel Gómez-Gualdrón and Luis Eduardo Bautista Rojas
Universidad Industrial de Santander, Bucaramanga, Colombia

igarnibo@uis.edu.co
clalogu@uis.edu.co
silvia2192343@correo.uis.edu.co
adrigonz@uis.edu.co

Abstract: A key challenge in clinical teaching is to create alternative environments due to restricted access to rare emergency practice settings, such as postpartum hemorrhage (PPH). Similarly, difficulties have emerged not only in representing biomodels but also in ensuring maneuver performance, considering components and their ability to replicate sensations akin to those felt by the affected tissues. A research initiative was launched to improve the training of healthcare personnel in low-level care facilities and educational institutions on the management of PPH, given that it remains a significant cause of maternal mortality globally. Consequently, doctors must develop proficiency in handling such emergencies. Hence, the research was conducted to create solutions tailored to local resources, minimizing the reliance on external technology through a collaborative approach between medicine and industrial design. The investigators focus on creating experiences and perceptions through three key components: first, aligning student skills and situations with emergency protocols and the medical curriculum; second, incorporating convergence technologies for emergency procedures; and third, employing a phantom model of a female body segment to facilitate maneuvers related to PPH, named 4T (tone, tissue, trauma, and thrombin). Methodological research conducted in the early stages of creating an intermediate-fidelity clinical simulator highlights the importance of input from a multidisciplinary team. Initially, the review of the literature identified various materials and feasible biomodels suitable for training exercises. Subsequently, the authors outlined the essential requirements for the physical element. Following this, they developed biomodels that integrate diverse shapes and materials to replicate the conditions encountered in obstetric interventions. Employing an iterative approach in conjunction with digital and hybrid manufacturing technologies from our institutional laboratories, the prototype was refined to mimic material perceptions. The next study phase will explore whether the model can enhance teaching and learning in various applications. Due to the high cost of detailed anatomical models, the research proposes an affordable, mid-level fidelity biomodel using digital manufacturing with elastomeric materials. However, our PPH biomodel needs to be improved for testing with medical students at the Universidad Industrial de Santander, to validate their skills safely.

Keywords. Postpartum Hemorrhage, Clinical Simulation-based Education, Additive Manufacturing, Biomodel.

1. Introduction

Simulation-based medical education (SBME) is critical for safe and effective training in obstetric emergencies, where error-free practice is essential (Carriel & Ramírez, 2011). In low and middle-income countries, PPH accounts for up to 19.7% of maternal deaths (López-García *et al.*, 2017; Montañez *et al.*, 2022). Although codes like Colombia's "código rojo" systematize response (Navarro & Castillo, 2010), hands-on training remains limited by resource constraints.

Commercial simulators (e.g., SimMom by Laerdal®, Noelle by Gaumard®) are costly and complex to maintain (Riaz, 2019). Low-cost creative models using animal tissues, fruit, or textiles improve affordability but fall short in realism, hygiene, repeatability, or anatomical accuracy (Lunardhi *et al.*, 2024; Ramseyer & Lutgendorf, 2019; Knobel *et al.*, 2020). In clinical practice at the UIS, mannequin elastomeric components degrade easily, and textile substitutes fail to emulate tissue properties effectively.

To address these limitations, this study develops a conceptual framework to improve the training of healthcare based on aligning student skills and situations with emergency protocols and updating the medical curriculum; second, incorporating convergence technologies for emergency procedures; and third, employing a modular biomodel built with an accessible digital and hybrid manufacturing approach. The model aims to simulate tactile responses of human tissues, enable repeatable maneuvers aligned with the 4Ts (tone, trauma, tissue, thrombin), and support teaching in resource-limited educational settings, thereby enhancing preparedness in obstetric emergencies.

2. Methodology

An interdisciplinary team from design and medicine at UIS applied Design Thinking across five phases (Liedtka, 2015):

2.1 Phase 1: Empathize

Researchers observed simulation-based training sessions and conducted semi-structured interviews with medical students and health professionals (e.g., poor tactile realism and component fragility). In this phase, the researchers could recognize types of models for training simulation practices at the faculty, identifying deficiencies in existing models.

2.2 Phase 2: Define

A systematic review using the PRISMA guidelines on WoS and Scopus identified 353 articles (45 selected) on low-cost clinical simulators utilizing digital or elastomeric technologies, none of which specifically targeted PPH. CES EduPack-guided material selection compared tissue-like properties: human skin, muscle, and bone tensile strength and elasticity informed choices (Ashby, 2008). Anthropometric measures for anatomical realism were sourced (Clerico *et al.*, 2017; Kreklau *et al.*, 2018). PPH response protocols guided functional requirements (Fescina *et al.*, 2012; FIGO, 2022).

2.3 Phase 3: Ideate

According to the last phases, we develop a conceptual map based on the integration of products into the learning experience. Then CAD models were configured, representing the organs of the reproductive system, such as the components. The approach of this research included digital design for manufacturing CAD RP technologies, integrating molds of polymeric materials. In fact, in parallel, the experiment with elastomeric materials like latex and silicon was made.

2.4 Phase 4: Prototype

Using Rhinoceros®, prototypes were CAD-modeled and fabricated at I+3DLAB using FDM (ABS/TPU), SLA, and SLS machines (Molitch-Hou, 2018). Elastomeric material trials included alginate-gelatin composites, natural latex, Ecoflex 00-30 silicone, and reinforced screws for modular assembly. Material properties (σ_{ts} and %ε) matched tissue ranges for skin, muscle, and bone (Ashby, 2008): latex (0.5–3.5 KSI, 700–750 %), Ecoflex (0.2 KSI, 900 %), elastic 80A resin (1.291 KSI, 100–120 %), TPU (1.41 KSI, 327 %).

2.5 Phase 5: Evaluate

While full validation is pending, early iterations underwent informal clinical simulation feedback to assess realism, assembly, and tactile response.

3. Results

Observations revealed low-fidelity assemblages; we found that textile vulvas and uteruses allowed only generic maneuvers, suffered tears, lacked penetration resistance, and failed to mimic tone. Fiberglass torsos improved portability but compromised anatomical detail. Figure 1 shows the different models used to make the practice for PPH. On the left, a high-resolution mannequin combined with a low-resolution model made of fabric with low tactile and anatomical fidelity, adapted to represent the vagina and vaginal canal; on the right, it is a simulation-based training session with a medium and low-resolution mannequin made of fiberglass, involved with a dress to simulate the skin. The current models have low anatomical, tactile, and dimensional fidelity.



Figure 1: Examples of mannequin models for PPH practices are used in medicine.

Literature review confirmed scarcity of PPH-specific low-cost models, though other specialties used FDM plus silicone (Comeau *et al.*, 2020), hybrid manufacturing (Gillis *et al.*, 2020). Material criteria were quantitatively aligned with human tissue benchmarks; analogues were selected successfully with CES Edupack®. The material selection criteria (Ashby, 2008) were made, see Figure 2. Among the properties consulted to select tissues similar to muscles, in relation to the which is the ratio between the tensile capacity tensile strength (σ_{ts}) and the degree of stretching percentage of elongation (%ε) before breaking (σ_{ts} / %ε). Human skin has been emulated with silicone, while muscle has a represented with polyurethane or polyethylene foams. The manufacturing of polymers was shaped by moulding to catalytic mixtures, temperature control, or vacuum. As for human bone, it is emulated with similar polymeric filament materials such as PLA, ABS, and PEEK to be printed in FDM.

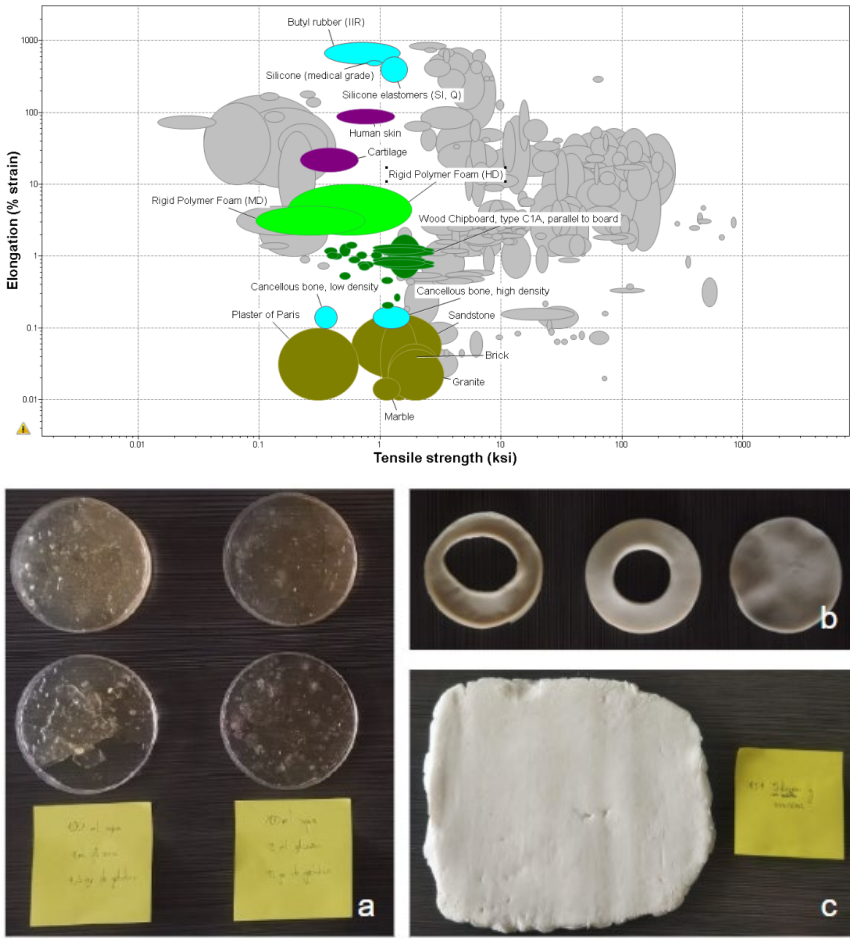


Figure 2: Preselection material by CES Edupack analysis and materials testing.

3.1 Development of the Biomodel

Develop a conceptual map based on the integration of products into the learning experience, composed of three moments configured with the key moments of the simulation strategy. 1-Prebriefing, involving the introduction and orientation before the simulation experience. 2-Briefing is a relevant scenario information just before the scenario begins. 3. Debriefing represented post-simulation analysis and post-simulation dialogue. The framework integrates two moments: The first one is a low-medium fidelity scenario, including a Hybrid Simulation configured with a Patient mannequin/simulator, a biomodel, and an Extended Reality Virtual and Augmented. The second one, high fidelity scenario, conformed to Product Hybrid Simulation by Patient mannequin/simulator biomodel.

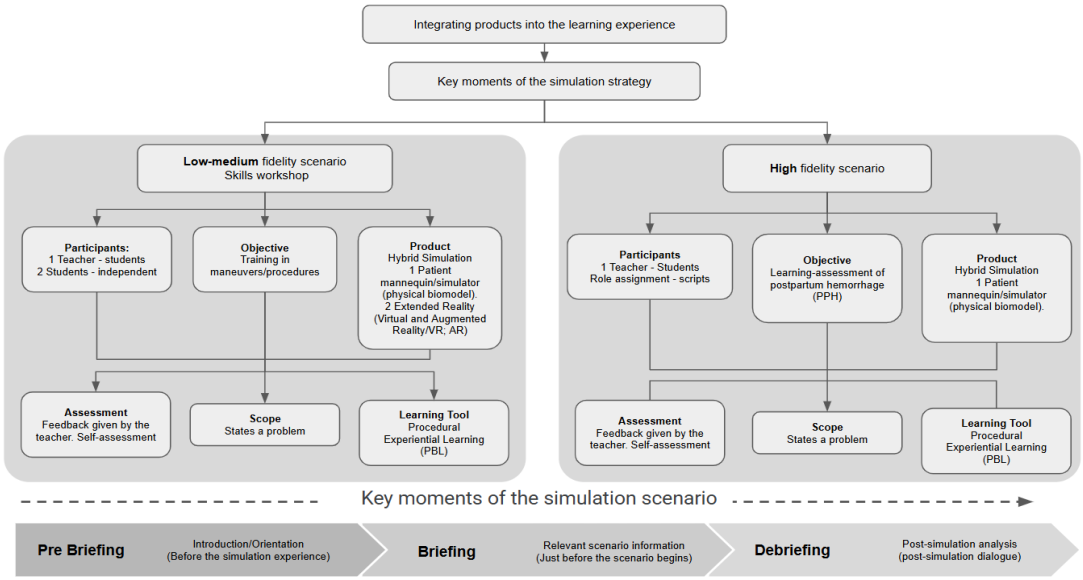


Figure 3: A framework of learning experience developed for teaching-based simulation.

Considering the process of design through the insights, CAD models of the reproductive system, such as the vagina and their canal, the cervix, and the uterus, were modeled. These design components featured a rigid PLA body with flexible elastomeric. CAD-printed rigid torso with layered latex overlays achieved realistic tactile behavior and modularity. Repeated maneuvers were feasible, with user feedback citing improved realism and durability over handcrafted versions durability see Figure 4.

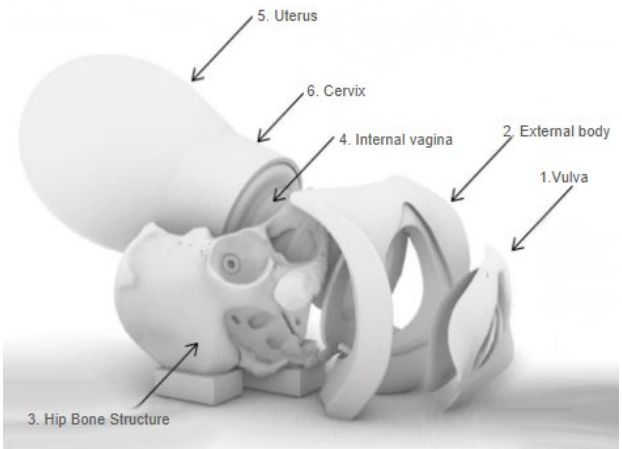




Figure 4: CAD and 3D printed model components, biomodels.

The material tests showed that alginate materials lacked stability. Natural latex and Ecoflex offered superior elasticity. Silicone molding introduced air bubbles and curing issues. ABS and TPU provided structural support.

Finally, early iterations by students in a clinical simulation scenario were made, and the feedback was oriented to assess realism perception by interaction, assembly, and tactile response, see figure 5.



Figure 5: First iteration of testing biomoldel.

4. Discussion and Conclusion

This biomodel offers several advantages over low-cost artisan models: according to the initial feedback in testing, it provides more realistic tactile simulation, modular replaceability, and durability, all created with accessible materials and institutional manufacturing capabilities. Compared to commercial simulators, it is cost-effective and adaptable, making it ideal for low-resource contexts.

Material selection grounded and manufacturing synergies between additive and elastomeric molding (Goudie *et al.*, 2019; Koh *et al.*, 2021) demonstrated feasibility for complex, anatomically coherent models. The modular design supports simulation of the 4Ts sequence (Fescina *et al.*, 2012) with tailored replacement options, advancing over handcrafted or static designs.

Limitations include challenges in achieving homogeneous elastomer curing and mold integrity, and the absence of formal validation data. Future research must involve controlled trials comparing skill acquisition outcomes between this biomodel and commercial simulators, and explore sensor integration for objective feedback.

In conclusion, the proposed modular biomodel presents a **suitable**, **scalable**, and **contextually adapted** tool for PPH training. By leveraging digital manufacturing and material science aligned with user-driven design, it addresses limitations in existing educational tools and supports enhanced competency development in maternal emergency care.

Ethics Declaration

Ethical clearance was not required for this study, as no patient data or vulnerable populations were involved.

AI Declaration

AI tools were not used in the creation of this manuscript.

References

Ashby, M.F. (2008) *Materials selection in mechanical design*. 3rd edn. Oxford: Butterworth-Heinemann.

Carriel, J.A. & Ramírez, G.O. (2011) 'Simulation practices in medicine: advantages, limitations, historical account and Ecuadorian perspective', *Rev. Med. FCM-UCSG*, 17, pp. 285–291.

Clerico, C. *et al.* (2017) 'Anatomy and Aesthetics of the Labia Minora: The Ideal Vulva?', *Aesthetic Plastic Surgery*, 41, pp. 714–719.

Comeau, M., Goudie, C., Murphy, D., Fowler, E. & Dubrowski, A. (2020) 'The use of silicone vaginal repair models as an adjunct to mannequins for simulation training in sexual assault clinical learning…', *Cureus*, 12(3).

Fescina, R., Ortiz, E.I. & Jarquin, D. (2012) *Guías para la atención de las principales emergencias obstétricas*. CLAP/SMR, OPS/OMS.

FIGO (2022) 'FIGO Generic Postpartum Haemorrhage Protocol and Care Pathways'.

Goudie, C. *et al.* (2019) 'The use of 3D printed vasculature for simulation-based medical education…', *Cureus*, 11(4).

Koh, J.C. *et al.* (2021) 'Creation of a three-dimensional printed spine model for training in pain procedures', *Journal of International Medical Research*, 49(11).

Knobel, R., Menezes, M.D.O., Santos, D.D.S. & Takemoto, M.L.S. (2020) 'Planning, construction and use of handmade simulators…', *Revista Latino-Americana de Enfermagem*, 28, e3302.

Liedtka, J. (2015) 'Perspective: Linking design thinking with innovation outcomes…', *Journal of Product Innovation Management*, 32(6), pp. 925–938.

López-García, L.F. *et al.* (2017) 'Incidence of postpartum hemorrhage…', *Revista Colombiana de Obstetricia y Ginecología*, 68(3), pp. 218–227.

Lunardhi, A., Stohl, H.E., Betson, L. & Saad, C. (2024) 'Low-cost, durable sheepskin uterine model…', *American Journal of Perinatology*, 41(S01), e3003–e3007.

Molitch-Hou, M. (2018) 'Overview of additive manufacturing process', in *Additive Manufacturing*, Butterworth-Heinemann, pp. 1–38.

Montañez, R.A.C. *et al.* (2022) 'Postpartum hemorrhage: Nursing interventions…', *Revista Cuidarte*, 13(1).

Navarro, J.R. & Castillo, V.P. (2010) 'Código rojo, un ejemplo de sistema de respuesta rápida', *Colombian Journal of Anestesiology*, 38(1), pp. 86–99.

Riaz, S. (2019) 'How simulation-based medical education can be started in low resource settings', *Journal of Ayub Medical College Abbottabad*, 31(4), pp. 636–637.

Education for Sustainable Development through Maker Education: Visions, Concepts And Experiences

Diana Pereira[1]; Cristina Sylla[1]; Ute Massler[2]; Fabian Pettig[3]; Holger Weitzel[2]; Claudia Bergmüller-Hauptmann[2]; Kerstin Hansson[4]; Moritz Wagner[2]; Philipp Wilfinger[3]; Sandra Palhares[1], Orlanda Tavares[1] and Eva Fernandes[1]

[1] Research Centre on Child Studies, Institute of Education, University of Minho, Braga, Portugal
[2]University of Education Weingarten; Weingarten, Germany
[3] Institut für Geographie und Raumforschung, University of Graz, Graz, Austria
[4]Linneus University, Smaland, Sweeden

cristina.sylla@ie.uminho.pt; dianapereira@ie.uminho.pt; sandrapalhares@ie.uminho.pt; orlandatavares@ie.uminho.pt; evalopesfernandes@ie.uminho.pt; massler@ph-weingarten.de; weitzel@ph-weingarten.de; bergmueller-hauptmann@ph-weingarten.de; moritz.wagner@ph-weingarten.de; fabian.pettig@uni-graz.at; philipp.wilfinger@uni-graz.at; kerstin.hansson@lnu.se

Abstract: This paper presents first results from an European Erasmus+ project that integrates ecological Making with interdisciplinary, CLIL-based STEAM education to address eco-anxiety and empower students to participate in negotiating livable futures for all. Drawing on Education for Sustainable Development (ESD), Maker Education, and Content and Language Integrated Learning (CLIL), the project fosters transformative, intercultural learning environments. Using Mobile Maker Boxes (MMBs), students and teachers engage in hands-on problem-solving around sustainability challenges. This paper outlines the project's aims, theoretical framework, methodology, and early insights from an international co-design workshop involving teachers and researchers from five countries. The findings suggest that interdisciplinary, collaborative making—whether physical, digital, or conceptual—enhances student agency, emotional engagement, foreign language and intercultural competence, and Futures Literacy. A Design-Based Research (DBR) methodology supports iterative development, preparing the project for classroom implementation.

Keywords: Ecological Making; Intercultural Cooperation; STEAM Education; CLIL; Education for Sustainable Development (ESD); Maker Education; Futures Literacy.

1. Introduction

Today's youth face a growing sense of disempowerment in the face of complex global crises, particularly climate change, which is increasingly linked to eco-anxiety (Hickman et al., 2021). Traditional education systems often emphasize cognitive knowledge acquisition over emotional engagement, failing to inspire the critical and affective capabilities needed for transformative societal change (Ulmanen et al., 2016).

The EMIC-STEAM project responds to this gap through a novel pedagogical framework that integrates Education for Sustainable Development (ESD), interdisciplinary Maker Education, and Content and Language Integrated Learning (CLIL) to foster interdisciplinary, intercultural, and emotionally resonant learning in grades 7 to 10. Thus, students elaborate creative projects on social-ecological challenges in Mobile Interdisciplinary Maker Boxes (MMB) and discuss their ideas in international cooperations. Thus, they develop Futures Literacy as well as intercultural and foreign language competence. The project particularly targets girls, who statistically show greater environmental concern but remain underrepresented in STEM pathways (Benavent et al., 2020; So et al., 2022). A central tool in this endeavor are the MMBs: thematic, portable kits enabling schools to implement ecological Making projects, even with limited resources.

The present paper aims to: (i) Articulate the theoretical and methodological foundations of EMIC-STEAM; (ii) present early findings from a transnational co-design workshop carried out with researchers and teachers; (iii) demonstrate how interdisciplinary, CLIL-enhanced Maker Education can address both cognitive and affective learning outcomes related to sustainability.

The short-paper is structured as follows: Section 2 describes the workshop design and pedagogical innovation; Section 3 discusses national adaptations and Making practices; Section 4 explores broader implications; Section 5 concludes with next steps and future directions.

2. Theoretical Framework

This study draws from four main strands of educational approaches:

- Education for Sustainable Development (ESD): Emphasizes the cultivation of transformative capabilities—critical thinking, anticipatory capacity, and agency—in addressing real-world problems (e.g. Pettig & Ohl, 2023).
- Maker Education: Positions students as creators rather than consumers, combining hands-on engagement with problem-solving and digital literacy (Martin, 2015). Ecological making, a core focus of this project, adds sustainability as a pedagogical priority.
- CLIL (Content and Language Integrated Learning): Supports simultaneous acquisition of subject knowledge and foreign language skills, enabling students to communicate solutions in international settings (Coyle et al., 2010, Wunderlich, 2023), as well as reflecting on the cultural situadedness of problem definitions and solution finding.
- Futures Literacy: Encourages learners to explore and imagine alternative futures, thus empowering them to act meaningfully in the present (Miller, 2018).

Together, these frameworks inform an approach that is interdisciplinary, multilingual, culturally sensitive, and grounded in real-world relevance.

3. Methodology

The project employs a Design-Based Research (DBR) methodology (Barab & Squire, 2004; McKenney & Reeves, 2021). DBR supports iterative co-creation between researchers, teachers, and students. It allows for continuous reflection and refinement across multiple cycles of design, implementation, and evaluation. Data collection methods include: Observations and field notes from the design workshop; Teacher reflections; Prototypes and documentation created during and after the workshop.

A total of five countries—Germany, Austria, Sweden, Portugal, and Luxembourg—are involved, each represented by interdisciplinary teams from universities and schools. The diversity of these contexts enriches both the design process and the analysis.

4. Design Workshop and Pedagogical Innovation

The EMIC STEAM teaching design is developed in close collaboration between researchers and teachers in accordance with the DBR approach. Thus, a key milestone was an international design workshop that brought together teachers and researchers from all partner countries. The focus of the workshop was to present first design steps to the teachers, initial design concepts for the Mobile Maker Box and suitable topics had already been discussed with the teachers in the first six months of the project and developed into a comprehensive design based on their feedback.



Figure 1: Participant choosing materials for the Making activity; Participant showcasing a handbag prototype (left).

At the project meeting, the teachers worked with the MMB FAST FASHION and reflected on its suitability for their school contexts from a student and teacher perspective as part of question-led feedback discussions. The focal theme FAST FASHION was chosen for its global relevance and accessibility for learners. The workshop

comprised of three phases: (i) Introduction (awareness and contextualization); (ii) Making (design and prototyping), and (iii) Discussion (presentation and reflection) (Figure 1).

Participants engaged in a two-part Maker challenge:

- Analog Phase: Teams designed and built handbags from discarded materials. These were not only functional but metaphorical—sparking reflection on consumer culture and environmental impact (Figure 1 and 2).
- Digital Phase: Participants used TinkerCAD to conceptualize digital prototypes, thereby integrating coding, electronics, and 3D design with sustainability learning.



Figure 2: Participants working in groups (left); and discussing the Making pedagogical approach.

5. National Adaptations and Making Practices

During the final session, country teams translated the workshop experience into context-specific educational applications:

- Austria: Emphasized combining student-led and teacher-guided explorations, proposing hands-on activities like natural dyeing, clothing swaps, and podcast production.
- Portugal: Focused on personal consumption habits. Students would trace the life cycle of their own clothes, culminating in upcycled fashion shows and social media campaigns.
- Germany: Proposed a 10-hour Making phase featuring mobile apps. Emotional and reflective elements were prioritized to deepen engagement.
- Luxembourg: Suggested linking fashion to broader consumer habits. Ideas included art installations and redesigned school uniforms.
- Sweden: Planned a pilot project for ages 12-14 centered on jeans. It would include blog writing, video production, and cross-border dialogue in English via CLIL.

These diverse approaches highlighted the flexibility of the MMB model and its resonance across pedagogical and cultural contexts (Figure 3).



Figure 3: Participants discussing possible teaching approaches.

6. Emotional and Reflective Engagement

Emotional engagement emerged as a critical driver of student motivation and deeper learning. Participants reflected on how the tactile nature of making activities—combined with real-world relevance—elicited empathy, responsibility, and solidarity.

Reflective tools such as journals, exhibitions, and peer discussions were proposed to further scaffold emotional learning. Teachers noted that addressing sustainability requires more than facts—it requires affective investment, which our approach of ecological Making can facilitate by connecting the personal to the planetary.

The international and collaborative nature of the meeting also fostered intercultural competence and solidarity among educators, further strengthening the ESD foundation of the project. Discussions surfaced new thematic directions for future MMB development, including climate change, gender equality, media literacy, digital well-being, and post-COVID realities.

7. Implications for Practice

The workshop revealed several insights:

- Interdisciplinary Flexibility: Making activities can integrate arts, sciences, and humanities while promoting both conceptual and practical knowledge.
- Language Learning through Purposeful Use: Using English to discuss real sustainability challenges gave authentic purpose to language learning.
- Infrastructure and Support: MMBs enable even under-resourced schools to adopt Maker Education. However, logistical planning (e.g., dedicated time, access to materials) remains a key implementation challenge.
- International Dialogue: Teachers appreciated the value of international co-creation. It expanded their own perspectives and highlighted how intercultural learning can be embedded into sustainability education.

8. Conclusion and Future Directions

The EMIC-STEAM project demonstrates how CLIL-infused, interdisciplinary Maker Education can help reimagine education for sustainable development. The co-design workshop validated the project's pedagogical approach and highlighted the power of emotional and reflective engagement in learning.

Next steps include:

- Piloting MMBs in classrooms across partner countries.
- Collecting empirical data on student learning outcomes.
- Refining materials and strategies for broader dissemination.

- Developing an online platform for cross-cultural student collaboration.

Our interdisciplinary approach of ecological Maker Education with a focus on sustainability-related challenges is already proving to be a promising way to inspire young people to find ways forward in light of global challenges by enabling hopeful, holistic and hands-on learning processes.

AI Declaration

AI tools were used to correct language issues

Ethics Declaration

Ethical clearance was not required for the research activities described.

References

Albert, M., Hurrelmann, K., Quenzel, G., Schneekloth, U., Leven, I., Utzmann, H. and Wolfert, S., 2019. *Jugend 2019. Eine Generation meldet sich zu Wort*. Weinheim: Beltz.

Barab, S. and Squire, K., 2004. Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences*, 13(1), pp.1–14.

Benavent, X., De Ves, E., Forte, A., Botella-Mascarell, C., López-Iñesta, E., Rueda, S., Roger, S., Perez, J., Portalés, C., Dura, E., Garcia-Costa, D., & Marzal, P. (2020). Girls4STEM: Gender Diversity in STEM for a Sustainable Future. Sustainability, 12(15), 6051. https://doi.org/10.3390/su12156051

Coyle, D., Hood, P., & Marsh, D. (2010). *CLIL: Content and Language Integrated Learning*. Cambridge University Press.

Faulstich-Wieland, H., 2008. Lernen Mädchen und Jungen anders? Befunde und praktische Konsequenzen. In: R. Lehberger and U. Sandfuchs, eds. *Schüler fallen auf. Hetereogene Lerngruppen in Schule und Unterricht*. Bad Heilbrunn: Klinkhardt, pp.91–105.

Hickman, C., Marks, E., Pihkala, P., Clayton, S., Lewandowski, R.E., Mayall, E.E., Wray, B., Mellor, C. and Van Susteren, L., 2021. Climate anxiety in children and young people and their beliefs about government responses to climate change: A global survey. *The Lancet Planetary Health*, 5(12), pp.e863–e873. https://doi.org/10.1016/S2542-5196(21)00278-3

Kilby, B., 2023. Gender and communication in children and school: aligning theory and evidence. *SN Social Sciences*, 3(36). https://doi.org/10.1007/s43545-023-00622-w

Martin, L. (2015). The Promise of the Maker Movement for Education. *Journal of Pre-College Engineering Education Research (J-PEER), 5*(1), Article 4. https://doi.org/10.7771/2157-9288.1099

Miller, R. (2018) (Ed.). Transforming the Future, Anticipation in the 21st Century. London, Routledge.

McKenney, S. and Reeves, T.C., 2021. Educational design research: Portraying, conducting, and enhancing productive scholarship. *Medical Education*, 55(1), pp.82–92. https://doi.org/10.1111/medu.14280

Pettig, F. & U. Ohl (2023). Dealing with uncertainty in a transformative education for sustainability. In O. Muñiz Solari and G. Schrüfer (eds.), Understanding Sustainability with Pedagogical Practice, Advances in Geographical and Environmental Sciences, (pp. 29-40). https://doi.org/10.1007/978-981-99-2687-9_3

Salonen, K. and Kallinen, A., 2023. A theory of planetary social pedagogy. *Educational Theory*, 73(4), pp.437–455. https://doi.org/10.1111/edth.12570

So, W. W. M., Chen, Y., & Chow, S. C. F. (2022). Primary school students' interests in STEM careers: How conceptions of STEM professionals and gender moderation influence. International Journal of Technology and Design Education, 32(1), 33–53. https://doi.org/10.1007/s10798-020-09599-6

TUI Stiftung, 2019. *Young Europe 2019: So much for lethargy! What people aged between 16 and 26 think*.

Ulmanen, S., Soini, T., Pietarinen, J. and Pyhältö, K., 2016. Students' experiences of the development of emotional engagement. *International Journal of Educational Research*, 79, pp. 86–96. https://doi.org/10.1016/j.ijer.2016.06.003

Wunderlich, S. (2023). Pathway to CLIL – A Proposed Sequence of Subjects in CLIL Education Based on Linguistic Requirements of Selected Subjects [Dissertation, Universität Koblenz].