Meeting the Demands of Industry: A Study on Identifying and Teaching Emerging Technologies in Engineering Education

Bronwyn Swartz and Sweta Patnaik
Faculty of Engineering and the Built Environment, Cape Peninsula University of Technology, Bellville Campus, Cape Town, South Africa

swartzb@cput.ac.za
patnaiks@cput.ac.za

Abstract: As technology advances at an unprecedented pace, it is crucial for engineering faculties at contemporary universities and higher education institutions to continuously update their curricula. This is to ensure that graduates are equipped with the skills and knowledge required to design, develop, and implement emerging technologies in various industries (Wahyuningsih et al., 2020). However, there is a lack of consensus on which emerging technologies should be included in the engineering curriculum and how they should be taught. This study aims to identify the emerging technologies that should be included in the engineering curriculum and the best practices for teaching these technologies to engineering students. By addressing this gap in knowledge, this study contributes to the development of a comprehensive and up-to-date engineering curriculum that prepares graduates for the challenges and opportunities of the 21st century. The objective of this research was to identify the most relevant emerging technologies, assess the current teaching practices and identify areas for improvement, and identify the key skills and knowledge that engineering students need to develop to prepare them for the challenges and opportunities of the 21st century. There were two phases to this study. An online survey was done in phase one to gather quantitative data from engineering educators on attitudes and perceptions on the emerging technologies that are most relevant to the engineering field, the current practices for teaching these technologies, and the key skills and knowledge that engineering students need to develop. In the second phase, a focus group interview was conducted to gather more in-depth qualitative data on how emerging technologies can be integrated into the curriculum. This research study found a comprehensive understanding of the emerging technologies that should be included in the engineering curriculum and the best practices for teaching these technologies to engineering students.

Keywords: Emerging Technologies, Engineering Education, Curriculum, Industry 4.0

1. Introduction & Background to the Research

The global community has entered the Fourth Industrial Revolution, marked by the integration of artificial intelligence (AI), big data, robotics, the Internet of Things (IoT), and other cutting-edge technologies. This transformation is poised to reshape the way people live and work, offering the potential for these technologies to become more intelligent and provide significant societal advantages. Disruptive technologies are already prevalent in our lives, such as smart sensors enhancing photography, self-driving vehicles, automated parking systems, smartphone digital assistants like Siri or Alexa, and personalized online experiences offered by search engines and tech giants like Amazon and Facebook. The profound impact of these technologies on every facet of life is likely to profoundly affect the labour force, leading to the evolution of nearly all industries and the automation of numerous processes. This shift will potentially render many current jobs obsolete while ushering in new or modified professions that demand expertise in AI and other emerging technologies (such as robotics, Augmented and Virtual Reality), proficiency in handling vast amounts of data, and cross-functional skills encompassing creativity, social and emotional intelligence, communication, collaboration, and critical thinking (Wahyuningsih et al., 2020). As technology advances at an unprecedented pace, it is crucial for engineering faculties at contemporary universities and higher education institutions to continuously update their curricula to ensure that graduates are equipped with the skills and knowledge required to design, develop, and implement emerging technologies in various industries. However, there is a lack of consensus on which emerging technologies should be included in the engineering curriculum and how they should be taught. This case study aims to identify the emerging technologies that can be included in the engineering curriculum and the best practices for teaching these technologies to engineering students. By addressing this gap in knowledge, this study will contribute to the development of a comprehensive and up-to-date engineering curriculum that prepares South African graduates for the challenges and opportunities of the 21st century.

The qualitative research case study was conducted at a University of Technology (UoT) in South Africa. The design was guided by the framework provided by the university's Vision 2030. The UoT's Vision 2030 encompasses two dimensions, namely Oneness and Smartness. The Smartness dimension specifically emphasizes technological advancements and innovations in alignment with present and future industrial revolutions. It underscores the university's commitment to leveraging technology comprehensively and positively to advance various societal aspects such as improved socio-economic conditions, healthcare, education, safety, food security, and overall living conditions across local, national, and global scales, wherever feasible. The Faculty of Engineering at the (UoT) where this study took place encompasses a diverse array of academic disciplines, comprising eight distinct Engineering Departments. These departments include Chemical Engineering, Civil Engineering and Geomatics, Construction Management and Quantity Surveying, Clothing and Textile Technology, Industrial and Systems Engineering, Electrical, Electronic and Computer Engineering, and Mechanical and Mechatronic Engineering and Maritime Studies. Within the faculty's Program Qualification Mix (PQM) of the undergraduate diplomas and bachelor's degrees offered by these departments, an integral component of the curriculum entails the completion of a mandatory six-month workplace learning internship. To ensure the seamless execution of these internships and facilitate their coordination, the faculty has designated a workplace-based learning (WIL) coordinator within each department.

The objective of this research is to identify the most relevant emerging technologies, assess the current teaching practices and identify areas for improvement, and identify the key skills and knowledge that engineering students need to develop in order to prepare them for the challenges and opportunities of the 21st century. Thus, three investigative research questions developed for this study. These are:

1. What are the emerging technologies that are most relevant to the engineering field, and how are they being used in various industries?
2. What are the current practices for teaching emerging technologies in engineering programs, and what are the strengths and weaknesses of these practices?
3. What are the key skills and knowledge that engineering students need to develop in order to design, develop, and implement emerging technologies, and how can these be integrated into the engineering curriculum?

The WIL coordinators were thus identified as the vehicle of analysis in this study as the WIL coordinators provided the qualitative data to meet the objectives of the study.

2. Literature Review

While Industry 4.0 focuses on harnessing cyber-physical systems through increased integration of information and communication technologies into production, process automation, and the implementation of distributed and intelligent edge computing, Industry 5.0 (also known as Society 5.0) seeks to address societal challenges by merging physical and virtual spaces (Kobelev & Borovik, 2017), a goal facilitated by the advancements of Industry 4.0. The products emerging from the fourth industrial revolution represent a fusion of software systems, communication technology, sensors/actuators, and embedded technologies, all working seamlessly together (Klotzer et. al., 2017). These intricate systems are increasingly operating in complex and loosely supervised environments, interacting with the Internet and its services, functioning with a high level of autonomy, involving human input, and often having safety-critical implications. To achieve the desired levels of safety, security, and privacy (Stankovic et. al., 2017), such systems need to address challenges like systems-of-systems complexities and desired failure modes. As the systems progress at an unprecedented pace in the era of the fourth industrial revolution, society and its generational characteristics are also evolving. Generational cohorts are groups of individuals born within a specific time frame who share similar cultural experiences. In the Western World, the recognized generations listed on Wikipedia (Generation, 2021) include the Lost Generation, the Greatest Generation, the Silent Generation, Baby Boomers, Generation X, Millennials (also known as Generation Y), and Generation Z. Generation Z is sometimes referred to as Generation C due to its notable attributes.

Some argue that Generation C does not pertain to a specific age group but rather a mindset. One can be 15 or 75 years old and still be considered a member of Generation C. What unites them is their status as digital natives, highly proficient in technology, and constantly connected. Furthermore, they are known for being Communicating, Content-centric, Computerized, Community-oriented, and Clicking. This generation is seen as a significant influence on all aspects of society, with most marketing decisions focusing on their preferences. It is not an exaggeration to say that many innovations are driven by them. Another noteworthy characteristic of Generation Z is their environmental and social consciousness, which will have an impact on the design of future cyber-physical systems. Nahavandi (2019) describes the current approach of Industry 4.0, stating that "unfortunately, Industry 4.0 does not place a strong emphasis on environmental protection or utilize technologies to enhance the Earth's environmental sustainability, despite numerous AI algorithms being employed to explore sustainability perspectives (Chen et. al., 2008) in the past decade." Industry 5.0 is expected to bridge this gap and develop future systems and services that prioritize social and environmental aspects while leveraging data and technological advancements.

In their study, Broo et al. (2020) engaged in a trend-spotting exercise to uncover influential factors and emerging trends that could significantly shape the future of engineering education and research. They identified a total of 44 distinct trends, out of which 12 were chosen as the most influential factors. These factors are quite interesting and are listed in Table I.

Table 1: Influencing factors and their descriptions.

Influencing Factor	Description	Reference
Automation	Automating tasks, processes, and machines is one of the goals of any industry for a long time now. Essentially, automation focuses on the technologies and techniques to enable an apparatus, a process, or a system operate automatically. While some see automation as a threat to the labor market, many researchers argues that the automation and labor market has a more complex relationship and instead automation may increase productivity and economic growth.	(Robotics business review 2019; Schwab & Davis, 2018; Copigneaux et. al., 2016; CyPhERS, 2014)
Connectivity	The products of the Industry 4.0 and the machines, which will deliver the benefits to Society 5.0, cyber-physical systems are connected. The networking abilities combined with the cloud technologies, 5 G cellular networks, wireless energy harvesting, big data, smart network slicing, and similar technologies promise to provide integration where these systems communicate with each other seamlessly.	(Xu et. al, 2018; Lasi et. al., 2014; Schwab & Davis, 2018; Rais, 2018; Gurdur et. al., 2018; Xu, 2011; Gurdur et. al., 2016; Gurdur & Asplund, 2017)
Data	Today, the amount of data that has been collected, stored, analyzed and the insights delivered from data is already changing the world in many ways including some unexpected ones. This data-driven world is always on, always tracking, always monitoring, always listening, and always learning. Many organizations are interested in leverage data to improve customer experiences, deliver insights, open new markets, increase productivity and create new sources for competitive advantage.	(Schwab & Davis, 2018; National Intelligence Council (2012); Columbus, 2018; Gurdur et. al., 2019; Reinsel et. al., 2018; Cheng et. al., 2017; Gurdur et. al., 2018; Wellington et. al., 2020)
Data ethics	The increased usage of data throughout different industries bringing ethical complexities where data ownership, privacy, equity, responsibility, explainability, and transparency are becoming important topics of the Industry 5.0.	(Schwab & Davis, 2018; Lomas, 2018; Thompson et. al., 2018; Philbeck et. al., 2018; Deloitte Insights, 2019)
Electrification	It has been mentioned by many that electricity has the potential to deliver equivalent energy service with less energy input because it avoids conversion losses associated with burning fossil fuels. This electrification possibilities are seen as an opportunity to change the many sectors. For instance, electric vehicles are becoming mass-market products and reaching record sales. Similarly, new approaches to battery technologies, powertrain architectures, native electric vehicle platforms, and similar enablers of the electrification are gaining importance.	(Schwab & Davis, 2018; UN 2018; Burston, 2016; European Commision, 2009; The Society of Motor Manufacturers and Traders, 2016; McKinsey & Company, 2018)
Higher Education (HE) Environment	Different dynamics of the higher education environment impact education and research. These includes rise of global university rankings, declarations by nations to have world-class universities, the development of regional units of control and reform, the development of cross-border quality assessment practices, and the internationalization of universities.	(Higgins, 2013; Rainie & Anderson, 2017; Musselin, 2018; Rust & Kim, 2013 Ferrari, 2020; Leoste et. al., 2021)
(Artificial) Intelligence	Intelligence enables the automated decision-making through interconnected networks of systems of systems and the intelligent systems are the results of a wide range of technologies including artificial intelligence, data analytics, cloud computing, cyber security, high performance CPUs and so on.	(Xu et. al, 2018; Robotics Business Review, 2019; Schwab & Davis, 2018; Copigneaux et. al., 2016; CyPhERS, 2014; Calderone, 2018; Boyd & Holton; 2018; Kim & Kim, 2020)

Influencing Factor	Description	Reference
Labor market	Several researchers pointed out the shift in the labor market which effects especially the basic skilled workers. The changes in the labor market due to technological advancements may cause unexpected effects in education, economy, and society.	(Schwab & Davis, 2018; Rainie & Anderson, 2017; Harris et. al., 2018)
Sustainable development goals (SDG)	SDG was adopted by all United Nations Member States in 2015 with an agenda [75] that provided a shared blueprint for peace and prosperity for people and the planet, now and into the future. These goals underline that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and drive economic growth which is at the very core of Industry 5.0.	(Rainie & Anderson, 2017; Harris et. al., 2018; UN, 2015)
Technological development	As we have already discussed continuous or disruptive technological developments such as the Internet, mobile phones, personal computers, social media, and similar technologies, illustrate new devices, technologies, methods, and methodologies may cause series of changes and in return how they influence the learning and teaching environments.	(Schwab & Davis, 2018; UN, 2018; Burston, 2016; European Commission, 2009; Grunwald, 2018; J. Margolies, *et al, 2018;* Advanced Functional Materials Congress, 2019; Roland & Trend, 2015; Swerea, 2016; Ghobakhloo & Ching, 2019; Chen & Huang, 2020)
Trust in technology	While technology's role and effects on society are increasing, keeping the level of trust in these new technologies is becoming important. Increased usage of automation, data, and artificial intelligence, and changing power structures may have an opposite consequence to the trust in technology.	(UN, 2018; Harris et. al., 2018; UN, 2015; Edelman, 2019)
Lifelong learning	Lifelong learning is defined as an ongoing, voluntary, and self-motivated pursuit to acquire new knowledge. Motivating and providing opportunities for lifelong learning increases social inclusion, active citizenship, and personal development and helps the workforce to stay competitive and employable.	(Higgins, 2013; Rainie & Anderson, 2017; Torngren et. al., 2015; Torngren et. al., 2017; Komiyana & Yamada, 2018; Tai et. al., 2020)

Underscored by the foregoing discussion Ali and Khan (2023) and Amoruso (2023) access to resources such as LinkedIn Learning and the utilization of simulations holds significant value and can function as micro-credentials. Through the strategic utilization of these technological tools, students gain the ability to tap into supplementary educational materials, sustain their skill enhancement, and effectively connect theoretical knowledge with real-world application. Notably, simulations stand out as an exceptional tool, elevating students' confidence levels and furnishing them with a hands-on comprehension of emerging technologies.

3. Methodology

This qualitative study commenced March 2023 with the application for ethical clearance and a literature survey. It was concluded from June to July 2023 when data was collected and the manuscript written. The data collection process entailed online interviews conducted via MS Teams with a total of five WIL coordinators. Before the commencement of data collection, informed consent was obtained from all participating individuals, ensuring their voluntary involvement in the study. Ethical clearance was obtained prior to data collection. The sample comprised a total of five WIL coordinators (Participant 1, 2, 3, 4 and 5). Their perspectives and experiences provided valuable insights into the coordination and facilitation of workplace learning internships within the Faculty of Engineering. Each online interview session was recorded and lasted between 45 minutes to 70 minutes. This allowed for in-depth exploration of the research topic.

Following the completion of the interviews, the audio recordings were transcribed verbatim to transform them into a written format suitable for analysis. To maintain participant confidentiality and anonymity, appropriate measures were taken during the transcription process to remove any identifiable information. The anonymization process ensured the protection of participants' privacy and confidentiality throughout the analysis and reporting stages of the study. The data transcripts were then thematically coded according to the three categories derived from this study’s investigative questions. which were (1) relevant emerging technologies (2) current practices for teaching emerging technologies and (3) key skills and knowledge that need to be integrated into the engineering curriculum. The key research finding related to each of the three above-mentioned categories are discussed in the section that follows.

4. Research Findings

4.1 Emerging Technologies in the Engineering Field

In the interviews with the WIL coordinators, several key perceptions emerged regarding the integration of emerging technologies into the engineering curriculum. In separate interviews Participant 2 and Participant 5 noted that while MS Excel may not be classified as an emerging technology, it remains highly desired by industry. Participant 2 gave an example of a student would eventually developed a project management application which started as an MS Excel spreadsheet that was highly commended by the organisation where she was placed. He added "*Industry keeps every year saying like you need to teach them these kids Advanced MS Excel or even just like basic MS Excel"*. Notably, Participant 5 also offered an example of a student in a different engineering discipline who used MS Exel in a manner that added significant value to the organisation where the student was place. Participant 5 described this as "N*ot a not an emerging technology, but the student managed to take the knowledge that he that he did have, turn it into turn it into something* [important]." This highlights the importance of industry demands for specific technical skills such as using MS Excel or being able to do basic computer programming to develop a simple application, even if they are not at the forefront of technological innovation.

Participant 3 shed light on the university's financial constraints, which pose challenges in acquiring the latest technologies. By the time funds become available, the technologies may already be outdated. This presents a limitation from the university perspective to keeping pace with the rapidly evolving landscape of emerging technologies. Also related to the cost of technology, Participant 1 emphasized the variability of technologies used in different companies. It was recognized that students may be trained on specific technologies, only to discover that the companies they join utilize different technologies, in some cases more expensive technology that is not available at the University. Participant 1 delayed an incident where an organisation adamant about only employing a student who had experience in specific software that was not available at the university. *"We don't offer an introduction to it in any way, it's a it's a really expensive package which is used in industry. After long deliberation, I had to convinced him that if a student has what we've given them which is the introduction to AutoCAD, they can adjust and adapt their knowledge to the new package because there are similarities. Yeah we sometimes have to give up because companies are just – they don't have the time to spend to train the student to use the new technology".* This underscores the need for engineering education to focus on developing adaptable students who can apply their learnings from one technology to another.

A consensus emerged among the participants, emphasizing the significance of continuous practice and application of technologies. It was acknowledged that simply training students on specific technologies without providing regular opportunities for practical implementation may lead to knowledge decay over time. Therefore, the development of resilient and adaptable students who are open to trying new technologies and can apply their learnings across different areas was seen as essential. These insights collectively emphasize the importance of striking a balance between incorporating emerging technologies into the curriculum and nurturing broader skills and competencies. By addressing financial constraints, promoting adaptability, and ensuring regular practical engagement, engineering education can better equip students to navigate the ever-changing technological landscape and meet the demands of industry effectively.

4.2 Teaching Emerging Technologies

In relation to research objective 2, which focuses on current teaching practices for emerging technologies, the interviews with Participant 1 and Participant 4, who are from the construction management and civil engineering field, revealed interesting perspectives. They highlighted the challenges faced by students when they have to go on-site, particularly in rural areas of South Africa, where there is no signal or access to technology. Participant 1 stated "*We still have places in South Africa which are not connected, ... students are not always able to access what we expect them to access... cellphone signal or IT connectivity ...we have to be very aware of that with the nature of our industry.*" Similarly Participant 4 said "[When] *they need to go out* [of town] *to build a road - I had a student last year who had to drive 20 minutes from sight just to pick up cellphone reception to make contact".*

This limited connectivity inhibits the use of technological tools and hinders students' ability to practice and apply emerging technologies in real-world scenarios.

Participant 4 specifically emphasized that the construction industry undergoes slow technological changes and expressed skepticism regarding the replacement of manual methods with technology. The participant raised concerns about the reliability of certain technological tools and the potential consequences if they were to malfunction.

These insights reveal the complexities and varied perspectives regarding the integration of technology into teaching practices. While some participants acknowledge the potential benefits of using technological tools, others express reservations about their suitability in certain contexts and industries. The concerns raised highlight the need for a balanced approach that considers the limitations and practicalities of technology while leveraging its potential benefits in engineering education.

4.3 Competencies and Knowledge Areas to be Incorporated in the Engineering Curriculum

In relation to the key skills and knowledge required for engineering students to design, develop, and implement emerging technologies, Participant 5 and Participant 2 emphasized the importance of mentorship and supervision. Participant 5 mentioned relying on former students to support current ones, while Participant 2 provided an example of a supportive former student who understands the challenges and experiences of being an intern. He offered the opinion that having a mentor who can empathize with the student's experience is highly advantageous. The participant further noted the value of being mentored by an accredited professional from the Engineering Council of South Africa (ECSA), as it aligns with the requirements set forth by the country's professional body "*we need to have a supervisors who has gone through the program, also it's an ECSA requirement".* These insights highlight the valuable role that mentorship plays in guiding and developing students' skills in the engineering field.

Additionally, all participants expressed concerns about the short duration of the workplace learning internship, which limits the amount of learning that students can acquire. To address this challenge, the utilization of technology platforms like LinkedIn Learning and other similar tools was seen as beneficial. These technologies can supplement students' learning experiences and provide additional resources for skill development in emerging technologies.

Simulation was another key aspect highlighted by Participants 2, 3, 4, and 5. They emphasized the value of simulation in training engineers and how it contributes to building confidence. Participant 5 specifically mentioned the noticeable improvement in students' confidence after using simulators before engaging in practical in-service training as illustrated by this quote "B*ut when they come back, it's almost like they are now willing, you know, to play, to learn to end. Then also the subsequent engagement in class, and it's almost like a transformation for our students*".

Regarding the integration of emerging technologies into the curriculum, Participant 3 provided valuable insights. They emphasized the importance of collaboration between industry and the university to identify the relevant emerging technologies that engineering students should possess. Furthermore, Participant 3 highlighted the need to create development opportunities that facilitate hands-on experience with emerging technologies. Additionally, the perception that emerging technologies could be seen as a threat by students, potentially leading to job displacement, was also mentioned. These findings underline the significance of mentorship, the benefits of utilizing technology for learning and skill development, and the role of simulation in building confidence. They also highlight the importance of collaboration between industry and academia in shaping the engineering curriculum to align with emerging technologies while addressing potential concerns related to job displacement.

5. Discussion

The findings from the participants' responses shed light on several important aspects related to the integration of emerging technologies in engineering education.

Firstly, aligned with the views of Alawamleh and Mahadin (2022), the significance of mentorship and supervision emerged as a key factor in supporting engineering students. Participant 5 highlighted the value of relying on former students as mentors, who offer understanding and support based on their own experiences. Similarly, Participant 2 emphasized the role of a supportive supervisor who can relate to the challenges faced by interns.

Mentorship bridges the gap between theoretical learning and practical application, aiding the development of students' skills and knowledge in emerging technologies.

Recognizing the limitations of short workplace learning internships, all participants agreed on the potential of technology in enhancing students' learning experiences. The availability of platforms like LinkedIn Learning and the use of simulations were highlighted as valuable tools. This consistent with Ali and Khan (2023) and Amoruso (2023). By leveraging these technologies, students can access additional resources, continue their skill development, and bridge the gap between theory and practice. Simulations, in particular, were praised for their ability to boost students' confidence and provide a practical understanding of emerging technologies.

Moreover, the integration of emerging technologies into the engineering curriculum requires collaboration between academia and industry. Participant 3 emphasized the importance of industry-university partnerships in identifying relevant emerging technologies and creating development opportunities. This collaborative effort ensures that the curriculum aligns with industry needs, preparing students effectively for the demands of the field. Additionally, concerns about job displacement were raised, underlining the need for responsible integration of emerging technologies and addressing students' anxieties.

In summary, in support of work by Broo et al. (2020), our findings highlight the interconnectedness of mentorship, technology integration, and collaboration in engineering education. Effective mentorship provides guidance and support, while technology tools supplement traditional learning and offer continuous skill development opportunities. By fostering collaboration between academia and industry, educational institutions can ensure the curriculum aligns with industry demands and address students' concerns about job displacement. By considering these aspects holistically, engineering programs can better equip students with the skills and knowledge necessary to thrive in the ever-evolving landscape of emerging technologies.

6. Limitations

One limitation of this study is its narrow scope, focusing solely on the Faculty of Engineering at a single university in South Africa. While the insights and deductions drawn from the data analysis provide valuable insights for engineering educators, it is important to recognize that the findings may not be directly transferable to other contexts and universities. Each institution has its own unique characteristics, including resources, industry partnerships, and curriculum structures, which may impact the integration of emerging technologies in engineering education. Therefore, further research conducted in diverse settings is necessary to capture a broader understanding of the challenges and opportunities associated with incorporating emerging technologies into engineering curricula.

7. Conclusion

In conclusion, this case study delved into the critical task of integrating emerging technologies into the engineering curriculum to ensure that graduates are well-prepared for the demands of the 21st century. The findings highlighted the need for ongoing curriculum updates and the significance of incorporating industry perspectives in this process. The participants' insights emphasized the importance of mentorship, technological tools, and simulations in enhancing students' learning experiences and bridging the gap between theory and practice. Furthermore, the study underscored the value of collaboration between academia and industry in identifying relevant emerging technologies and creating development opportunities. By considering these findings, engineering faculties can shape a comprehensive and forward-thinking curriculum that equips students with the necessary skills, adaptability, and confidence to design, develop, and implement emerging technologies in diverse industries. This research contributes to the broader objective of preparing South African graduates to navigate the ever-evolving technological landscape and capitalize on the opportunities it presents.

References

Alawamleh, M. and Mahadin, B.K., 2022. Will university internship secure you a job?: interplaying factors from an emerging market perspective. Education+ Training, 64(4), pp.491-515.

Ali, S.A. and Khan, R., 2023. Harnessing the Digital Nature of Micro-Credentials in Higher Education.

Amoruso, P., 2023. Micro-Credentialing with Fuzzy Content Matching: An Educational Data-Mining Approach (Doctoral dissertation, University of Central Florida Orlando, Florida).

A.B. Swerea The Future of Materials (2016)

A. Grunwald Technology Assessment in Practice and Theory (2018) Abingdon, Oxon; New York, NY: Routledge, 2019.: Routledge

Advanced Functional Materials Congress Bridging Functional Materials (2019) Availablehttps://www.advancedmaterialsseries.com/afmc19/pages/about-afmc-2019

Ahlam Rais Next Stop: Industry 4.0 – Three Trends For the Digital Transformation (2018) [Online]. Available: https://www.process-worldwide.com/next-stop-industry-40-three-trends-for-the-digital-transformation-a-712526/

B. Copigneaux, S. Engell, R. Paulen, M. Reniers, C. Sonntag, H. Thompson. (2016). Proposal of a European Research and Innovation Agenda On Cyber-physical Systems of Systems 2016-2025

C. Musselin New forms of competition in higher education Socio-Econ. Rev., 16 (3) (2018), pp. 657-683, 10.1093/SER/MWY033

Chen, C. C., & Huang, P. H. (2020). The effects of STEAM-based mobile learning on learning achievement and cognitive load. *Interactive Learning Environments*, **31**, 100–116. https://doi.org/10.1080/10494820.2020.1761838

CyPhERS CPS20: CPS 20 Years from Now (2014)

CyPhERS Structuring of CPS Domain: characteristics, trends, challenges and opportunities associated with CPS - Deliverable D2.2," *CyPhERS - Cyber-Physical Eur* Roadmap Strateg (611430) (2014), p. 41

C. Klotzer, J. Weibenborn, A. Pflaum The Evolution of Cyber-Physical Systems as a Driving Force behind Digital Transformation Proc. - 2017 IEEE 19th Conf. Bus. Informatics, CBI 2017, 2 (2017), pp. 5-14, 10.1109/CBI.2017.8

D. Gürdür, *et al.* Knowledge Representation of Cyber-physical Systems for Monitoring Purpose Procedia CIRP, 72 (2018), 10.1016/j.procir.2018.03.018

D. Gürdür Broo, U. Boman, M. Törngren. Cyber-physical Systems Research and Education in 2030: scenarios and Strategies. J. Ind. Inf. Integr. (2020)

D. Gürdür, J. El-Khoury, T. Seceleanu, L. Lednicki. Making interoperability visible: data visualization of cyber-physical systems development tool chains J. Ind. Inf. Integr., 4 (2016), pp. 26-34, 10.1016/j.jii.2016.09.002

D. Gürdür, F. Asplund. A systematic review to merge discourses: interoperability, integration, and cyber-physical systems. J. Ind. Inf. Integr., 9 (2017), pp. 14-23, 10.1016/j.jii.2017.12.001 December 2017

D. Gürdür, J. El-khoury, M. Törngren. Digitalizing Swedish industry: what is next? Comput. Ind., 105 (2019), pp. 153-163, 10.1016/j.compind.2018.12.011

D. Reinsel, J. Gantz, J. Rydning. Data age 2025: the digitization of the world from edge to core Int. Data Corp. (2018), p. 28

Deloitte Insights. Government Trends 2020 (2019)

Edelman 19th Annual Edelman Trust Barometer: Trust in Technology (2019)

European Commission. EU Energy Trends to 2030 (2009) The Society of Motor Manufacturers and Traders. The Future of UK Automotive Manufacturing in 2025 and Beyond (2016)

"Fridays for Future," 2018. [Online]. Available: https://fridaysforfuture.org.

Ferrari, P. (2020). Trends in learning. STEM, STEAM, STREAM… A battle of acronyms? Available online: https://www.capstan.be/trends-in-learning-stem-steam-stream-a-battle-of-acronyms/

Global Trends 2030: Alternative worlds: a Publication of the National Intelligence Council. National Intelligence Council (2012)

H. Lasi, P. Fettke, H.G. Kemper, T. Feld, M. Hoffmann Industry 4.0

Bus. Inf. Syst. Eng., 6 (4) (2014), pp. 239-242, 10.1007/s12599-014-0334-4

H. Thompson, *et al.* Platforms4CPS Key Outcomes and Recommendations (2018)

J. Margolies, *et al.* Tech Trends 2018: the symphonic enterprise Deloitte Insights (2018), p. 162

J.M. Higgins The Fourth Singularity and the Future of Jobs World Futur. Rev., 5 (1) (Mar. 2013), pp. 11-23, 10.1177/1946756712473437

J. Burston. 5 Predictions For Energy in 2030 | World Economic Forum (2016) [Online]. Available https://www.weforum.org/agenda/2016/11/5-predictions-for-energy-in-2030

J. Stankovic, J. A, J.W. Sturges, Eisenberg A 21st Century Cyber-Physical Systems Education Computer (Long. Beach. Calif), 50 (12) (2017), pp. 82-85

K. Harris, A. Kimson, A. Schwedel Labor 2030: the Collision of Demographics, Automation, and Inequality - Bain & Company (2018) [Online]. Available https://www.bain.com/insights/labor-2030-the-collision-of-demographics-automation-and-inequality/

K. Schwab, N. Davis (2018) Shaping the Future of the Fourth Industrial Revolution: A guide to Building a Better World. Penguin Books Limited (2018)

Kim, J.-O., & Kim, J. (2020). Development and application of art based STEAM education program using educational robot. In *Robotic systems* (pp. 1675–1687). IGI Global. https://doi.org/10.4018/978-1-7998-1754-3.ch080

L.Da Xu, E.L. Xu, L. Li. Industry 4.0: state of the art and future trends

Int. J. Prod. Res., 56 (8) (2018), pp. 2941-2962, 10.1080/00207543.2018.1444806

L.Da Xu Enterprise systems: state-of-the-art and future trends IEEE Trans. Ind. Inform., 7 (4) (2011), pp. 630-640, 10.1109/TII.2011.2167156

Lee Rainie, Janna Anderson The Future of Jobs and Jobs Training (2017)

Len Calderone AI Could Beat Humans at Everything by 2030 | RoboticsTomorrow (2018) [Online]. Available https://www.roboticstomorrow.com/article/2018/09/ai-could-beat-humans-at-everything-by-2030/12536

Leoste, J., Jõgi, L., Õun, T., Pastor, L., San Martín López, J., & Grauberg, I. (2021). Perceptions about the future of integrating emerging technologies into higher education—The case of robotics with artificial intelligence. *Computers*, **10**(9), 110. https://doi.org/10.3390/computers10090110

Louis Columbus. 10 Charts That Will Change Your Perspective of Big Data's Growth (2018). Available: https://www.forbes.com/sites/louiscolumbus/2018/05/23/10-charts-that-will-change-your-perspective-of-big-datas-growth/#5dfd9b272926.

M. Ghobakhloo, N.T. Ching Adoption of digital technologies of smart manufacturing in SMEs J. Ind. Inf. Integr., 16 (2019), Article 100107, 10.1016/j.jii.2019.100107

McKinsey & Company. Insights On Best Practices For Paving the Road For Mass-Market Electric Vehicles (2018)

N. Lomas. Gartner Picks Digital Ethics and Privacy As a Strategic Trend For 2019 | TechCrunch (2018) [Online]. Available https://techcrunch.com/2018/10/16/gartner-picks-digital-ethics-and-privacy-as-a-strategic-trend-for 2019/?guccounter=1&guce_referrer_us=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_cs=CQaA9EsJmZJPrdKkXZA6yg

Pew Research Center The Generation Gap in American Politics: Wide and Growing Divides in Views of Racial Discrimination (2018)

P.O.S. Kobelev, S.Y. Borovik On the Way From Industry 4 . 0 To Industry 5. 0 Int. Sci. J. "Industry 4.0, 2 (6) (2017), pp. 307-311

R. Boyd, R.J. Holton Technology, innovation, employment, and power: does robotics and artificial intelligence really mean social transformation? J. Sociol., 54 (3) (2018), pp. 331-345, 10.1177/1440783317726591

Robotics Business Review. 10 Trends in Robotics, AI, and Autonomous Systems to Watch in 2019 (2019) Available https://www.roboticsbusinessreview.com/news/automation-business-2019-10-trends/

S. Nahavandi Industry 5.0-a human-centric solution Sustain, 11 (16) (2019), 10.3390/su11164371

T. Roland, B. Trend RBI Trend Compendium 2030 (2015)

T. Philbeck, N. Davis, A.M.E. Larsen. Values, Ethics, and Innovation: Rethinking Technological Development in the Fourth Industrial Revolution (2018)

United Nations. World Economic and Social Survey 2018: Frontier technologies For Sustainable Development (2018) vol. E/2018/5027 July 2017–26 July 2018

Tai, J., Ajjawi, R., Bearman, M., & Wiseman, P. (2020). Conceptualizations and measures of student engagement: A worked example of systematic review. In O. Zawacki-Richter, M. Kerres, S. Bedenlier, M. Bond, & K. Buntins (Eds.), *Systematic reviews in educational research: Methodology* (pp. 91–110). Perspectives and Application.

U.S. National Intelligence Council

United Nations Introduction: the scope of the inequality discussion in the 2030 Agenda for Sustainable Development Dev. Issues (4) (2015), pp. 1-10

V.D. Rust, S. Kim. The Global Competition in Higher Education World Stud. Educ., 13 (1) (2013), pp. 5-20, 10.7459/wse/13.1.02

Wikipedia, "Generation," 2021. [Online]. Available: https://en.wikipedia.org/wiki/Generation

Wahyuningsih, S., Nurjanah, N. E., Rasmani, U. E. E., Hafidah, R., Pudyaningtyas, A. R., & Syamsuddin, M. M. (2020). STEAM learning in early childhood education: A literature review. *International Journal of Pedagogy and Teacher Education*, **4**(1), 33–44.

Wellington, A., Easton, G., Davis, J. P., & Yeh, A. (2020). Beat and rhythm: Teaching science via integrated STEAM and digital technologies. *Teaching Science*, **66**(2), 20–25.

Y. Cheng, K. Chen, H. Sun, Y. Zhang, F. Tao. Data and Knowledge Mining with Big Data towards Smart Production. J. Ind. Inf. Integr., 9 (2017), pp. 1-13, 10.1016/j.jii.2017.08.001 August 2017