Review Article

e-ISSN: 2710-2122, p-ISSN: 2710-2114
2025: Vol 7(s1), pp 1-13. https://doi.org/10.38140/ijer-2025.vol7.s1.10
Interdisciplinary Journal of Education Research

Innovations in Pedagogy and Technology for Engineering Education: A Systematic Review

Nokulunga X. Mashwama[1*]
Bubele Madubela[2]

AFFILIATIONS
[1]Built Environment Department, Walter Sisulu University, Buffalo City, South Africa.
[2]Faculty of Education, Walter Sisulu University, Mthatha Campus, South Africa.

CORRESPONDENCE
Email: xolilemash9@gmail.com*

EDITORIAL DATES
Received: 27 September 2024
Revised: 23 February 2025
Accepted: 05 March 2025
Published: 17 April 2025

DOI: 10.38140/ijer-2025.vol7.s1.10

Abstract: Engineering education has undergone a significant transformation driven by rapid technological advancements and innovative pedagogical approaches. This study presents a systematic review of 23 scholarly articles, integrating both qualitative and quantitative findings to explore the impact of technology on engineering education. Utilising the PRISMA guidelines, the review highlights the role of emerging educational technologies in enhancing student engagement, academic performance, and accessibility. Key findings emphasise the growing importance of flexible learning, which enables students to balance academic responsibilities with work and other commitments. Technologies such as virtual and augmented reality have emerged as powerful tools, offering immersive learning experiences that replicate real-world engineering scenarios. These advancements enhance conceptual understanding, problem-solving skills, and interdisciplinary collaboration, which are critical in preparing students for the evolving demands of a globalised workforce. Furthermore, the integration of information technology has revolutionised engineering education by streamlining instructional delivery, improving knowledge dissemination, and facilitating global connectivity in academic research and collaboration. However, the effectiveness of these innovations depends on their strategic and thoughtful implementation, considering diverse learner needs and ensuring equitable access. This study underscores the transformative potential of technology in engineering education, advocating for a balanced approach that maintains academic rigour while fostering creativity, critical thinking, and adaptability. By leveraging these innovations, higher education institutions can enhance learning experiences, better equip students for future challenges, and bridge the gap between theoretical knowledge and practical application in engineering disciplines.

Keywords: Critical thinking, engineering education, flexible learning, student, technology.

1. Introduction

Engineering education is undergoing a remarkable transformation, driven by the fusion of innovative pedagogical approaches and cutting-edge technologies (Eden et al., 2024). This paradigm shift has not only enhanced student engagement and academic performance but has also contributed to greater inclusivity and accessibility in education (Ye & Li, 2022). As the demands of the modern workforce evolve, engineering programmes are redefining their methodologies to cultivate creativity, problem-solving skills, and interdisciplinary collaboration. One of the most impactful innovations in engineering education is the adoption of active learning techniques. Strategies such as project-based and problem-based learning have revolutionised traditional teaching methods by encouraging students to engage in hands-on, real-world problem-solving (Pepin, Biehler & Gueudet, 2021). These approaches facilitate the development of essential skills, including critical thinking, teamwork, and adaptability. Additionally, interactive elements like clicker quizzes, in-class group activities, and field experiences have been shown to significantly enhance student motivation and comprehension (Michalaka & Davis, 2015). By shifting from passive lecture-based instruction to

How to cite this article:
Mashwama, N. X., & Madubela, B. (2025). Innovations in pedagogy and technology for engineering education: A systematic review. *Interdisciplinary Journal of Education Research, 7*(s1), a10. https://doi.org/10.38140/ijer-2025.vol7.s1.10

dynamic, participatory learning environments, educators are fostering a deeper understanding and retention of complex engineering concepts.

Technology has become an indispensable force in reshaping engineering education. The integration of e-learning platforms, distance education models, and digital assessment tools has created more personalised and flexible learning experiences (Ogwu et al., 2022). The rise of simulation-based learning, virtual reality (VR), and augmented reality (AR) has provided students with immersive environments where they can visualise and experiment with intricate engineering principles in real time (Eden et al., 2024). These innovations bridge the gap between theoretical knowledge and practical application, making engineering education more engaging and effective than ever before. Beyond technical proficiency, modern engineering education places a strong emphasis on developing 21st-century skills such as creativity, entrepreneurship, and interdisciplinary collaboration (Ghafar, 2020). Universities are embedding entrepreneurship courses into their curricula to cultivate an innovative mindset, encouraging students to take risks and think beyond conventional problem-solving frameworks. However, traditional pedagogical methods in entrepreneurship education have been critiqued for focusing primarily on new venture creation while neglecting the development of broader entrepreneurial competencies (Miranda et al., 2020). Addressing this gap requires a more holistic approach to assessing and nurturing entrepreneurial skills among engineering students (Huang-Saad et al., 2018).

Globalisation has significantly influenced higher education, necessitating continuous skill development to keep pace with the evolving knowledge economy (McLain, 2022). Key drivers of this transformation include the increasing role of the private sector, the widespread adoption of information and communication technologies (ICTs), and the integration of educational services into international trade agreements (Pigozzi, 2009). In response, universities are adapting their strategies to cater to non-traditional learners, meet the growing demand for lifelong learning, and maintain competitiveness in the digital education landscape (Foster, 2001). Higher education institutions now serve as pivotal hubs for producing skilled professionals, conducting pioneering research, and fostering innovation in technology-driven economies (Castells, 2000). As the future of engineering education continues to unfold, interdisciplinary collaboration and adaptability will be paramount. Howells (2018) highlights the importance of cultivating creativity, curiosity, and open-mindedness to thrive in an innovation-driven world. The process of knowledge creation is increasingly collaborative, leveraging existing research to generate groundbreaking solutions. By embracing interdisciplinary perspectives and cooperative learning models, engineering programmes can equip students with the skills necessary to address complex global challenges.

This study employs a systematic review of the literature (SRL) to synthesise a vast array of research on the evolution of engineering education. The SRL methodology ensures a comprehensive analysis of existing scholarly work, identifying gaps in current pedagogical and technological strategies. Unlike previous studies, this research brings together a substantial volume of insights from diverse sources, offering valuable contributions to academic institutions, policymakers, and society at large. By elucidating the transformative impact of innovation and technology on higher education, this study aims to shape the future of engineering pedagogy and its role in global development. The ongoing evolution of engineering education underscores the necessity for continuous adaptation and innovation. As new technologies emerge and pedagogical approaches evolve, the field must remain agile, embracing change to prepare future engineers for the dynamic challenges of the 21st century.

1.1 Problem statement

The rapid globalization of higher education has introduced complex challenges for engineering education, necessitating a shift towards knowledge-based economies where advanced technical skills, interdisciplinary collaboration, and continuous learning are essential. Engineering programmes must adapt to the increasing influence of the private sector, the widespread integration of information and communication technologies (ICT), and the pressures of international competition in education. These factors have created an urgent need for universities to provide flexible, lifelong learning opportunities while ensuring that engineering graduates possess not only technical proficiency but also critical thinking, problem-solving, and entrepreneurial skills.

However, despite the adoption of innovative pedagogical methods and digital learning tools, engineering education continues to struggle with aligning curriculum design with the evolving demands of industry and global markets. The challenge lies in maintaining academic rigour and research excellence while integrating modern technological advancements, interdisciplinary knowledge, and real-world applications. Furthermore, there remains a gap in effectively assessing and developing 21st-century skills, particularly in fostering creativity and adaptability among engineering students. Without addressing these challenges, universities risk producing graduates who are ill-equipped to navigate the dynamic, technology-driven global workforce. Therefore, a critical evaluation of engineering educational methodologies is necessary to ensure that they meet the evolving needs of globalisation while preserving the fundamental mission of higher education institutions.

1.2 Research question

How can engineering education programmes in higher education institutions effectively integrate technological advancements, interdisciplinary collaboration, and private sector engagement while maintaining academic rigor, fostering critical thinking, and preparing students for the evolving demands of a globalised workforce?

2. Methodology

This section outlines the methodology employed in conducting a systematic review of innovation and technology in transforming the landscape of engineering education. The systematic review sought to identify patterns across engineering and education in higher education institutions and integrate various qualitative studies. The research approach was qualitative, aligned with the systematic review method and the guidelines of PRISMA. The objectives were to identify, classify, and summarise research on innovation and technology within engineering education. The search strategies resulted in 23 peer-reviewed papers used for analysis. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines checklist by Page et al. in 2020, an extensive search was conducted on Scopus, Google Scholar, and Elsevier (ScienceDirect) for relevant articles. Search terms included "higher education," "engineering," "innovation," "technology," and "transformation." This search yielded 815 articles; 154 were removed due to duplication, and 511 were deemed irrelevant, leaving 150 articles. A further search led to the screening of 150 abstracts, resulting in the exclusion of 113 papers that did not specifically address the study's objectives. Consequently, 37 articles were retrieved by the authors for full analysis. Ultimately, only 23 articles were accessed and included in the study, which are presented in Table 1, along with citations of the journals.

Data collection encompassed article details, authors' affiliations, journal names, and publication years, all organised in an Excel spreadsheet. The 23 articles underwent an eligibility assessment by two reviewers, with any disagreements resolved through consensus or by involving a third reviewer. By incorporating pre-defined keywords and refining the checklist based on a preliminary trial, the study evaluated literature related to innovation and technology transforming engineering and the built environment education landscape in higher education institutions. Adaptations were made to suit the engineering and built environment domain, streamlining the checklist to 18 key points. One author led the data extraction, cross-validated by another, with discrepancies resolved through dialogue. Inclusion and exclusion criteria were established based on PRISMA recommendations. Non-research articles, works in progress, and those not meeting the inclusion criteria were excluded.

The search was restricted to peer-reviewed journal articles published in English and required at least three citations. Google Scholar and Scopus were the main databases used for information retrieval. The specific inclusion and exclusion criteria can be found in Figure 1.

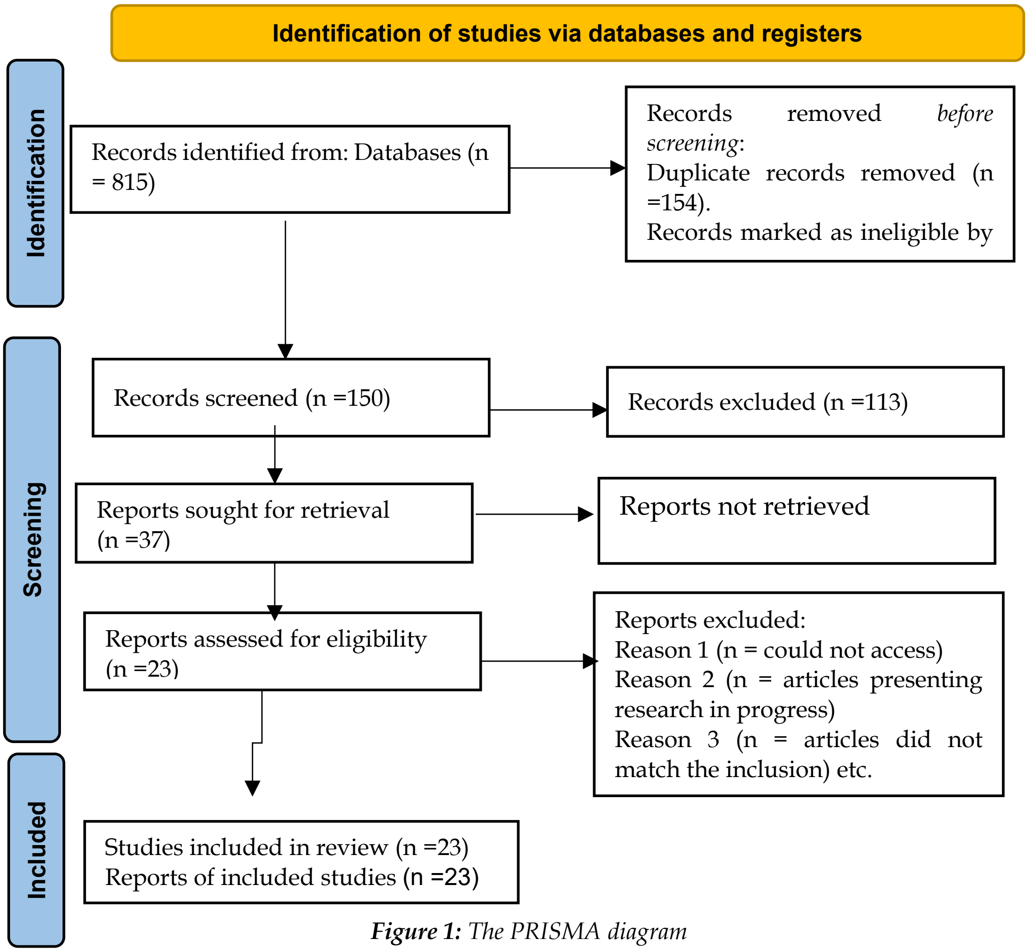

Figure 1: *The PRISMA diagram*

3. Review of Selected Articles

This section presents the findings from the review of the literature. Below, we discuss the role of innovation and technology in transforming the landscape of engineering and built environment education. A search was conducted across several databases for keywords as previously described. Figure 1 displays the PRISMA diagram, which illustrates the flow chart of the article selection process. The articles were analysed for their general characteristics to extract data on how innovation and technology are transforming the educational landscape of engineering in higher education. Based on all criteria used to perform the systematic review, the evolution of studies published in this area during the period covered by this study can be identified. Figure 2 shows the number of documents published per year from 1990 to 2023. It was also found that the number of published papers increased over time, with a sharp rise between 2014 and 2022, indicating a growing interest in the topic. Moreover, institutions are strongly encouraged to be more innovative and incorporate technology to equip engineering students, ensuring their relevance in an ever-evolving world. The COVID-19 pandemic taught higher education institutions an important lesson about embracing and adapting to change.

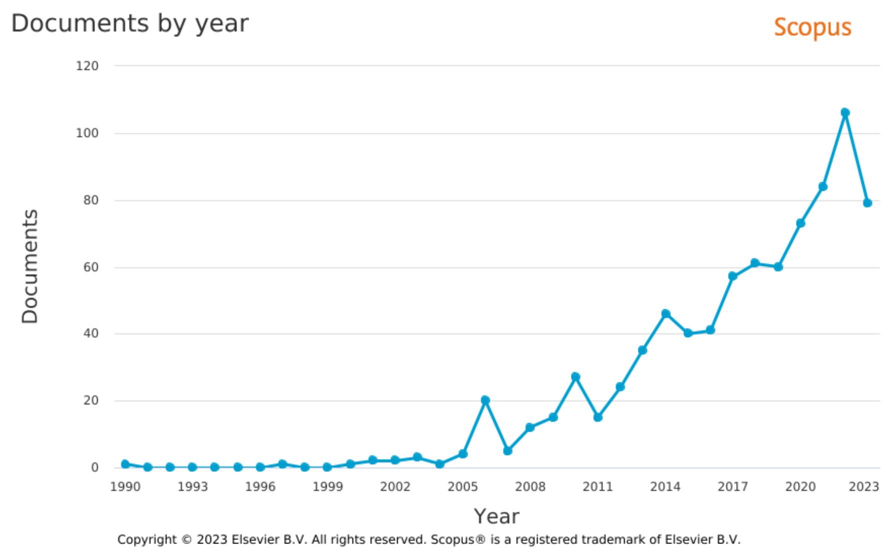

Figure 2: *Documents by year*

Figure 3 below reveals the number of publications per country and their connections. America, the United Kingdom, Australia, and South Africa had the highest number of documents published between 2014 and 2023.

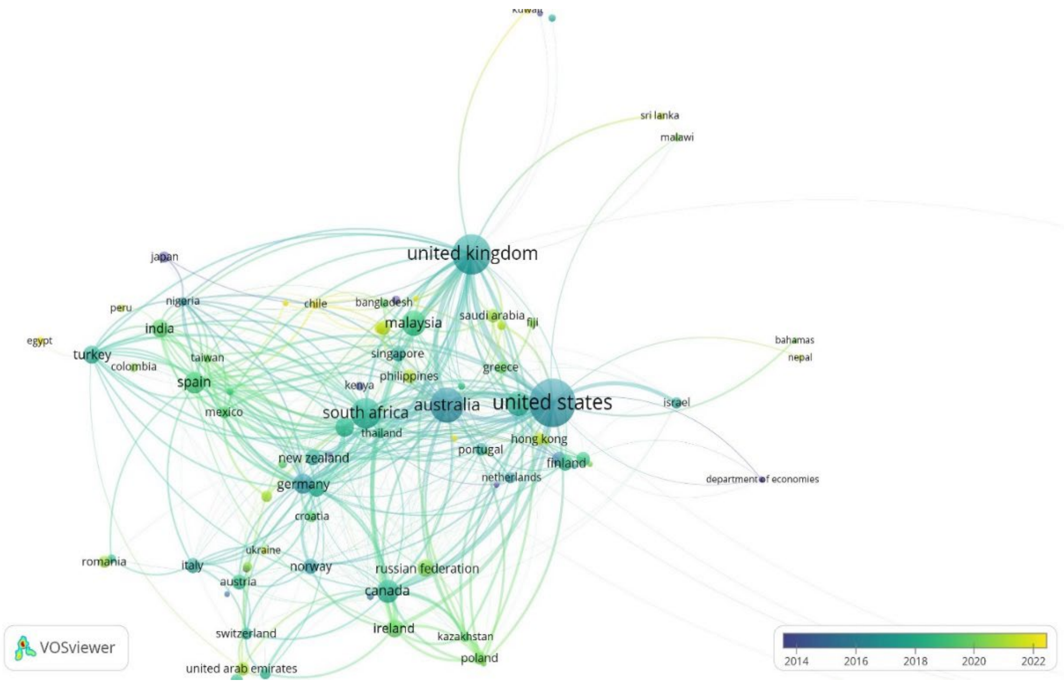

Figure 3: *Bibliometric countries*

Figure 4 reveals that most of the reviewed articles were from social sciences, accounting for 60.9%, followed by computer science at 30.4%. Business management and engineering each represented 4.3%. This once again demonstrates a growing interest in this area of study, particularly within the fields of social sciences and computer science, while engineering is still taking initial steps at 4.3%.

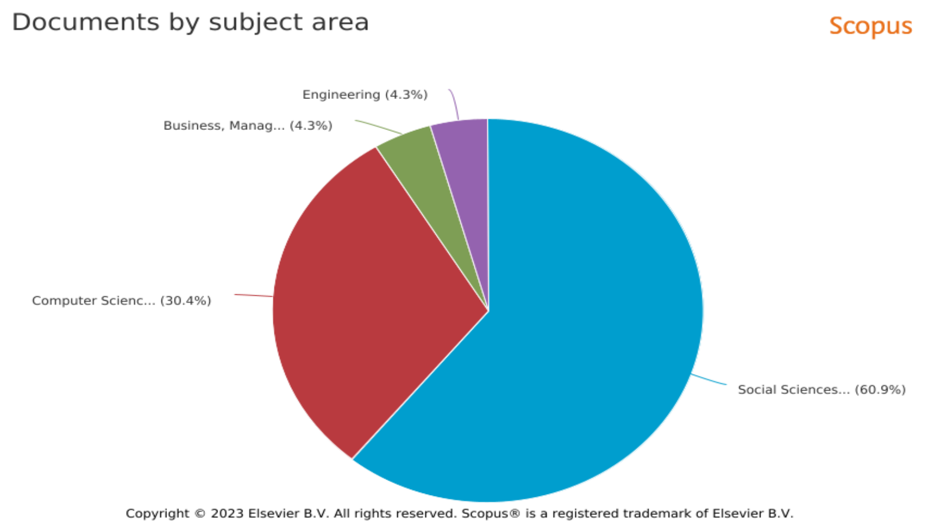

Figure 4: *Documents by subject*

Figure 5 below reveals that 52.9% of documents used were journals, followed by conference proceedings at 29.4%, book chapters at 11.8%, and lastly, books at 5.9%. All the documents have been peer-reviewed.

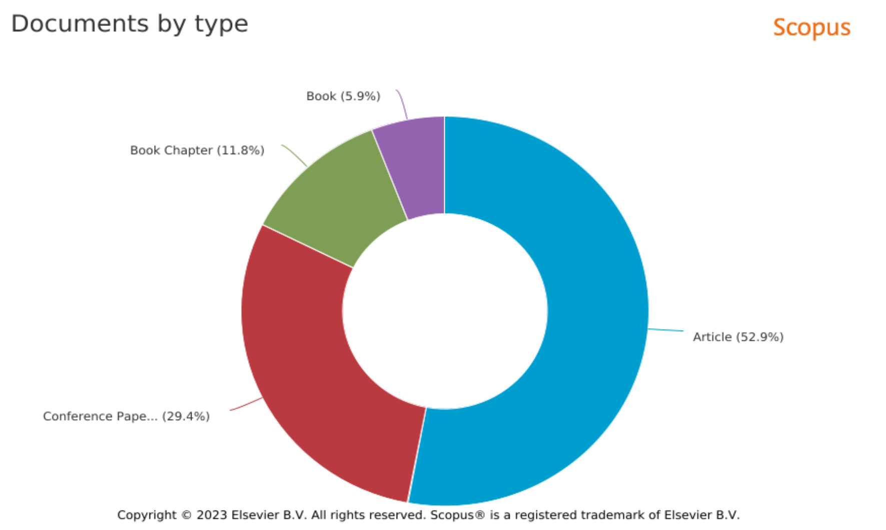

Figure 5: *Document source*

Table 1 below reveals the journals used for the SRL, including the publication period and the year of publication of the articles. This result shows the evolution and interest in the topic over the years. Table 1 reveals journals, books, book chapters, and conference proceedings such as Contemporary Issues in Technology and Teacher Education, with an article published in 2009 and cited 6,598; Telemanipulator and Telepresence Technologies, with an article published in 1995 and cited 4,586; The British Journal of Sociology, with an article published in 2000 and cited 3,144; Computers & Education, with articles published in 2013, 2012, and 2011, cited 3,892; Journal of Research on Technology in Education, which published an article in 2009, cited 2,156; Teachers College Record, which published an article in 2002, cited 1,800; Journal of Technology and Teacher Education, which published an article in 2008, cited 580; The Review of Higher Education, which published an article in 2008, cited 357; British Journal of Educational Technology, which published two articles in 2013 and 2006, cited 579; The Journal of Open, Distance and e-Learning, which published an article in 2002, cited 317; Postdigital Science and Education, which published an article in 2021, cited 232; and International Perspectives on the Goals of Universal Basic and Secondary Education, which published an article in 2009, cited 100. The authors only highlighted the highly cited documents; this study rigorously searched the databases for documents that have looked into the topic in depth.

Table 1: *Document citations*

Item	Title	Year	Citation
1	Contemporary issues in technology and teacher education	2009	6598
2	Telemanipulator and telepresence technologies	1995	4586
3	The British journal of sociology	2000	3144
4	Computers & Education	2013,2012,2011	3892
5	Journal of Research on Technology in Education	2009	2156
6	Teachers College Record,	2002	1800
7	Journal of Technology and Teacher Education	2008	580
8	The Review of Higher Education	2008	357
9	British journal of educational technology	2013,2006	579
10	The Journal of Open, Distance and e-Learning	2002	317
11	Postdigital Science and Education	2021	232
12	International perspectives on the goals of universal basic and secondary education	2009	100
13	E-Learning and Digital Media	2021	25
14	Social Sciences and Education Research Review	2018	23
15	International Journal of Technology and Design Education	2022	16
16	Computers and Education: Artificial Intelligence	2023	13
17	Acta Sociologica,	1997	12
18	ASCILITE 2011 - The Australasian Society for Computers in Learning in Tertiary Education	2010	10
19	IEEE Region 10 Annual International Conference, Proceedings/TENCON	2008	10
20	New Review of Academic Librarianship	2018	8
21	Lecture Notes in Educational Technology. Springer	2020	4
22	CSEDU 2014 - Proceedings of the 6th International Conference on Computer Supported Education	2014	3
23	ASCILITE 2011 - The Australasian Society for Computers in Learning in Tertiary Education	2011	3

4. Presentation of Results

This section systematically presents the findings from twenty-three studies, categorising them into key themes relevant to engineering education, particularly in the integration of technology, interdisciplinary collaboration, and private sector engagement. The analysis focuses on how these elements can enhance academic rigor, foster critical thinking, and prepare students for the challenges of a globalised workforce.

4.1 Technological advancements in engineering education

The adoption of multimedia learning programs relies on two fundamental aspects: human-machine interaction and the encoding of diverse information formats, including text, images, sound, and audiovisual elements (Khusainova & Galikhanov, 2022; Pigozzi, 2009). Advances in technology have enhanced these capabilities, enabling more immersive and interactive learning environments. However, historical limitations in technological infrastructure have affected the effectiveness of these approaches (Rapanta et al., 2021).

4.2 Effectiveness of educational technology in pedagogy

The differentiation of teaching and learning processes through technology is widely recognised across 23 studies. The evolution of Technology-Enhanced Adaptive Learning Environments (TEALE) has facilitated more personalised educational experiences (McLain, 2022; Foster, 2001). Learning is viewed as a cumulative process in which isolated knowledge elements are integrated into broader frameworks of understanding (Howells, 2018). Ed-tech pedagogy, as defined by Koehler and Mishra (2009) and Harris et al. (2009), extends beyond mere technology integration, emphasising its role in enriching the educational journey.

4.3 Enhancing instructional delivery and personalised learning

Technological tools have diversified instructional delivery methods. Multimedia presentations, interactive simulations, and online learning platforms enhance conceptual understanding and engagement. Learning Management Systems (LMS) and educational applications facilitate adaptive learning experiences, tailoring content to individual student needs (Zhao et al., 2002; Danilaev & Malivanov, 2020; Ferdig, 2006).

4.4 Interdisciplinary collaboration and communication

Technology fosters collaboration among educators, students, and industry professionals. Virtual classrooms, discussion forums, and video conferencing tools enable seamless communication, extending interactions beyond traditional learning environments (Collis & Moonen, 2002; Ferdig, 2006; Jirgensons, 2014). These advancements promote interdisciplinary learning, aligning engineering education with real-world problem-solving.

4.5 Access to information and knowledge resources

The digitalisation of educational content provides engineering students with access to vast repositories of academic materials, including e-books, research papers, and video tutorials. This ensures exposure to diverse perspectives and up-to-date industry knowledge (Mpofu-Hamadziripi et al., 2022).

4.6 Active learning and blended learning approaches

Active learning techniques, supported by technology, enhance student engagement through problem-solving exercises, simulations, and virtual laboratories (Southworth et al., 2023; Martin et al., 2011; Levin & Wadmany, 2008). Blended learning models combine traditional instruction with online components, accommodating varied learning styles and schedules. Formative assessment tools, such as quizzes and real-time feedback mechanisms, help address individual learning needs.

4.7 Digital literacy and responsible technology use

Engineering education must emphasise digital citizenship, ensuring students understand responsible internet use, cybersecurity, and ethical considerations in digital learning environments (Jirgensons, 2014).

4.8 Professional development for educators

The effective integration of technology in engineering education requires continuous professional development for educators. Staying updated on emerging educational technologies and best practices is essential for maintaining instructional quality and ensuring equitable access to learning tools (McLain, 2022; Rapanta et al., 2021).

4.9 Information technology and quality enhancement

Advancements in information technology have transformed higher education by improving communication, knowledge storage, and access to academic resources (Jirgensons, 2014). Digital libraries and online research databases expand learning opportunities. However, concerns about knowledge ownership, intellectual property, and the sustainability of distance education models remain significant (Karabulut-Ilgu et al., 2018). The intersection of efficiency, access, and quality must be carefully managed to uphold educational integrity (Wu et al., 2013; Howells, 2018).

4.10 Flexible learning models and institutional challenges

Flexible learning approaches offer students greater autonomy in their educational journey. However, effective implementation requires strategic institutional planning, technological infrastructure, and well-defined pedagogical frameworks (Munir et al., 2024; Chen & Tsai, 2012; Kondratyev, Kazakova, Kuznetsova, 2022).

4.11 Emerging technologies in engineering education

Augmented Reality (AR) is increasingly integrated into engineering education, providing immersive learning experiences that enhance student engagement and conceptual comprehension (Chen & Tsai, 2012; Zhao et al., 2002). AR applications, including mobile AR and remote laboratories, support hands-on learning, correct misconceptions, and bridge the gap between theoretical and practical knowledge (Chang et al., 2013; Milgram et al., 1995).

5. Discussion of Findings

The findings underscore the necessity of a student-centred approach in engineering education, where technology enhances personalised learning, fosters interdisciplinary collaboration, and prepares students for an evolving workforce. Professional development for educators remains critical to ensuring the effective use of technology, while issues of accessibility, infrastructure, and ethical considerations require ongoing attention. Augmented Reality, when aligned with learning objectives, offers transformative potential. However, successful implementation demands careful planning and continuous assessment. The shift towards flexible learning models highlights the need for scalable solutions tailored to diverse educational needs.

Ultimately, engineering education must balance technological integration, interdisciplinary engagement, and private sector collaboration while maintaining academic rigor and fostering innovation. Continuous evaluation and refinement of teaching strategies will be essential in preparing students to thrive in an increasingly globalised and technology-driven professional landscape.

5.1 Justification for policy adoption

The increasing demands of globalisation, rapid technological advancements, and the growing involvement of the private sector in education necessitate a fundamental rethinking of engineering education. Traditional pedagogical models, while effective in the dissemination of foundational knowledge, often fail to keep pace with the evolving needs of the global economy and industry. Engineering graduates today require a robust blend of technical expertise, creativity, problem-solving abilities, and adaptability to meet the challenges posed by automation, artificial intelligence, and interdisciplinary technological convergence.

To bridge this gap, higher education institutions must adopt policies that prioritise the seamless integration of emerging technologies such as Artificial Intelligence (AI), Augmented Reality (AR), Virtual Reality (VR), and Learning Management Systems (LMS) into engineering curricula. These technologies enhance instructional delivery, enable personalised learning, and foster engagement through immersive and interactive educational experiences. Policy frameworks should support investments in digital infrastructure, faculty training, and research initiatives that promote the effective use of these technologies.

Furthermore, engineering education must embrace interdisciplinary collaboration by facilitating partnerships across different academic disciplines, research fields, and industry sectors. By integrating entrepreneurship, design thinking, and sustainability into engineering programmes, institutions can produce graduates who are not only technically proficient but also capable of leading innovation and tackling complex global challenges. Policies should encourage interdisciplinary coursework, cross-sector collaborations, and real-world problem-solving experiences through project-based learning and industry internships.

Another crucial policy consideration is the equitable accessibility and inclusivity of engineering education. With globalisation driving increased competition among institutions and expanding opportunities for remote and distance learning, universities must ensure that technological integration does not create a digital divide. Policies should address affordability, digital literacy training, and the development of open-access educational resources to ensure that all students, regardless of socioeconomic background, have the tools needed for success.

Finally, maintaining academic rigour and fostering critical thinking must remain at the core of engineering education reforms. While technology offers powerful tools for enhanced learning, its adoption should not compromise the depth of analytical and theoretical foundations that engineering education requires. Institutions must implement continuous assessment mechanisms that evaluate not only technical skills but also higher-order thinking, creativity, and problem-solving abilities. Accreditation bodies, industry stakeholders, and educational policymakers must collaborate to establish standards that uphold both innovation and academic excellence. Thus, by implementing forward-thinking policies that integrate technology, interdisciplinary approaches, and private-sector collaboration, engineering education can effectively prepare students for the demands of the 21st-century workforce while maintaining its fundamental mission of advancing knowledge, research, and societal progress.

6. Limitation and Future work

The study was limited to published journals written in English articles. A need has been identified for a Long-term Impact Assessment to investigate the long-term effects of technology-enhanced pedagogy on students' academic performance, retention rates, and career success. This includes exploring how the skills acquired through technology-enhanced learning translate into real-world applications and job market demands. In terms of Teacher Training and Professional Development, effective methods for training and developing educators in technology integration should be examined. Furthermore, the impact of various professional development programmes on teacher confidence and competence in using educational technology should also be evaluated. Lastly, the study has identified that the accessibility and inclusivity aspects of technology-enhanced learning need to be examined, including strategies to ensure that all students, particularly those with disabilities and from underserved communities, can benefit from technology in education.

7. Conclusion

Engineering education must embrace a student-centred approach, leveraging technology to enhance personalised learning, foster interdisciplinary collaboration, and prepare students for the evolving demands of a globalised workforce. The integration of educational technology, including Learning Management Systems (LMS), virtual simulations, and augmented reality (AR), must align with specific learning objectives to maximise engagement and knowledge retention. Continuous professional development for educators is essential to equip them with the skills necessary for effective technology integration. Additionally, ensuring accessibility and inclusivity in technology-enhanced learning environments is crucial to providing equitable educational opportunities for all students, regardless of background or ability. Augmented Reality (AR) has the potential to bridge the gap between theory and practice by enabling students to interact with virtual objects and real-world engineering scenarios. However, its implementation must be accompanied by ethical considerations, including data privacy and responsible content use. Flexible learning models, supported by robust technological infrastructure, allow for greater customisation of learning experiences but require strategic planning to ensure engagement and effectiveness. Collaboration between universities and the private sector can enhance the relevance of engineering curricula, aligning them with industry needs. However, maintaining academic rigour and fostering critical thinking remain paramount. Effective assessment strategies, incorporating formative and summative evaluations, are necessary to track student progress and refine teaching methodologies. Ultimately, continuous evaluation and feedback from educators, students, and industry stakeholders are vital to optimising technology-enhanced learning. By strategically integrating technology, fostering interdisciplinary collaboration, and maintaining educational quality, engineering education can effectively prepare students for the challenges and opportunities of a rapidly evolving global landscape.

8. Declarations

Author Contributions: Conceptualisation (N.X.M. & B.M.); Literature review (N.X.M. & B.M.); methodology (**B**.M.); software (N/A.); validation (N.X.M.); formal analysis (N.X.M. & B.M.); investigation (N.X.M. & B.M.); data curation (N.X.M.) drafting and preparation (N.X.M. & B.M); review and editing (N.X.M. & B.M); supervision (N/A); project administration (N.X.M.); funding acquisition (N/A). All authors have read and approved the published version of the article.

Funding: This research did not receive any external funding. The Article Processing Charge (APC) was covered by Walter Sisulu University.

Acknowledgements: The Authors declare no acknowledgements.

Conflict of Interest: The authors declare no conflict of interest.

Data Availability: This review is based entirely on publicly available data and information sourced from peer-reviewed articles, reports, and other academic publications cited in the manuscript. No new primary data were generated or analysed during this study. Readers may refer to the cited sources for detailed information.

References

Castells, M. (2000). Materials for an exploratory theory of the network society. *The British Journal of Sociology*, *51*(1), 5–24. https://doi.org/10.1111/j.1468-4446.2000.00005.x

Chang, H. Y., Wu, H. K., & Hsu, Y. S. (2013). Integrating a mobile augmented reality activity to contextualise student learning of a socio-scientific issue. *British Journal of Educational Technology*, *44*(3). https://doi.org/10.1111/j.1467-8535.2012.01379.x

Chen, C. M., & Tsai, Y. N. (2012). Interactive augmented reality system for enhancing library instruction in elementary schools. *Computers & Education*, *59*(2), 638-652. https://doi.org/10.1016/j.compedu.2012.03.001

Collis, B., & Moonen, J. (2002). Flexible learning in a digital world. *Open Learning: The Journal of Open, Distance and e-Learning*, *17*(3), 217–230. https://doi.org/10.1080/0268051022000048228

Danilaev, D. P., & Malivanov, N. N. (2020). Technological education and engineering pedagogy. *The Education and Science Journal*, *22*(3), 55-82. https://doi.org/10.17853/1994-5639-2020-3-55-82

Eden, C. A., Chisom, O. N., & Adeniyi, I. S. (2024). Harnessing technology integration in education: Strategies for enhancing learning outcomes and equity. *World Journal of Advanced Engineering Technology and Sciences*, *11*(2), 001-008. https://doi.org/10.30574/wjaets.2024.11.2.0071

Ferdig, R. E. (2006). Assessing technologies for teaching and learning: Understanding the importance of technological pedagogical content knowledge. *British Journal of Educational Technology*, *37*(5), 749-760. https://doi.org/10.1111/j.1467-8535.2006.00559.x

Foster, L. (2001). Technology: Transforming the landscape of higher education. *The Review of Higher Education*, *25*(1), 115-124. https://dx.doi.org/10.1353/rhe.2001.0018

Ghafar, A. (2020). Convergence between 21st century skills and entrepreneurship education in higher education institutes. *International Journal of Higher Education*, *9*(1), 218. https://doi.org/10.5430/ijhe.v9n1p218

Harris, J., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education*, *41*(4), 393-416. https://doi.org/10.1080/15391523.2009.10782536

Howells, K. (2018). The future of education and skills: Education 2030: The future we want.

Huang-Saad, A., Morton, C., & Libarkin, J. C. (2018). Entrepreneurship assessment in higher education: A research review for engineering education researchers. *Journal of Engineering Education*, *107*(2), 263. https://doi.org/10.1002/jee.20197

Jirgensons, M. (2014, April). Educating the future with disruptive e-learning solutions. In *International Conference on Computer Supported Education* (Vol. 2, pp. 65-70). SCITEPRESS. https://doi.org/10.5220/0004846500650070

Karabulut-Ilgu, A., Jaramillo Cherrez, N., & Jahren, C. T. (2018). A systematic review of research on the flipped learning method in engineering education. *British Journal of Educational Technology*,*49*(3), 398-411. https://doi.org/10.1111/bjet.12548

Khusainova, G. R., & Galikhanov, M. F. (2022, November). Development of engineering university educator's creativity within the framework of the discipline "innovations in engineering pedagogy". In*AIP Conference Proceedings* (Vol. 2647, No. 1). AIP Publishing. https://doi.org/10.1063/5.0104352

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*,*9*(1), 60-70.

Kondratyev, V. V., Kazakova, U. A., & Kuznetsova, M. N. (2022). Development and implementation of the module "Engineering, education and pedagogy in Industry 4.0" in the structure of the curriculum "Innovative Pedagogy for Teachers of Engineering Universities" (iPET). In M. E. Auer, H. Hortsch, O. Michler, & T. Köhler (Eds.), Mobility for smart cities and regional development - challenges for higher education. ICL 2021. Lecture Notes in Networks and Systems (Vol. 390). Springer. https://doi.org/10.1007/978-3-030-93907-6_68

Levin, T., & Wadmany, R. (2008). Teachers' views on factors affecting effective integration of information technology in the classroom: Developmental scenery. *Journal of Technology and Teacher Education*,*16*(2), 233-263. https://doi.org/10.1016/j.compedu.2011.04.003

Martin, S., Diaz, G., Sancristobal, E., Gil, R., Castro, M., & Peire, J. (2011). New technology trends in education: Seven years of forecasts and convergence. *Computers & Education*,*57*(3), 1893-1906. https://doi.org/10.1016/j.compedu.2011.04.003

McLain, M. (2022). Towards a signature pedagogy for design and technology education: A literature review. *International Journal of Technology and Design Education*,*32*(3), 1629-1648. https://doi.org/10.1007/s10798-021-09667-5

Michalaka, D., & Davis, W. J. (2015). Application of active learning techniques in undergraduate civil engineering curriculum. https://doi.org/10.18260/p.23558

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995, December). Augmented reality: A class of displays on the reality-virtuality continuum. In *Telemanipulator and telepresence technologies* (Vol. 2351, pp. 282–292). SPIE. https://doi.org/10.1117/12.197321

Miranda, C., Goñi, J., Berhane, B., & Carberry, A. (2020). Seven challenges in conceptualising and assessing entrepreneurial skills or mindsets in engineering entrepreneurship education. *Education Sciences*, *10*(11), 309. https://doi.org/10.3390/educsci10110309

Mpofu-Hamadziripi, N., Rauch, F., & Dulle, M. (2022, February). Transforming curricula in higher education: Description of two perspectives from the Global South and the Global North. In *Frontiers in Education* (Vol. 7, p. 775406). Frontiers Media SA. https://doi.org/10.3389/feduc.2022.775406

Munir, M. T., Jamwal, P. K., Li, B., Carter, S., & Hussain, S. (2024). Revolutionising engineering pedagogy: The role of 3D printing in modern engineering education. *Innovations in Education and Teaching International*, 1–19. https://doi.org/10.1080/14703297.2024.2346554

Ogwu, E. N., Emelogu, N. U., Azor, R. O., & Okwo, F. A. (2022). Educational technology adoption in instructional delivery in the new global reality. *Education and Information Technologies*, *28*(1), 1065. https://doi.org/10.1007/s10639-022-11203-4

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T., Mulrow, C. D., Shamseer, L., & Moher, D. (2020). Mapping of reporting guidance for systematic reviews and meta-analyses generated a comprehensive item bank for future reporting guidelines. *Journal of Clinical Epidemiology*, *118*, 60–68. https://doi.org/10.1016/j.jclinepi.2019.11.010

Pepin, B., Biehler, R., & Gueudet, G. (2021). Mathematics in engineering education: A review of the recent literature with a view towards innovative practices. *International Journal of Research in Undergraduate Mathematics Education*, *7*, 163–188. https://doi.org/10.1007/s40753-021-00139-8

Pigozzi, M. J. (2009). Quality education: A UNESCO perspective. In *International perspectives on the goals of universal basic and secondary education* (pp. 249–259). Routledge. https://doi.org/10.4324/9780203882146

Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., & Koole, M. (2021). Balancing technology, pedagogy, and the new normal: Post-pandemic challenges for higher education. *Postdigital Science and Education*, *3*(3), 715–742. https://doi.org/10.1007/s42438-021-00249-1

Southworth, J., Migliaccio, K., Glover, J., Reed, D., McCarty, C., Brendemuhl, J., & Thomas, A. (2023). Developing a model for AI across the curriculum: Transforming the higher education landscape via innovation in AI literacy. *Computers and Education: Artificial Intelligence*, 4, 100127. https://doi.org/10.1016/j.caeai.2023.100127

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities, and challenges of augmented reality in education. *Computers & Education*, 62, 41-49. https://doi.org/10.1016/j.compedu.2012.10.024

Ye, H., & Li, C. (2022). Engineering education understanding expert decision system research and application. In V. Kumar (Ed.), *Computational intelligence and neuroscience* (Vol. 2022, p. 1). Hindawi Publishing Corporation. https://doi.org/10.1155/2022/9662301

Zhao, Y., Pugh, K., Sheldon, S., & Byers, J. L. (2002). Conditions for classroom technology innovations. *Teachers College Record*, *104*(3), 482-515. https://doi.org/10.1177/016146810210400308