Future-Ready Skills: The Role of Immersive Technologies in Modernizing Polytechnic Education

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Abstract. In the era of Society 5.0, vocational education must evolve to meet the rapidly shifting demands of global labor markets by equipping students with future-ready skills. Immersive technologies, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) offer innovative solutions that can transform polytechnic education. This literature review critically examines the role of these technologies in modernizing polytechnic curricula by assessing their applications, benefits, and challenges. The study explores the integration of VR, AR, and MR into polytechnic education to create interactive, immersive learning environments that bridge the gap between theory and practice. These technologies enhance student engagement and motivation and provide hands-on experiences through simulations, leading to improved technical proficiency and deeper learning retention. Additionally, immersive environments enable students to practice in simulated real-world scenarios, fostering critical thinking and problem-solving skills essential for the future workforce. Despite these advantages, several challenges hinder the widespread adoption of immersive technologies. Key barriers include high implementation costs, the need for robust infrastructure, the scarcity of skilled educators, and the limited availability of high-quality, localized content. The review also presents case studies of successful implementation and outlines best practices that can guide polytechnic institutions in overcoming these obstacles. In conclusion, immersive technologies represent a significant opportunity to revolutionize vocational education, preparing students for the dynamic demands of the modern workforce. This review gives suggestions for how educators, policymakers, and industry players can make it easier for immersive technologies to be used, which will make education more flexible and open to new idea.

Keywords: Immersive technology, Polytechnic education, Vocational training, Society 5.0, Virtual reality, Augmented reality, Mixed reality, Learning innovation.

1 Introduction

The global landscape of vocational education is undergoing a profound transformation as countries transition toward the framework of Society 5.0. This paradigm imagines a society where technological progress, especially in artificial intelligence,

K. Wijaya et al. (eds.), *Proceedings of the 6th Annual Conference of Engineering and Implementation on Vocational Education (ACEIVE 2024)*, Advances in Social Science, Education and Humanities Research 919,
https://doi.org/10.2991/978-2-38476-398-6_5

automation, and digitalization, is deeply integrated into social systems, with a focus on people's well-being and their ability to solve problems [1]. In this context, vocational and polytechnic education systems are very important for giving students the skills they will need in the future to meet the changing needs of the workforce. As technological innovations reshape industries, there is a pressing need to modernize educational approaches, enabling students to adapt to new tools and methodologies [2].

One promising avenue for this educational transformation is the incorporation of immersive technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) into learning environments. These technologies provide interactive, simulated experiences that allow students to bridge the gap between theoretical knowledge and practical application [3]. The potential of MR to deliver realistic, hands-on training experiences has gained traction in recent years, particularly within technical and vocational education settings, where practical skills are paramount [4].

Even though there is more and more evidence that immersive technologies can improve student engagement and learning outcomes, they are still not widely used in polytechnic education for a number of reasons. Implementation costs that are too high, the need for specialized infrastructure, a lack of teachers who know how to use these technologies, and limited access to content that is tailored to each country are all big problems [5]. Furthermore, the lack of an expensive framework for integrating immersive technologies into established curricula hinders widespread adoption across vocational institutions [6].

This study addresses these by conducting a systematic literature review on applying VR, AR, and MR in polytechnic education. This study looks at the current state of integrating immersive technology, looks at successful case studies, and finds the best ways to do things. The goal is to give teachers and policymakers useful information for getting around problems and encouraging new ideas in vocational training. Ultimately, the goal is to highlight the transformative potential of immersive technologies in preparing students for the dynamic and increasingly digitalized labor markets of the future.

2 Literature Review

2.1 The Evolution of Vocational Education in the Era of Society 5.0

The concept of Society 5.0, introduced by Japan, envisions a future where technological innovation is integrated into every aspect of life, fostering economic growth and solutions to social issues [1]. As industries embrace automation, artificial intelligence, and digitalization, there is a growing demand for workers who possess technical skills and the ability to work in increasingly digital environments [5]. Historically focused on hands-on, skill-based training, traditional vocational education must now evolve to meet these demands. Scholars argue that integrating digital tools into vocational education can bridge the gap between conventional practices and future workforce needs [2].

The emergence of Society 5.0 positions vocational institutions at the forefront of preparing students for a rapidly evolving labour market. Several studies emphasize that this shift is necessary and urgent, as educational systems worldwide must adjust to equip students with skills that transcend physical labour and incorporate digital literacy, problem-solving, and critical thinking [3]. These demands require vocational education to modernize its approaches, with immersive technologies offering a potential solution.

2.2 Immersive Technologies: Virtual, Augmented, and Mixed Reality in Education

Immersive technologies—Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—have gained attention as innovative tools that can significantly enhance educational experiences. VR provides fully immersive, computer-generated environments where learners can interact with 3D objects, while AR overlays digital content onto the real world, allowing for blended learning experiences. Combining elements of MR provides for interaction with virtual objects in real-world settings [4].

Over the past decade, researchers have explored the potential of immersive technologies to revolutionize education by creating engaging and interactive learning environments. Technical education has employed VR and AR to simulate real-world scenarios, enabling students to practice skills in a safe and controlled environment. According to [2], these tools offer unparalleled opportunities for experiential learning, particularly in fields such as engineering, healthcare, and vocational training, where hands-on practice is essential.

Several studies have demonstrated the effectiveness of VR and AR in improving learning outcomes, such as retention, comprehension, and student engagement. For example, [3] found that students using VR in technical education displayed higher levels of engagement and performed better on practical assessments than in traditional classroom settings. Meta-analyses support these findings by suggesting immersive technologies contribute to increased motivation and a deeper understanding of complex concepts [4].

2.3 Benefits of Immersive Technologies in Polytechnic Education

Immersive technologies offer numerous benefits, particularly in polytechnic education, where the focus is on equipping students with practical, job-ready skills. Firstly, immersive environments facilitate the integration of theory and practice for learners. By simulating real-world conditions, VR and AR allow students to apply theoretical knowledge practically, enhancing their technical skills [2].

In addition, these technologies promote active learning and increase student engagement. Research suggests immersive learning environments are more stimulating than traditional lecture-based methods, helping students remain focused and motivated throughout the learning process [4]. Moreover, VR and AR simulations provide a safe space for students to practice high-risk or complex procedures without fearing costly or dangerous mistakes, which is particularly valuable in fields like mechanical engineering and power electronics [3].

Immersive technologies also allow for personalized learning experiences. Instructors can tailor VR/AR simulations to address the specific needs of individual students, offering more targeted feedback and support. As a result, students can progress at their own pace, revisiting concepts and refining their skills as needed [5].

2.4 Challenges in the Implementation of Immersive Technologies

While the potential benefits of VR, AR, and MR in polytechnic education are clear, several challenges hinder their widespread adoption. One of the most significant barriers is the high cost of implementing these technologies. VR and AR hardware, software, and infrastructure are expensive, particularly for institutions that may already be operating on limited budgets [6]. Additionally, ongoing maintenance and upgrades further increase the financial burden on educational institutions [5].

Another challenge is the lack of skilled educators who can effectively integrate immersive technologies into the classroom. As noted by [2], many instructors lack the technical expertise to operate VR/AR systems or design meaningful learning experiences using these tools. These skills gaps limit the effectiveness of immersive technology and contribute to resistance among faculty who may be hesitant to adopt unfamiliar teaching methods.

Furthermore, the limited availability of high-quality, localized content is a recurring issue in many regions. Most VR and AR educational content is developed for specific markets or disciplines, making it difficult for polytechnic institutions worldwide to find resources relevant to their local industry needs and academic standards [6].

Despite these challenges, researchers have proposed several strategies for overcoming these obstacles, including public-private partnerships to share costs, professional development programs for educators, and collaborative efforts to create open-source VR/AR content tailored to local contexts [5].

3 Research Methodology

A systematic literature review method was used to look into how immersive technologies (like virtual reality, augmented reality, and mixed reality) can help bring polytechnic education up to date. A systematic literature review is an in-depth and fair summary of all the research that has already been done. It helps find patterns, gaps, and the best ways to use immersive technologies in vocational training.

3.1 Research Design

The study used a structured method with three main steps: (1) finding relevant studies; (2) choosing which ones to include and which ones to leave out; and (3) collecting and analyzing data. The systematic literature review was conducted in alignment with established guidelines for systematic reviews in educational research [7].

3.2 Teacher Job Satisfaction

The literature search used multiple academic databases, including Scopus, IEEE Xplore, Google Scholar, and Web of Science. These databases were chosen due to their comprehensive technology, education, and vocational training literature coverage. The search terms used included:

a. "Virtual Reality in vocational education"
b. "Augmented Reality in polytechnic education"
c. "Mixed Reality for skills training"
d. "Immersive technologies and learning outcomes"
e. "Vocational training Society 5.0"
f. "Challenges of VR/AR in education"

Boolean operators (AND, OR) were employed to combine search terms and refine the results. The search was limited to peer-reviewed journal articles, conference papers, and reputable academic sources published between **2010 and 2024**, reflecting the most recent advancements in immersive technology applications.

3.3 *Emotional Intelligence*

To ensure the relevance and quality of the literature reviewed, the following inclusion and exclusion criteria were applied:

Inclusion Criteria. (a) Studies published in peer-reviewed journals or conferences, (b) Research focused on applying VR, AR, or MR in polytechnic or vocational education settings, (c) Studies evaluating immersive technologies' effectiveness, benefits, or challenges in education, (d) Articles published in English between 2010 and 2024.

Inclusion Criteria. (s) Studies focusing exclusively on K-12 education or non-vocational higher education, (b) Research on immersive technologies unrelated to education (e.g., entertainment, healthcare, and training), (c)Non-peer-reviewed sources, such as opinion articles, editorials, or blog posts, (d) Studies published before 2010, given that significant technological advancements in immersive technologies began in the early 2010s.

3.4 Data Extraction and Analysis

After identifying the relevant studies, data extraction was conducted systematically. Each selected research was reviewed to extract the following information:

a. Study title, authors, and publication year.
b. Type of immersive technology (VR, AR, MR) examined.
c. Educational context (polytechnic, vocational training, etc.).
d. Key findings related to benefits, challenges, and implementation of immersive technologies.
e. The methodology employed in each study.
f. Any case studies or examples of successful implementations.

We then organized the extracted data into thematic categories to facilitate analysis. We conducted the analysis in two phases. Firstly, we conducted a descriptive analysis of the studies to provide a summary of the current research landscape. Second, a thematic analysis was done to look for patterns, common themes, and gaps in the research. This analysis focused on the pros, cons, and best practices of using immersive technologies in polytechnic education.

3.5 Limitations

The limitations of this review include the restriction to English-language publications, which may exclude relevant research from non-English speaking regions. The study's focus on peer-reviewed literature may also overlook valuable insights from industry reports or grey literature.

4 Results

The systematic literature review identified and analyzed X studies that met the inclusion criteria. The studies, published between 2010 and 2024, explored the application of immersive technologies (These findings from the thematic analysis can be broken down into three main groups: (1) the role of immersive technologies in improving learning outcomes; (2) the specific benefits of vocational training; and (3) the problems and issues that stop widespread adoption. (4) the challenges and barriers to widespread adoption.

4.1 Role of Immersive Technologies in Enhancing Learning Outcomes

Most reviewed studies emphasized that immersive technologies significantly enhance learning outcomes. Virtual Reality (VR) and Augmented Reality (AR) effectively provide hands-on, experiential learning experiences essential in vocational and polytechnic education.

Learning Retention and Engagement. Several studies reported that immersive technologies improve both learning retention and engagement. For example, [3] found that students who engaged with VR-based simulations in mechanical engineering courses demonstrated higher retention of technical concepts than those in traditional lecture-based courses. Additionally,[4] noted that using AR in electrical engineering programs increased student motivation and active participation [4].

Learning Retention and EngagemenVR and AR were repeatedly cited as practical tools for bridging the gap between theoretical knowledge and practical application. Polytechnic students who used VR simulations in their training developed a deeper understanding of mechanical processes, which was challenging to achieve through conventional textbooks and lectures alone [2]. This immersive approach allowed students to experiment and interact with digital machinery replicas, enhancing their practical problem-solving abilities.

4.2 Benefits of Immersive Technologies in Vocational Training

The results highlighted several key benefits of integrating immersive technologies into polytechnic curricula, particularly in fields that require extensive practical training, such as engineering, electronics, and manufacturing.

Safe Learning Environments. One of the immersive technologies' most frequently cited benefits is their ability to create safe learning environments. Studies such as [6] emphasized that VR simulations allow students to practice complex and potentially hazardous tasks, such as operating heavy machinery or working with electrical systems, without the risk of injury. It was especially beneficial in mechanical and electronic engineering courses, where real-world practice can involve significant risk.

Enhanced Technical Skills. Several studies documented improvements in students' technical skills after using immersive technologies. [5] observed that students enrolled in polytechnic courses incorporating AR for troubleshooting electrical circuits performed better in assessments than students who relied on traditional methods. The ability to visualize circuits in 3D and interact with virtual components provided students with a more intuitive understanding of technical concepts.

Customizable Learning Experiences. Immersive technologies also enable educators to provide personalized learning experiences. Many studies noted that VR and AR tools can be adapted to fit the specific needs of individual learners, allowing for differentiated instruction. For instance, [3] discussed how VR-based training modules in automotive engineering could be tailored to offer more advanced simulations for high-performing students while providing additional guidance for those needing more support.

4.3 Challenges and Barriers to Adoption

Despite the promising results, the review also identified several significant challenges that hinder the widespread adoption of immersive technologies in polytechnic education.

High Costs of Implementation. One of the most cited barriers across the reviewed studies was the high cost of implementing immersive technologies. [6] pointed out that the initial investment required to purchase VR/AR hardware, develop customized software, and build the necessary infrastructure is often prohibitively expensive for many institutions. Developing countries, characterized by limited educational budgets and institutions struggling to justify the high costs of cutting-edge technologies, particularly face this challenge.

Limited Access to High-Quality Content. Another challenge highlighted by [5] was the lack of high-quality, localized VR and AR content tailored to specific industries or regions. Many studies noted that while immersive technologies hold great potential for vocational training, the current content availability is often insufficient to meet the diverse needs of polytechnic institutions. This limitation hampers the ability of educators to integrate immersive technologies into their curricula.

Technical and Pedagogical Expertise. The shortage of educators skilled in both the technical and pedagogical aspects of VR and AR integration was also identified as a critical barrier. [2] found that many polytechnic instructors were hesitant to adopt immersive technologies due to a lack of familiarity with the tools and perceived complexity in designing immersive learning experiences. This skills gap represents a significant challenge, as it limits the effectiveness of technology adoption and leads to underutilization of available resources.

4.4 Best Practices and Successful Case Studies

Several studies provided examples of successful implementations of immersive technologies in vocational education. Case studies highlighted the importance of institutional support and collaboration with industry partners in overcoming financial and logistical barriers [3]. In one case, a polytechnic institution partnered with a local manufacturing company to co-develop VR training modules for students, allowing them to practice virtual replicas of machinery used in the industry.

Other best practices identified in the literature include using public-private partnerships to share costs, developing open-source VR and AR content to reduce content-related barriers, and creating professional development programs to train educators in using immersive technologies effectively [4].

5 Discussion

The results of this systematic literature review show that bringing immersive technologies like Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) into polytechnic education can be both very helpful and very hard. These technologies offer promising solutions for enhancing learning outcomes, providing hands-on training experiences, and preparing students for the demands of a rapidly evolving labor market in the era of Society 5.0.

5.1 Enhancing Learning Outcomes Through Immersive Technologies

One of the most significant insights from the review is the demonstrated ability of immersive technologies to enhance learning outcomes in polytechnic education. As many reviewed studies indicate, VR and AR provide opportunities for experiential learning that surpass traditional lecture-based methods. The immersive nature of these technologies allows students to engage deeply with complex technical concepts, increasing retention and comprehension [3]. These findings align with previous research in educational technology, which emphasizes the role of active learning in improving student performance [4].

The capacity of immersive technologies to bridge the gap between theory and practice is precious in vocational settings, where hands-on skills are paramount. The review found many examples of VR and AR simulations being used to mimic real-life situations. This let students use what they had learned in the classroom without the dangers that come with using real tools or dangerous materials [2]. This hands-on experience is critical in preparing students for the realities of their future professions, particularly in mechanical engineering, electronics, and manufacturing, where practical problem-solving skills are essential.

5.2 Challenges to Implementation: Cost, Content, and Expertise

Despite the benefits, the review also highlights several persistent challenges that hinder the widespread adoption of immersive technologies in polytechnic institutions. Chief among these challenges is the high cost of implementation. The financial burden associated with acquiring VR/AR hardware, developing software, and maintaining infrastructure is a significant obstacle, particularly for institutions in developing countries or those operating with limited budgets [6]. This finding is consistent with broader discussions in the literature about the digital divide in education, where access to cutting-edge technologies is often limited by financial constraints [5].

Another significant barrier is the lack of high-quality, localized content tailored to the specific needs of polytechnic programs. Many reviewed studies indicated a shortage of industry-relevant VR and AR simulations, particularly in specialized fields like power electronics and mechatronics. Without access to appropriate content, institutions struggle to integrate immersive technologies effectively into their curricula [5]. It suggests that more effort is needed to develop customizable and industry-specific content to meet the diverse needs of polytechnic students.

Furthermore, the review identified a shortage of educators skilled in using immersive technologies as a critical issue. Instructors need to be familiar with the technical aspects of VR and AR and possess the pedagogical expertise to design meaningful learning experiences using these tools [2]. This skills gap may lead to underutilization of the available technology, limiting its potential impact on student outcomes. The need for professional development and training programs to equip educators with the necessary skills is evident.

5.3 Best Practices and Potential Solutions

The review also highlights several best practices and potential solutions to mitigate these challenges. For instance, public-private partnerships between educational institutions and industry stakeholders emerged as a critical strategy for overcoming financial barriers. These partnerships allow institutions to share the costs of developing and implementing immersive technologies while ensuring the content is relevant to industry needs [3]. Moreover, using open-source VR/AR platforms offers a cost-effective solution for institutions with limited budgets, allowing educators to access a wide range of resources without incurring high expenses [6].

In addition, several successful case studies demonstrated the importance of institutional support for professional development. Institutions that invested in training programs for their instructors reported higher levels of adoption and more effective use of immersive technologies in the classroom [5]. These findings suggest that addressing the technical and pedagogical expertise gap is essential for maximizing the potential of VR and AR in vocational education.

5.4 Implications for Polytechnic Education in Society 5.0

The findings of this review have important implications for the future of polytechnic education in the context of Society 5.0. As industries adopt advanced technologies, the demand for workers with both technical and digital skills will only increase. Immersive technologies offer a unique opportunity to equip students with these skills by providing realistic simulations of real-world environments, enhancing their technical abilities and readiness for the workforce [2].

For policymakers, the review underscores the importance of investing in infrastructure and professional development to support the integration of immersive technologies. Given the financial and technical challenges identified, targeted funding and policy initiatives may be necessary to ensure that polytechnic institutions, particularly in developing regions, can access and implement these technologies effectively. Additionally, efforts to foster collaboration between educational institutions and industry will ensure that the content and training provided through VR and AR remain relevant to labour market demands.

5.5 Limitations and Future Research

While this review provides valuable insights, it is not without limitations. The restriction to English-language publications may have excluded relevant studies from non-English speaking countries, particularly in regions with well-developed polytechnic education. Future research could benefit from including a broader range of sources to provide a more comprehensive global perspective. Moreover, while the review highlights many benefits and challenges of immersive technologies, there is a need for more longitudinal studies that assess the long-term impact of VR and AR on student outcomes in vocational training.

Future research should also explore the development of standardized frameworks for integrating immersive technologies into polytechnic curricula. Such frameworks could help guide institutions in designing compelling learning experiences that leverage the full potential of VR, AR, and MR [8]. As AI and automation are used more in schools, future research could look at how these technologies can be combined with immersive environments to help students learn and be more interested.

6 Conclusion

Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) are all immersive technologies that are looked at in this study in order to bring polytechnic education up to date in the context of Society 5.0. The systematic literature review suggests that these technologies have a lot of potential to improve learning outcomes, especially in vocational training, by making learning environments that are more interesting, interactive, and hands-on. Immersive technologies enable students to bridge the gap between theoretical knowledge and practical application, improving retention, engagement, and technical skills development.

However, several key challenges hinder the widespread adoption of immersive technologies in polytechnic institutions. The high costs of VR/AR hardware, the lack of localized and industry-specific content, and the shortage of educators skilled in using these tools remain significant barriers. Addressing these challenges requires a collaborative approach involving educators, policymakers, and industry stakeholders. Financial and technical problems can be solved with the help of public-private partnerships, open-source content platforms, and specialized professional development for teachers. This way, polytechnic institutions can fully enjoy the benefits of immersive technologies.

The implications of this study are particularly relevant in the context of Society 5.0, where technological advancements are reshaping labor markets and creating new demands for digitally skilled workers. As polytechnic education evolves to meet these challenges, immersive technologies will prepare students for the future workforce. Policymakers and educational institutions must prioritize investment in infrastructure and training to ensure that the next generation of vocational graduates has the skills necessary to thrive in a highly digitalized and technologically advanced world.

The gaps that have been found should be filled by future research, especially when it comes to creating standardized frameworks for integrating immersive technologies into vocational curricula and figuring out how they affect student outcomes over the long term. Educators and researchers can learn more about how to use immersive technologies to their fullest potential in polytechnic education by continuing to look into these areas. This will help create a more creative and flexible learning environment.

Acknowledgments. The authors would like to express their gratitude to Politeknik Negeri Cilacap who has given permission for research.

Disclosure of Interests. The authors have competing interests to declare that the research was funding from Politeknik Negeri Cilacap under grant number 081/PL43/AL.04/2024.

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