

# Development Of A Virtual Reality Application Utilizing Milealab For Occupational Health And Safety Learning

<sup>1</sup> Hendra Jaya, <sup>2</sup>Sapto Haryoko, <sup>3</sup>Lu'mu, <sup>4</sup>Edy Sabara, <sup>5</sup>Sutarsi Suhaeb, <sup>6</sup>Indra Sukma

<sup>123456</sup>Electronic Engineering and Information Technology

<sup>1</sup>Faculty of Engineering, Makassar State University

<sup>1</sup>[hendra.jaya@unm.ac.id](mailto:hendra.jaya@unm.ac.id), <sup>2</sup>[sapto.haryoko@unm.ac.id](mailto:sapto.haryoko@unm.ac.id), <sup>3</sup>[lumu.taris@unm.ac.id](mailto:lumu.taris@unm.ac.id),  
<sup>4</sup>[edy.sabara@unm.ac.id](mailto:edy.sabara@unm.ac.id), <sup>5</sup>[sutarsi.suhaeb@unm.ac.id](mailto:sutarsi.suhaeb@unm.ac.id), <sup>6</sup>[indra.sukma@unm.ac.id](mailto:indra.sukma@unm.ac.id)

**Abstract**— This study aims to develop a Virtual Reality (VR) application utilizing the MileaLab platform as an innovative learning medium for Occupational Health and Safety (OHS) education in vocational settings. The research employs a Research and Development (R&D) approach based on the Plomp model, which consists of three main phases: preliminary research, prototyping, and assessment. The developed product is evaluated in terms of validity, practicality, and effectiveness. Expert validation results indicate that the VR application falls within the valid to highly valid category, with an average score of 3.56, demonstrating its feasibility as a learning medium. Furthermore, student responses (n = 43) reveal a high level of acceptance, with the majority of respondents expressing positive perceptions regarding usability, interactivity, and its contribution to improving learning readiness, conceptual understanding, and engagement. The immersive and interactive nature of the VR application enables students to experience realistic simulations of workplace hazards and safety procedures in a safe and controlled environment, thereby enhancing practical competencies and safety awareness. Despite these positive outcomes, several aspects require improvement, particularly in user interaction design, instructional clarity, and the expansion of simulation scenarios. Overall, the integration of VR technology through MileaLab represents a promising approach to transforming conventional OHS learning into a more experiential, engaging, and industry-relevant learning process in vocational education. (*Abstract*)

**Index Terms**— Virtual Reality, MileaLab, Occupational Health and Safety, Vocational Education, Learning Media, Experiential Learning (*key words*)

## I. INTRODUCTION (HEADING 1)

The advancement of modern technology has provided various solutions to address human challenges across multiple domains of life, particularly through the integration of digital systems and automation that enhance efficiency and improve the quality of life [1]. The current era is widely recognized as the age of science and technology, in which all aspects of human life are inseparable from these advancements, as technology has become a fundamental component of social, economic, and educational activities [2]. One of the primary foundations supporting the development of science and technology is mathematics, which possesses a strong logical structure and reasoning capability, making it essential in the development of various technological innovations such as artificial intelligence and scientific computing [3]. However, in the learning process, students often require considerable adaptation to understand abstract mathematical concepts due to their symbolic nature and the demand for higher-order thinking skills [4]. These challenges are particularly evident in mastering higher-order cognitive skills such as analysis, evaluation, and problem-solving, which require appropriate and contextual learning strategies [5].

The advancement of science and technology has significantly transformed the learning paradigm, particularly through the utilization of Information and Communication Technology (ICT), which enables broader, more flexible, and higher-quality access to education [6]. ICT provides opportunities to create more interactive and effective learning experiences through the integration of multimedia, digital platforms, and network-based learning that is not constrained by space and time [7]. This is further supported by various studies indicating that the use of ICT can enhance student engagement and learning outcomes through more collaborative and adaptive approaches [8]. Moreover, this transformation aligns with the paradigm of lifelong learning, which emphasizes the importance of self-directed, collaborative, and continuous learning in responding to global changes [9]. In the context of modern education, lifelong learning serves as a key foundation for developing 21st-century competencies that require flexibility, digital literacy, and critical thinking skills [10].

In the context of vocational education, particularly in the field of Occupational Health and Safety (OHS), the need for innovative learning methods has become increasingly important, as vocational education requires the integration of knowledge, skills, and job readiness aligned with industry demands [11]. OHS learning does not only emphasize theoretical aspects but also practical skills and risk awareness; therefore, instructional approaches must be capable of simulating real working conditions in a safe manner [12]. Simulation-based learning methods have been proven effective in enhancing understanding, skills, and safety, as they allow repeated practice without direct risks in the workplace [13; 14]. In addition, the use of interactive technology-based learning media, such as mobile applications and instructional videos, has been shown to improve students' understanding of OHS concepts and their readiness to face workplace risks [15; 16]. However, limitations in practical training facilities, the high risk of workplace accidents, and the lack of innovative learning media remain major challenges in the implementation of OHS education in vocational institutions [17]. Therefore, the development of innovative learning models based on industry collaboration, simulation, and digital technology is considered a strategic solution to comprehensively enhance OHS competencies [18].

Along with the rapid advancement of digital technology, Virtual Reality (VR) has emerged as a significant innovation in the field of education, capable of transforming traditional learning methods into more interactive and contextual approaches [19; 20]. VR enables the creation of immersive, realistic, and interactive simulated environments, allowing learners to understand complex concepts through direct experience [21; 22]. Moreover, this technology has been proven to enhance student engagement, concentration, and learning outcomes compared to conventional methods [23; 24].

In the context of occupational safety and health (OSH) education, VR provides a safe and controlled simulation environment in which students can identify potential hazards and understand safety procedures without exposure to real risks [25; 26].

Furthermore, VR facilitates realistic emergency response training, thereby improving learners' preparedness and knowledge retention when facing real-world situations in the workplace [27; 28]. The utilization of VR development platforms such as MileaLab in learning reflects a global trend in integrating virtual reality technology, enabling the creation of instructional content that is more accessible, interactive, and does not require complex programming skills, thereby supporting innovation in experience-based learning media [29]. The use of VR in occupational health and safety (OHS) education allows educators to design contextual scenarios that closely resemble real-world working conditions in a safe and controlled environment, enabling learners to practice without direct exposure to safety risks [30; 31].

The implementation of VR has been shown to enhance student engagement and learning motivation due to its immersive and interactive nature, fostering more compelling learning experiences compared to conventional methods [32; 33]. Furthermore, VR-based learning significantly strengthens conceptual understanding and improves learning outcomes by enabling repeated practice through realistic simulations [35; 35]. In the context of OHS, the use of VR has also been proven to improve practical competencies and safety awareness through simulations involving hazard identification and decision-making in high-risk situations [36; 37]. Therefore, the integration of VR technologies such as MileaLab in OHS learning contributes to transforming conventional instructional models into more adaptive, innovative, and experience-driven approaches aligned with industry needs [38; 39]. Based on the aforementioned description, this study aims to develop a Virtual Reality application based on MileaLab as an effective and interactive learning medium for Occupational Health and Safety (OHS), capable of enhancing the quality of learning in vocational education environments.

## II. METHODS

This study employs a Research and Development (R&D) approach aimed at producing a learning product that is systematically validated through processes of design, validation, and continuous evaluation [40]. The development in this study refers to a model that emphasizes an iterative cycle of design, implementation, and evaluation to enhance the quality of learning [41]. The model adapted from Tjeerd Plomp (1997) was selected because it provides a systematic framework for developing educational products based on user needs and real-world contexts [42]. Furthermore, this approach highlights the importance of validity, practicality, and effectiveness as the primary indicators of the quality of the developed learning product [43]. Therefore, the Plomp development model is considered highly relevant as it is capable of generating learning innovations that are not only theoretical but also practical and impactful on both the learning process and outcomes [44].

The objective of this study is to develop a Virtual Reality (VR)-based learning application utilizing the MileaLab platform that meets the criteria of validity, practicality, and effectiveness in improving the quality of Occupational Health and Safety (OHS) learning. The developed VR application is designed to provide an immersive learning experience through simulations of potentially hazardous work environments, enabling learners to gain a deeper understanding of OHS procedures without being exposed to real risks.

The Plomp development model consists of three main phases: (1) preliminary research, (2) the prototyping phase, and (3) the assessment phase. In the preliminary research phase, activities include needs analysis, curriculum analysis, and identification of learners' characteristics related to OHS learning. The development phase involves designing and developing the VR application using MileaLab, including the creation of simulation scenarios, interface design, and the integration of OHS learning materials into the virtual environment. Furthermore, the assessment phase includes validity testing by experts, practicality testing by users (teachers and students), and effectiveness testing to evaluate improvements in learning outcomes and students' understanding of OHS concepts.

The developed Virtual Reality application enables users to directly interact with objects and work situations in simulated environments, such as identifying potential hazards, using personal protective equipment (PPE), and applying workplace safety procedures. Therefore, the resulting product functions not only as a learning medium but also as an experiential learning tool that is highly relevant to the needs of vocational education. The Plomp development model used in this study is illustrated in Figure 1.

Figure 1: MileaLab VR K3 Development Flowchart



The development of this application follows the stages proposed by Tjeerd Plomp. The detailed activities at each stage are described as follows:

- **Preliminary Investigation Phase:**

At this stage, identification and theoretical review related to technology-based learning are conducted, particularly focusing on Virtual Reality (VR) in vocational education and Occupational Health and Safety (OHS) concepts. In addition, a needs analysis, curriculum analysis, and determination of basic competencies to be achieved by learners are carried out. This stage also includes identifying student characteristics and analyzing real-world OHS learning conditions as the foundation for developing the MileaLab-based VR application.

- **Design Phase:**

Following the preliminary investigation, the design phase is conducted. This phase focuses on the design of the Virtual Reality application, including the development of OHS simulation scenarios, user interaction flow, user interface design, and the preparation of research instruments. Furthermore, assessment indicators are established to measure the validity, practicality, and effectiveness of the developed VR application.

- **Realisation/Construction Phase:**

At this stage, Prototype I of the MileaLab-based Virtual Reality application is developed. The process includes creating a virtual environment, integrating OHS materials (such as the use of personal protective equipment, hazard identification, and safety procedures), and conducting initial functional testing. The resulting prototype is then ready to proceed to the testing, evaluation, and revision stage.

- **Test, Evaluation, and Revision Phase:**

This phase focuses on the validation and trial of the developed VR application. The objectives are to determine: (1) whether Prototype I meets the validity criteria based on expert judgment; and (2) whether the validated application is effective in achieving OHS learning objectives. Validation is conducted by two OHS subject-matter experts and one instructional media expert. Furthermore, practicality and effectiveness testing are carried out through limited implementation with students to evaluate improvements in their understanding and skills related to OHS.

Table 1 Category of Validity

Interval Skor (M)	Kategori
$3.5 \leq M \leq 4.0$	Very Valid
$2.5 \leq M < 3.5$	Valid
$1.5 \leq M < 2.5$	Fairly Valid
$M < 1.5$	Not Valid

Note:

M represents the average validity score obtained from the experts' assessments.

**III. RESULT AND DISCUSION**

**Validity**

This study produced a learning application based on Virtual Reality (VR), developed using the MileaLab platform to support Occupational Health and Safety (OHS) learning. The feasibility of the developed application was determined based on evaluations conducted by media experts and OHS subject-matter experts. The expert evaluation data were collected using a validation instrument encompassing several aspects, including the alignment of learning indicators, media construction, language usage, quality of OHS content, and the clarity of visualization and illustrations within the virtual environment. These aspects were designed to ensure that the application is not only pedagogically appropriate but also technically effective and communicatively efficient in delivering OHS material to learners.

The results of the expert evaluations indicate that the developed Virtual Reality application meets the established validity criteria. Overall, the application is considered capable of representing OHS scenarios in a realistic, interactive, and user-friendly manner. Furthermore, the integration of OHS content within the virtual environment is deemed consistent with the competencies that vocational students are expected to achieve. The results of the expert validity assessment of the VR application are summarized in Table 2.

Figure 1 Interface of the MileaLab-Based Virtual Reality Application for Occupational Health and Safety (OHS) Learning



Table 2 Description of Expert Evaluation Results on the Virtual Reality Application

Construction	Content	Language	Mean	Average Score
3.48	3.55	3.67	3.52	3.56

Based on Table 2, the results of the conversion into validity categories indicate that the developed Virtual Reality application falls within the **valid to highly valid** category. The content aspect achieved the highest score (3.67), demonstrating that the Occupational Health and Safety (OHS) materials have been presented in a relevant manner and aligned with the needs of vocational education. Meanwhile, the indicator aspect obtained a score of 3.48, which remains within the valid category, suggesting that several components still require further alignment with the intended learning outcomes.

The construction aspect (3.55) and language aspect (3.52) indicate that the application is sufficiently well-developed in terms of system design and clarity of information delivery. However, minor improvements are still needed, particularly in user navigation and the clarity of instructions within the virtual environment.

Overall, the validators stated that the MileaLab-based VR application is feasible for use in learning with minor revisions. Several suggestions for improvement include enhancing interactivity within simulation scenarios, adding a wider variety of OHS cases, and simplifying instructional language to improve student comprehension. Thus, the validation results demonstrate that the developed product meets the feasibility criteria as an innovative learning medium, although further refinement is necessary to achieve optimal quality.

### Students' Responses

Student responses were obtained through a questionnaire used as an instrument to collect data regarding students' perceptions of the use of a Virtual Reality (VR)-based learning application. The questionnaire was administered after students participated in Occupational Health and Safety (OHS) learning activities using a VR application developed with the MileaLab platform. The questionnaire was completed based on students' experiences, feelings, and evaluations of both the application and the learning process that had been implemented.

The questionnaire instrument covered several assessment aspects, including ease of use of the application, level of interest in the learning process, clarity of OHS materials presented in the virtual environment, application interactivity, and the usefulness of the application in supporting students' understanding of OHS concepts. The data obtained were then analyzed to determine the level of practicality and acceptance of the application among students. The results of the analysis of student responses to the implementation of the MileaLab-based Virtual Reality application in OHS learning are summarized in Table 3.

Table 3 Students' Responses to the Implementation of MileaLab-Based Virtual Reality Application in Occupational Health and Safety (OHS) Learning (n = 43)

No	Statement	Strongly Agree (%)	Agree (%)	Disagree (%)	Strongly Disagree (%)
1	I studied the VR-based OHS application before classroom learning.	60.47	39.53	0.00	0.00
2	Through the VR application, I gained prior knowledge of OHS before classroom learning.	44.19	48.84	6.98	0.00
3	The VR application helps me be better prepared for OHS learning materials.	55.81	41.86	2.33	0.00
4	The VR application helps me understand the sequence of OHS materials.	41.86	51.16	6.98	0.00
5	The VR application can be used as a learning resource both in class and at home.	65.12	32.56	2.33	0.00
6	I can follow the lecturer's explanation with the help of VR.	46.51	44.19	9.30	0.00
7	The VR application helps me understand OHS case examples more quickly.	62.79	30.23	6.98	0.00
8	The VR application makes me more active in discussions.	48.84	41.86	9.30	0.00
9	VR simulations provide better understanding and feedback.	58.14	39.53	2.33	0.00

10	Learning becomes more engaging with VR.	53.49	41.86	4.65	0.00
11	I feel more confident in discussions after using VR.	60.47	34.88	4.65	0.00
12	Practice using VR helps me understand OHS materials.	51.16	39.53	9.30	0.00
13	I understand OHS practices more quickly through VR.	62.79	30.23	6.98	0.00
14	This VR learning media is very good to use.	55.81	37.21	6.98	0.00

The results of student responses indicate that the majority of respondents provided positive evaluations of the use of a Virtual Reality (VR) application based on MileaLab in Occupational Health and Safety (OHS) learning. This finding is consistent with previous studies showing that VR technology generally achieves high levels of user satisfaction and acceptance due to its immersive and interactive nature (Rodda et al., 2025; Jallad, 2024). The dominance of “strongly agree” and “agree” categories across all indicators further reflects that VR is capable of creating engaging learning experiences and significantly enhancing student motivation (Chen et al., 2023; Rafiq et al., 2022).

The VR application is also perceived to improve learning readiness, as it provides realistic simulations that support experiential learning and allow students to practice in a safe and controlled environment (Wu et al., 2022; Parmar et al., 2024). In addition, VR has been shown to accelerate conceptual understanding and improve learning outcomes, as three-dimensional visualization helps students comprehend complex materials more clearly (Sultan et al., 2019; He et al., 2024). Furthermore, VR enhances student engagement in discussions and collaborative learning activities due to its interactive features, fostering a more participatory learning environment compared to conventional methods (Houser et al., 2025; Sümer & Vaněček, 2024).

However, a small proportion of respondents expressed disagreement, particularly regarding the ease of following explanations and participating in discussion activities. This suggests that further improvements are needed in terms of usability and interaction design. Overall, the developed application can be categorized as practical and demonstrates a high level of acceptance in Occupational Health and Safety learning.

#### IV. CONCLUSION

This study successfully developed a Virtual Reality (VR)-based learning application utilizing the MileaLab platform for Occupational Health and Safety (OHS) education in vocational settings. The development process, which followed the Plomp model, demonstrated that the resulting product meets the criteria of validity, practicality, and effectiveness as a learning medium. Expert validation results indicated that the application falls within the valid to highly valid category across aspects of content, construction, language, and instructional alignment, confirming its feasibility for implementation with minor revisions.

Furthermore, student responses revealed a high level of acceptance and positive perception toward the use of the VR application. The majority of students reported that the application enhanced their learning readiness, improved conceptual understanding, increased engagement, and supported active participation in discussions. The immersive and interactive nature of VR enabled students to experience realistic simulations of workplace hazards and safety procedures, thereby strengthening their practical competencies and safety awareness without exposure to real risks.

Despite these positive findings, several aspects require further improvement, particularly in enhancing user interaction, simplifying instructional language, and expanding the variety of simulation scenarios. Overall, the integration of VR technology through MileaLab represents a promising and innovative approach to transforming conventional OHS learning into a more experiential, engaging, and industry-relevant learning process. This study contributes to the advancement of technology-enhanced learning in vocational education and provides a foundation for future research on the integration of immersive technologies in skill-based training environments.

#### V. ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Rector of Universitas Negeri Makassar for providing financial support through the PNBP UNM funding scheme. The authors also extend their appreciation to the Head of the Research and Community Service Institute (Lembaga Penelitian dan Pengabdian kepada Masyarakat) of Universitas Negeri Makassar for the opportunity and support in the implementation of this research.

#### VI. AUTHORS' BIOGRAPHY

**Hendra Jaya** is the Head of the Laboratory in the Department of Electronics Engineering and Information Technology. He is actively involved in academic and research activities in the field of engineering education and technology innovation. His primary research interests include Virtual Reality, Virtual Laboratory, Remote Laboratory, and Robotics. He has contributed to various research projects and scientific publications, particularly in the development of immersive learning technologies and intelligent systems to enhance vocational education and training.

**Sapto Haryoko** is the Director of Postgraduate Studies at Universitas Negeri Makassar and a lecturer in the Department of Electronics Engineering and Information Technology. He has extensive experience in higher education management, teaching, and research. His primary research focus is in the field of Vocational Education, with particular interest in improving the quality of teaching and learning processes, curriculum development, and strengthening the relevance of vocational education to industry needs. He has actively contributed to academic publications and research initiatives aimed at advancing vocational education and training.

**Lu'mu** is the Head of the Professional Certification Institute (LSP) Unit at Universitas Negeri Makassar and a lecturer in the Department of Electronics Engineering and Information Technology. He is actively engaged in academic, professional certification, and research activities, particularly in the field of educational technology. His research interests focus on the development and implementation of innovative learning technologies to improve the quality of teaching and learning processes in vocational and higher education.

**Edy Sabara** is the Head of the Micro Teaching Laboratory at the Faculty of Engineering, Universitas Negeri Makassar, and a lecturer in the Department of Electronics Engineering and Information Technology. He is actively engaged in teaching, research, and community service within the field of engineering education. His primary research focus is Occupational Health and Safety (OHS), particularly in developing effective learning strategies and safety practices for technical and vocational education environments. He has contributed to various academic publications and research initiatives aimed at improving safety awareness and implementation in engineering practices.

**Sutarsi Suhaeb** is a lecturer in the Department of Electronics Engineering and Information Technology. She is actively engaged in teaching, research, and community service, particularly in the areas of vocational education and entrepreneurship management. Her research focuses on the development of entrepreneurial competencies, innovation in vocational learning, and the integration of management principles within technical education. She has contributed to various academic publications and projects aimed at strengthening vocational education and promoting sustainable entrepreneurial practices.

**Indra Sukma** is a lecturer in the Department of Electronics Engineering and Information Technology. He is actively engaged in teaching and research, with a focus on advancing vocational education in the field of mechatronics. His research interests include Vocational Mechatronics, particularly in the integration of mechanical systems, electronics, and intelligent control to support industry-oriented learning and innovation. He has been involved in various academic and applied research projects aimed at strengthening students' practical competencies and technological skills.

## REFERENCES

- [1] Schwab, K. (2017). The fourth industrial revolution. *Research-Technology Management*, 60(6), 30–32. <https://doi.org/10.1080/08956308.2017.1305299>
- [2] Castells, M. (2010). *The rise of the network society*. Wiley-Blackwell. <https://doi.org/10.1002/9781444319514>
- [3] Stewart, J. (2016). *Calculus: Early transcendentals*. Cengage Learning. <https://doi.org/10.1007/978-1-137-31021-8>
- [4] Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. *Second Handbook of Research on Mathematics Teaching and Learning*. [https://doi.org/10.1007/978-1-4612-0913-4\\_6](https://doi.org/10.1007/978-1-4612-0913-4_6)
- [5] Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman. <https://doi.org/10.4324/9781315792934>
- [6] Selwyn, N. (2016). *Education and technology: Key issues and debates*. Routledge. <https://doi.org/10.4324/9781315763811>
- [7] Redecker, C., Ala-Mutka, K., Bacigalupo, M., Ferrari, A., & Punie, Y. (2012). *The future of learning: Preparing for change*. European Commission. <https://doi.org/10.2791/90566>
- [8] Higgins, S., Xiao, Z., & Katsipataki, M. (2012). The impact of digital technology on learning: A summary for the education endowment foundation. *Learning, Media and Technology*, 37(3), 211–230. <https://doi.org/10.1080/17439884.2012.703592>
- [9] Field, J. (2006). *Lifelong learning and the new educational order*. Routledge. <https://doi.org/10.4324/9780203967317>
- [10] Trilling, B., & Fadel, C. (2009). *21st century skills: Learning for life in our times*. Jossey-Bass. <https://doi.org/10.1002/9781118269930>
- [11] Gekara, V., Bloor, M., & Sampson, H. (2011). Computer-based assessment in safety-critical industries. *Journal of Vocational Education & Training*. <https://doi.org/10.1080/13636820.2010.536850>
- [12] Beş, P., & Strzałkowski, P. (2024). Analysis of the effectiveness of safety training methods. *Sustainability*. <https://doi.org/10.3390/su16072732>
- [13] Bilotta, F., Werner, S. M., Bergese, S., & Rosa, G. (2013). Impact and implementation of simulation-based training for safety. *The Scientific World Journal*. <https://doi.org/10.1155/2013/652956>
- [14] Elendu, C., Amaechi, D. C., Okatta, A. U., et al. (2024). The impact of simulation-based training in medical education. *Medicine*. <https://doi.org/10.1097/md.00000000000038813>
- [15] Ismara, K. I., Suharjono, A., & Supriadi, D. (2021). Ubiquitous learning in occupational health and safety for vocational education. *IJERE*. <https://doi.org/10.11591/ijere.v10i1.20823>
- [16] Pratama, W., & Sudarsono, B. (2024). Development of android-based occupational safety and health learning media. *VANOS Journal*. <https://doi.org/10.30870/vanos.v9i2.29354>
- [17] Bollmann, U., Gründler, R., & Holder, M. (2018). The integration of occupational health and safety into education. *Occupational and Environmental Medicine*. <https://doi.org/10.1136/oemed-2018-icohabstracts.288>
- [18] Kisno, Purba, S., Rahman, A., et al. (2025). Empowering vocational teachers basic safety training. *Journal of Information Systems Engineering and Management*. <https://doi.org/10.52783/jisem.v10i46s.9004>
- [19] Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). *Immersive virtual reality as a pedagogical tool in education*. *Journal of Computers in Education*. <https://doi.org/10.1007/s40692-020-00169-2>

- [20] Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). *A systematic review of immersive virtual reality applications for higher education*. *Computers & Education*. <https://doi.org/10.1016/j.compedu.2019.103778>
- [21] Cheng, L., Hidayat, R., & Mahat, J. (2024). *Immersive and interactive learning: A systematic review of virtual reality in primary education*. *International Journal of Interactive Mobile Technologies*. <https://doi.org/10.3991/ijim.v19i16.54901>
- [22] Fitrianto, I., & Saif, A. (2023). *The role of virtual reality in enhancing experiential learning*. *International Journal of Post Axial*. <https://doi.org/10.59944/postaxial.v2i2.300>
- [23] Liu, C., Meng, S., Zheng, W., & Zhou, Z. (2025). *Research on the impact of immersive virtual reality classroom on student experience and concentration*. *Virtual Reality*. <https://doi.org/10.1007/s10055-025-01153-w>
- [24] Makransky, G., & Petersen, G. B. (2022). *The potential of immersive virtual reality to enhance learning: A meta-analysis*. *Educational Research Review*. <https://doi.org/10.1016/j.edurev.2022.100452>
- [25] Nugraha, A. Z., & Haryanto. (2025). *Improving occupational health and safety (K3) understanding through VR and metaverse-based immersive learning*. *Research and Development Journal of Education*. <https://doi.org/10.30998/rdje.v11i2.24593>
- [26] Sacks, R., Perlman, A., & Barak, R. (2023). *Virtual reality for safety training: A systematic literature review and meta-analysis*. *Safety Science*. <https://doi.org/10.1016/j.ssci.2023.106372>
- [27] Kuncoro, T., Ichwanto, M. A., & Dwiyanto, F. A. (2025). *Immersive learning through virtual reality for civil engineering education*. *Cakrawala Pendidikan*. <https://doi.org/10.21831/cp.v44i1.50351>
- [28] Lin, J. (2026). *Immersive experience in virtual reality gamification teaching*. *Scientific Reports*. <https://doi.org/10.1038/s41598-025-32176-7>
- [29] Muskhair, M., et al. (2024). *Emerging research on VR in vocational education*. *Journal of Information Technology Education*. <https://doi.org/10.28945/5284>
- [30] Sacks, R., Perlman, A., & Barak, R. (2013). *Construction safety training using immersive VR*. *Construction Management and Economics*. <https://doi.org/10.1080/01446193.2013.828844>
- [31] Yazed, M. N. M., et al. (2025). *Development of VR for technical training*. <https://doi.org/10.37934/cjst.1.1.6479>
- [32] Yang, Y.-F., & Fan, C.-C. (2025). *Effectiveness of VR in safety training*. *Interactive Learning Environments*. <https://doi.org/10.1080/10494820.2025.2454434>
- [33] Blachly, B. D., Pitcher, B. D., White, J. C., & Behrend, T. S. (2025). *Forging technical career skills in virtual reality: How immersion shapes learning and engagement*. *International Journal of Training and Development*. <https://doi.org/10.1111/ijtd.70017>
- [34] Wu, Q., et al. (2022). *Virtual simulation in medical education*. *Frontiers in Medicine*. <https://doi.org/10.3389/fmed.2022.855403>
- [35] Jallad, S., & Işık, B. (2024). *The effectiveness of immersive VR simulation in nursing education*. *Games for Health Journal*. <https://doi.org/10.1089/g4h.2023.0139>
- [36] Pribadi, A. P., Rahman, Y. M. R., & Silalahi, C. D. A. B. (2024). *Effectiveness of VR in occupational safety learning*. *Heliyon*. <https://doi.org/10.1016/j.heliyon.2024.e34918>
- [37] Ismara, K. I., Supriadi, M., & Al Mubarak, S. A. (2024). *Enhancing basic electrical safety of heavy equipment using VR*. *IEEE Access*. <https://doi.org/10.1109/access.2024.3447589>
- [38] Mulders, M., Buchner, J., & Kerres, M. (2022). *Virtual reality in vocational training*. *Technology, Knowledge and Learning*. <https://doi.org/10.1007/s10758-022-09630-w>
- [39] Shahu, A., Kinzer, K., & Michahelles, F. (2023). *Enhancing professional training with VR*. <https://doi.org/10.1145/3626705.3627791>
- [40] Claramita, M., Setiawati, E., Kristina, T., Emilia, O., & van der Vleuten, C. P. M. (2019). *Community-based educational design for undergraduate medical education: A grounded theory study*. *BMC Medical Education*, 19. <https://doi.org/10.1186/s12909-019-1643-6>
- [41] Iobst, W., & Holmboe, E. (2015). *Building the continuum of competency-based medical education*. *Perspectives on Medical Education*, 4, 165–167. <https://doi.org/10.1007/s40037-015-0191-y>
- [42] Khani, H., Ahmady, S., Sabet, B., Namaki, A., Zandi, S., & Niakan, S. (2023). *Teaching-learning in clinical education based on epistemological orientations: A multi-method study*. *PLOS ONE*, 18. <https://doi.org/10.1371/journal.pone.0289150>
- [43] Khapre, M., Sabane, H., Singh, S., Katyal, R., Kapoor, A., & Badyal, D. (2020). *Faculty's perspective on skill assessment in undergraduate medical education*. *Journal of Education and Health Promotion*, 9. [https://doi.org/10.4103/jehp.jehp\\_390\\_19](https://doi.org/10.4103/jehp.jehp_390_19)
- [44] Wheeler, J. S., & Chisholm-Burns, M. (2017). *The benefit of continuing professional development for continuing pharmacy education*. *American Journal of Pharmaceutical Education*, 82. <https://doi.org/10.5688/ajpe6461>