*Review Article*

# Artificial Intelligence and Immersive Technologies in Teacher Education: A Systematic Review

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## Abstract

*The rapid advancement of Artificial Intelligence (AI), Virtual Reality (VR), Augmented Reality (AR) and the Metaverse is reshaping teacher education by offering adaptive and immersive learning experiences. This systematic review examines the current scenario of AI and immersive technologies in teacher education (training and professional development). This study follows a PRISMA methodology and has analysed approximately 43 studies related to teacher education. The study has also considered the insights from student focused research which offers valuable implications for teachers and instructional design. This review highlights key applications, benefits and challenges of AI and immersive learning environments in teacher education. It also discusses how teachers can use findings from student experiences to enhance their pedagogical strategies. The findings reveal a gap in teacher specific research and propose future directions to integrate AI and immersive technologies into teacher education. This study provides a better understanding of how AI and Metaverse based tools can transform teacher training along with addressing the challenges faced in their adoption.*

**Keywords:** Artificial Intelligence in Education, Metaverse in Teacher Training, Virtual Reality, Augmented Reality, Immersive Learning Environments, Technology Integration in Teacher Education, AI-driven Pedagogy

## Introduction

The integration of new technologies like Artificial Intelligence (AI) and immersive technologies namely, Virtual Reality (VR), Augmented Reality (AR) and Metaverse are revolutionising many sectors including education. It is very important that the education system must reflect the real world so that students are better prepared for life (Alda et al., 2020). Education 4.0 includes all the teaching-learning experiences which effectively use the opportunities provided by these advanced technologies. AI, VR/AR are gaining a lot of prominence in the education sector. It has the potential to upgrade the teaching-learning process (Zouhri and Mallahi, 2024). In the results of a study, it was indicated that AI can improve students' performance, engagement and motivation although certain challenges like biases and discriminations still remain (Halkiopoulos and Gkintoni, 2024). Similarly, there is an increasing interest in the latest technology called 'Metaverse' and its potential to enrich education. Metaverse is a virtual space which integrates AR and VR technologies, often called "Internet of the future". Educational stakeholders are positively inclined towards using this technology, although some concerns regarding the confidentiality of educational data still exist (Lampropoulos et al., 2025).

Studies have explored that these technologies benefit students as well as teachers. Teachers must be adequately trained to integrate AI, AR, VR and Metaverse related applications into their teaching practice. By making teachers well prepared and well versed to use such technology, learning of students can be made more effective. Teachers are central to the successful use and integration of these technologies in education. Nonetheless, there is less emphasis on integrating these technologies in teacher training and professional development programmes. Traditional teacher education programs mostly focus on theoretical knowledge. There are not enough provisions for providing hands-on experiences with such technologies. This leads to lack of confidence and skills in teachers to implement these technological tools in their classrooms. This further widens the already created gap between rapidly growing technology and outdated teacher training programmes. It is the need of the hour to address this gap and proactively integrate AI, VR, AR and Metaverse into teacher education. Studies have shown that AI literacy plays a significant role in teacher's acceptance of AI and other technologies (Al-Abdullatif, 2024). It is imperative to conduct proper training and workshops for teachers. According to a study by Hassan et al. (2021), there is a great need to focus on IoT, Robotics, Data Science, AI, Cloud computing and other technologies into Technical and Vocational Education and Training (TVET).

Although the interest in AI, VR, VR and Metaverse in education is increasing, the existing literature shows several gaps. Firstly, there are a few studies specifically on teacher education. Most of the research explores student's experiences and learning outcomes only. Secondly, the studies are exploratory in nature with limited empirical research in the teacher professional development domain. Thirdly, there is major emphasis on students' perception while teachers' skill, readiness and training needs are not explored. These gaps highlight the need for more research focused on teacher training and professional development.

To make this study more meaningful, the student focused studies are also reviewed. It indirectly helped to understand what necessary skills are required by teachers. This will further help in shaping teacher training curriculum based on student's perception. This study systematically reviews existing research on applications, benefits and challenges of AI, VR, AR and metaverse in teacher education. By analysing and synthesising findings from both teacher and student related studies, this study aims to answer two Research Questions (RQ) written as follows:

**RQ 1. What are the key applications of AI, VR/AR and Metaverse in teacher training and professional development?**

**RQ 2. What are the benefits and challenges of using AI, VR/AR and Metaverse based tools in teacher training?**

The insights from this review will help educators, policymakers, and researchers develop strategies for effectively integrating AI and Metaverse-based tools into teacher's professional development.

## Methodology

The systematic review of this study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analysis) framework and selects relevant studies in a structured way. The goal of this study was to identify

research related to the role of AI, VR/AR and Metaverse in teacher education, mainly focusing on their application, benefits and challenges.

**Search strategy and study selection**

To relevant literature, a structured advanced search query was used in the SCOPUS database. The following keywords and Boolean operators were applied:

("Artificial Intelligence" OR "AI in Education" OR "AI tools")

AND ("Metaverse" OR "Virtual Reality" OR "Augmented Reality" OR "Extended Reality" OR "Immersive Technology"

AND ("Teacher Education" OR "Teacher Training" OR "Teacher Professional Development")

AND ("Application" OR "Challenges" OR "Benefits" OR "Opportunities" OR "Barriers")

This search initially retrieved 4331 documents. To further refine the results, the following inclusion criteria was used:

1. Publication Type: Articles and reviews only
2. Language: English
3. Publication Period: 2018–2025
4. Subject Areas: Computer Science, Social Sciences, Arts and Humanities
5. Access Type: Open Access

When these filters were applied, the number of relevant studies was reduced to 732 documents. In the second step, a title, abstract and full text screening was done to remove irrelevant studies. All the studies related to AI and metaverse outside the educational context were removed. Full text screening removed the studies which were not directly related to application, challenges, and benefits provided by these technologies. This reduced the final number of documents to approximately 43 as shown in the Figure 1 below:

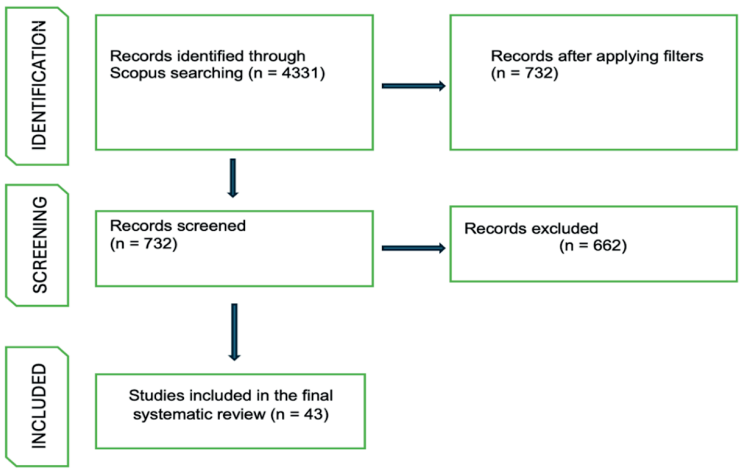


*Fig. 1. PRISMA flow diagram*

Quality appraisal of the included studies: 43 studies were finally included as per the predefined research objectives and relevance to teacher education as well as professional development. The findings from these studies ensure that the current state of AI and immersive technologies in teacher education is accurately reflected.

## Analysis of the Studies Reviewed

### RQ 1: What are the key applications of AI, VR, AR and Metaverse in teacher education?

### AI in Teacher Education

AI holds immense potential to revolutionise teacher education. It provides personalised learning experiences as well as real time feedback whenever and wherever required. It also helps in automating administrative tasks, therefore saving teacher's precious time and efforts. It has been found that AI-enabled tools like Intelligent Tutoring Systems (ITS) and adaptive learning platforms significantly improve teacher training as well as Professional development programmes as shown in Figure 2. A personalised learning system developed by Stanford University offers customised training experiences as per individual teachers' needs as well as skill levels (Chadha, 2024).

For language teachers, AI plays a significant role by enhancing the instructional quality. AI powered applications help in conducting interactive simulations, adaptive learning and providing individualised feedback to the teachers (Mananay, 2024). AI also supports professional development of teachers by offering them the opportunities to improve their digital literacy skills. This further helps teachers to smoothly integrate AI and other technologies into their pedagogy. In a study by Tafazoli (2024), it was highlighted that AI offers critical thinking and inclusivity in education. This enables teachers to fulfil their need of catering to a diverse student population and bridging the digital divide.

There has been a growing acceptance among teachers towards the AI integration in teacher education. A study by Altamimi (2024) has found that around 63% of teachers have a positive attitude towards AI technologies. This indicates a strong willingness of teachers to use AI based tools for their continuous professional development. This study further highlights that AI adoption is equally supported by administrators, which further reinforces the potential of AI in teacher training programs.

### VR/AR in Teacher Education

VR/AR have been widely adopted in teacher training programs to create immersive learning experiences. These technologies allow pre-service and in service teachers to engage themselves in realistic simulations as well as hands-on training. This helps teachers to enhance their teaching competence as shown in Figure 2. VR and AR can be helpful in microteaching practices, experiential learning as well as for professional development workshops. For instance, TeachLivE is a mixed reality learning environment introduced by the University of Central Florida. It was implemented in the Australian teacher training program to enhance instructional strategies of pre-service teachers (Ledger et al., 2020). By using this technology, teachers can practice classroom management as well as lesson delivery in a controlled virtual environment. This improves confidence as well as the teaching skills of teachers. Similarly, AI can also be used in teacher training. It can provide personalised training as per teacher's need. It can provide automated feedback on microteaching sessions of pupil teachers.

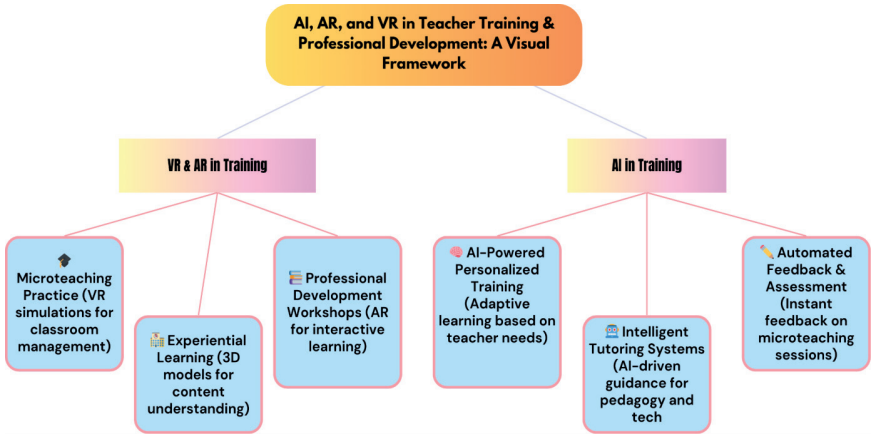


*Fig. 2. AI, AR, and VR in Teacher Training and Professional Development: A Visual Framework*

Similarly, the use of Natural User Interfaces (NUI) in virtual laboratories has also proven to be an effective teaching aid. In a study by Jagodziński and Wolski (2015), virtual chemistry laboratories allowed students to simulate real-world laboratory activities. Findings of the study indicated that working in virtual labs increased students' emotional involvement as well as academic performance. These results indirectly throw light on the efficiency of AR/VR and further suggest that these applications can improve teacher training through immersive and interactive learning experiences.

Another significant application of AR/VR in teacher training is the use of mixed reality environments for teaching social skills. The iAnimate Live project done by Kellems et al. (2020), used virtual environment, AR as well as avatars to support teachers in delivering social skills while interacting with disabled students. This approach shows the potential of AR/VR in inclusive teacher training and education. The effectiveness of these technologies in education can further be supported by a study done by Mitrakas et al. (2024). In this study, it was found that students who interact with mixed relative environments develop a deeper understanding of educational concepts. It suggests that these technologies can also be beneficial for teacher training as they provide experiential learning as well as improve pedagogical strategies.

## Metaverse in Teacher Education

The metaverse is another emerging powerful technology for teacher training. It offers a highly immersive collaborative as well as interactive learning environment. Virtual worlds within the matter worlds such as adventure world, creative world, simulation world, role-playing world etc. provide innovative platforms for teacher education (Damaševičius & Sidekerskienė, 2024). These virtual environments enhance learning outcomes by promoting creativity, critical thinking, communication as well as collaboration skills which are very essential for effective teaching.

One of the most important applications of the metaverse is its role in language learning. Tan et al. (2024) studied the impact of metaverse based activities on English language learning in rural Malaysian communities. Their findings highlighted that metaverse environments significantly improved communication, engagement, skills and social interaction among the users. This suggests that similar metaverse-based training modules could be

used in teacher education to enhance pedagogical skills.

The combination of collaborative learning and virtual reality is a promising pedagogical approach to teacher training. According to De Lorenzis et al. (2024), collaborative learning promotes teamwork and critical thinking by enabling teachers to work collaboratively in a metaverse environment. This method further allows teachers to practice instructional strategies in real time scenarios.

There is also a need to think about ethical and policy considerations of integrating AI, AR/VR, and the metaverse into teacher training programs. Chadha (2024) studied the importance of clear guidelines about these technologies to ensure their responsible and equitable use. Issues of data privacy, fairness etc. must be addressed so that the benefits of AI-driven and immersive training programs can be obtained.

RQ 2: What are the benefits and challenges of using AI and Metaverse-based tools in teacher education?

These technologies have both benefits as well as challenges when used in teacher education. Critical analysis of these technologies has been done after reviewing relevant studies.

**Benefits of Metaverse in Teacher Education**

Metaverse has the potential to improvise communication and collaboration in the teaching-learning process. It is a technologically advanced application but there is a lack of data-based evidence in the educational settings. Some studies show that metaverse has the capability to provide personalised and adaptive learning. It allows learners to virtually interact amongst each other as well as with the virtual environment (Ogegbo et al., 2024). Lampropoulos et al. (2025) in his study found that the public has positive attitudes toward the use of the metaverse in education. The study concluded that the metaverse integration will open new approaches for the educational community and support technology-based learning. Another study emphasised the immense potential of the metaverse in English language learning in Felda Malaysian communities. This study found that various activities of metaverse can create a more engaging learning environment to enhance communicative competencies, such as speaking, listening, and social skills among young learners in rural areas (Tan et al., 2024). Lampropoulos et al. (2025) has examined the role of metaverse in education along with its significance in teaching- learning. The study has highlighted that it can improve the education system by making it more meaningful. These can be used in both formal and informal learning environments. This approach holds the potential to promote social learning, self-improvement, high retention, engagement and motivation among students. The overall teaching and learning process can be enhanced by real-time identification, analysis, tracking, and visualization of multimodal learning data of learners' cognitive and affective domain. Shwedeh (2024) in his study emphasised the need for policy regulations for practical adoption and implementation of metaverse by stakeholders, policymakers and educational institutions.

**Benefits of AI in Teacher Education**

AI integration in teacher training provides personalised professional development as per needs and demands of the teacher. It enhances digital literacy along with addressing the digital divide. In terms of use of AI in English language instruction,

it helps teachers to develop critical thinking and openness among learners. AI can provide customised learning experiences for students with different cultural backgrounds and learning needs, thus making the education more inclusive in nature (Tafazoli, 2024). Another study by Altamimi (2024) found that more than half of the total students, teachers, and administrators have a positive attitude towards use of ChatGPT whereas 10%, 15%, and 8% respectively, have a negative attitude towards it. This high positive score highlights that there is a good perception of educational stakeholders about the adoption of AI technologies in their institutions. Another study supported the previous study by reviewing favourable perceptions concerning utilizing AI tools in teaching and learning process (Al-Raimi et al., 2024). Wu et al. (2024) in his study emphasised that AI facilitates teachers in delivering smart lessons, providing personalised and adaptive learning experiences. AI learning environments further contribute to improving teacher support and learning strategies. This ultimately increases students' self-efficiency, technological acceptance and learning motivation. Another study indicated that teachers' preparedness for AI can be influenced by technology integration, social influence, attitudes, and perceived self-efficacy (Ayanwale et al., 2024). Another example of AI benefiting teachers can be of a virtual facilitator based on natural language processing who can interact with middle school mathematics teachers and provide personalised as well as real-time feedback (Copur-Gencturk et al., 2024). Another important aspect is that AI-based learning environments in music education can enhance motivation by increasing interest in innovative learning tools and fostering engagement. AI enhances educational outcomes in music education by making learning more interactive, personalised and engaging, thereby improving student performance and creativity (Chen, 2025). Some studies highlighted that machine-assisted teaching helps AI to focus on specific learning goals, which further helps to achieve better educational outcomes. (López-Meneses et al., 2025).

**Benefits of VR/AR in Teacher Education**

VR provides immersive as well as interactive learning experiences in education. It provides personalised learning experience and promotes creativity through 3D interactive models. These models create virtual worlds for students so that they can better understand and retain the concepts. VR also solves educational issues by fulfilling unique needs of special as well as distant learners. Despite having so many benefits, VR also faces challenges like high cost, lack of proper implementation strategy which further results in its limited adoption in classroom settings. A new technology complementing VR in education is Additive Manufacturing (AM). It provides 3D physical models along with digital models provided through VR. These advancements decrease paperwork and reduce travelling requirements of learners (Javaid et al., 2024). Paulsen et al. (2024) in their study found that VR creates a collaborative space where the learner is engaged without any risk of interfering with actual practice. Another study found that VR 3D models help school students to enhance their creativity and develop problem-solving abilities which are essential in understanding abstract concepts (Chen et al., 2024).

Some studies emphasised that AR scale can determine their AR competencies, teacher professional development and help policy makers to develop training programs in AR and help software

companies to enhance AR experiences to empower teachers (Nikou et al., 2024). One of the studies investigated that it is very important to have proper digital infrastructure and good internet facilities for using these technologies in the classroom settings (Mkwizu and Bordoloi, 2024). Some studies investigated that learners achieve a higher level of learning when taught through all forms of AR active learning strategies (Tuta and Luić, 2024). Augmented reality can help students in the educational context as it will boost learner's engagement and improve understanding of complex subjects (Masneri et al., 2024). Sulistyanto et al. (2024) in their study concluded that the use of AR in learning can improve students' critical thinking skills. His findings recommended that AR can be used widely to improve students' thinking skills in this century.

**Challenges of AI, VR/AR and Metaverse in Teacher Education**

The use of immersive technologies also poses a lot of challenges to students, teachers and schools. The students face distractions, reduced efficiency and discomfort in the classroom settings. The teachers face difficulties maintaining the classroom, organising activities, learning technical competencies and adapting to the student-centred learning process (Jiang et al., 2025). The first challenge related to AR/VR/XR lies in its dearth of research work about teacher's competence in utilising these technologies for teaching and learning (Nikou et al., 2024). The VR usage in education is becoming more common especially in providing hands-on experiences. The use of VR can compensate for dangerous or costly activities that a real classroom setting cannot manage. But another issue of engaging large numbers of students in an immersive laboratory remains. It is still difficult because VR kits are expensive and may also require heavy computers (De Lorenzis et al., 2024). Some studies revealed that there is less knowledge about AR/VR/XR technologies among teachers. Although most teachers expressed curiosity about the use of immersive technologies, most of them have not used them in teaching practice (Schwaiger et al., 2024). The absence of AR digital competencies among instructors is another obstacle to using immersive technologies.

When we discuss the challenges related to AI in teacher training, the studies reveal that the educational institutions are training teachers, but there is a lack of investigation of the teacher training who utilise AI (Aljemely, 2024). Another study highlights challenges such as biases in AI algorithms, erosion of human connection and erosion of interpersonal dynamics in traditional teacher-student classroom settings (Adel et al., 2024) Some studies investigated other factors like work overload, technological issue and other distractions that can hamper teaching-learning processes in classroom settings (Norabuena-Figueroa et al., 2025). On one hand, AI can provide meaningful support to the teaching-learning process but on the other hand, a risk that AI systems can replace natural human presence exists (Isop, 2025). The challenges surrounding AI and ML also include biases in AI algorithms, lack of inclusive data and concerns like data privacy. The studies have also highlighted that utilisation of AI and ML in science subjects is in the early stage. The training programs for teachers are required to equip them with skills to create interactive learning processes in educational settings (Iyamuremye et al., 2024). The inclusive growth in education is hampered because of lack of trained teachers as well as students' preference for project-based curriculum (Mkwizu and Bordoloi, 2024). Although the

perception regarding the integration of AI tools is reviewed, it seems favourable; however, the pedagogical aspects of utilising AI tools from the teachers' point of view have insufficient research literature (Al-Raimi et al., 2024).

## Discussion, Reflections and Suggestions

Hazzan-Bishara et al. (2025) in their study suggest that educational stakeholders and policymakers should provide technical support, proper infrastructure, and professional development courses like Training programs on Generative AI. This will increase AI adoption among teachers. Another study supports the previous research by highlighting the important role of policy reforms in addressing the challenges and providing comprehensive regulations on technology's use in education and sustainable development. The immersive technologies lead to ethical concerns, data privacy issues and the risk of widening the digital divide; however, there is a need for further exploration of innovative strategies to utilise the actual potential of AI in language learning (Mananay, 2024). Mnguni et al. (2024) suggests that targeted teacher training programs and supportive educational policy frameworks are important for increasing AI readiness, particularly in the areas where resources are not abundant. Another suggestion is to protect privacy and make AI algorithms as transparent as possible. This is very important to promote equity in an inclusive learning environment (López-Meneses et al., 2025). Sadykova and Kayumova (2024) in their study investigated the urgent need to design and implement professional development and teacher training programmes for educators to address the myths about AI and develop practical skills for implementing AI in all levels of education.

Another study emphasises the importance for higher education institutions to promote AI literacy among future teachers and prepare them for inclusive practices and sustainable development (Kalniņa et al., 2024). Yaseen et al. (2025) suggest the teacher to synergise themselves and learners in such a manner that it enhances students as well as teachers' digital capacities, which will lead to more engagement and learning outcomes. There is an immense need to dive deeper and expand understanding of these immersive technologies for teachers; then only they will develop technology-friendly teaching strategies and educational contexts (Silva Díaz et al., 2024). They also suggested collaborative learning in VR can make pedagogical approaches interesting, which will enable team building, critical thinking and active learning. AR can be recommended as one of the best technology choices that can be made in delivering learning materials to improve students' thinking skills (Sulistyanto et al., 2024).

## Conclusion

In conclusion, this systematic review has emphasised the significance of AI and immersive learning technologies such as VR, AR and metaverse to revolutionise the teaching-learning process. The findings highlight their ability to develop immersive and interactive learning experiences that have the potential to enhance students' learning outcome, increased engagement in the classroom and memory retention. Based on the analysis by the PRISMA systematic literature review methodology, there is no doubt that these technologies will act as a paradigm shift in the advancement of educational technology. The twenty-first century requires learning new technologies and skills to develop AI literacy, digital citizenship and

sustainable development. The current study only investigated the key applications, benefits and challenges of using AI and immersive technologies. Future research work can explore the comparison of AI and immersive learning technologies with traditional teaching methods and the actual implementation of these technologies in the teaching learning process. In summary, the systematic literature review indicates that AI, AR/VR and Metaverse have the immense potential to be transformative platforms for teaching and learning but it also highlights their limitations in education. This research paper highlights the issues that need to be addressed such as high cost of implementation, erosion of human connections, digital divide and gaps, technical inadequacy, and lack of policy and regulations to fully utilise these emerging technologies in education. The research work focuses on the need to promote equity, ensuring ethical considerations such as data privacy and algorithm biases to make the classroom implications fair and inclusive to all the learners. This study furthermore highlights the significance of continued research and evidence gathering to fully understand the effectiveness of these immersive learning technologies in the teaching-learning process in the educational context.

## References


Adel, A., Ahsan, A., & Davison, C. (2024). ChatGPT promises and challenges in education: Computational and ethical perspectives. Education Sciences, 14(8), 814.

Al-Abdullatif, A. M. (2024). Modeling teachers' acceptance of generative artificial intelligence use in higher education: The role of AI literacy, intelligent TPACK, and perceived trust. Education Sciences, 14(11), 1209.

Al-Raimi, M., Mudhsh, B. A., Muqaibal, M. H., & Al-Yafaei, Y. (2024). To what extent has artificial intelligence impacted EFL teaching and learning? A systematic review. Jurnal Arbitrer, 11(3), 399-412.

Alda, R., Boholano, H., & Dayagbil, F. (2020). Teacher education institutions in the Philippines towards Education 4.0. *International Journal of Learning, Teaching and Educational Research,* 19(8), 137–154. Retrieved from https://www.researchgate.net/publication/344530521_Teacher_Education_Institutions_in_the_Philippines_towards_Education_40

Aljemely, Y. (2024, October). Challenges and best practices in training teachers to utilize artificial intelligence: a systematic review. In Frontiers in Education (Vol. 9, p. 1470853). Frontiers Media SA.

Altamimi, A. (2024). Harnessing the integration of chat GPT in higher education: the evaluation of stakeholders' sentiments using NLP techniques. Discover Sustainability, 5(1), 1-17.

Ayanwale, M. A., Ntshangase, S. D., Adelana, O. P., Afolabi, K. W., Adam, U. A., & Olatunbosun, S. O. (2024). Navigating the future: Exploring in-service teachers' preparedness for artificial intelligence integration into South African schools. Computers and Education: Artificial Intelligence, 7, 100330.

Chadha, A. (2024). Transforming Higher Education for the Digital Age: Examining Emerging Technologies and Pedagogical Innovations. *Journal of Interdisciplinary Studies in Education*, 13, 53-70.

Chen, L. (2025). Unlocking the Beat: How AI Tools Drive Music Students' Motivation, Engagement, Creativity and Learning Success. *European Journal of Education*, 60(1), e12823.

Chen, S. J., Chen, C. Q., & Shan, X. F. (2024). The effects of an immersive virtual-reality-based 3D modeling approach on the creativity and problem-solving tendency of elementary school students. Sustainability, 16(10), 4092.

Copur-Gencturk, Y., Li, J., Cohen, A. S., & Orrill, C. H. (2024). The impact of an interactive, personalized computer-based teacher professional development program on student performance: A randomized controlled trial. Computers & education, 210, 104963.

Damaševičius, R., & Sidekerskienė, T. (2024). Virtual worlds for learning in metaverse: A narrative review. Sustainability, 16(5), 2032.

De Lorenzis, F., Visconti, A., Restivo, S., Mazzini, F., Esposito, S., Garofalo, S. F. & Lamberti, F. (2024). Combining virtual reality with asymmetric collaborative learning: a case study in chemistry education. Smart Learning Environments, 11(1), 43.

Halkiopoulos, C., & Gkintoni, E. (2024). Leveraging AI in e-learning: Personalized learning and adaptive assessment through cognitive neuropsychology—A systematic analysis. Electronics, 13(18), 3762.

Hassan, Rana & Hassan, Malik & Naseer, Sheraz & Khan, Zafran & Jeon, Moongu. (2021). ICT enabled TVET education: a systematic literature review. IEEE Access. PP. 1-1. 10.1109/ACCESS.2021.3085910.

Hazzan-Bishara, A., Kol, O., & Levy, S. (2025). The factors affecting teachers' adoption of AI technologies: A unified model of external and internal determinants. Education and Information Technologies, 1-27.

Isop, W. A. (2025). A conceptual ethical framework to preserve natural human presence in the use of AI systems in education. Frontiers in Artificial Intelligence, 7, 1377938.

Iyamuremye, A., Niyonzima, F. N., Mukiza, J., Twagilimana, I., Nyirahabimana, P., Nsengimana, T. & Nsabayezu, E. (2024). Utilization of artificial intelligence and machine learning in chemistry education: a critical review. Discover Education, 3(1), 95.

Jagodziński, P., & Wolski, R. (2015). Assessment of application technology of natural user interfaces in the creation of a virtual chemical laboratory. *Journal of Science Education and Technology*, 24(1), 16–28.

Javaid, M., Haleem, A., Singh, R. P., & Dhall, S. (2024). Role of Virtual Reality in advancing education with sustainability and identification of Additive Manufacturing as its cost-effective enabler. Sustainable Futures, 100324.

Jiang, H., Zhu, D., Chugh, R., Turnbull, D., & Jin, W. (2025). Virtual reality and augmented reality-supported K-12 STEM learning: trends, advantages and challenges. Education and Information Technologies, 1-37.

Kalniņa, D., Nīmante, D., & Baranova, S. (2024, November). Artificial intelligence for higher education: benefits and challenges for pre-service teachers. In Frontiers in Education (Vol. 9, p. 1501819). Frontiers Media SA.

Lampropoulos, G., López-Belmonte, J., Marín-Marín, J. A., & Pozo-Sánchez, S. (2025). Exploring the General and Educational Use of the Metaverse: Public Perspectives, Sentiments, Attitudes, and Discourses. SN Computer Science, 6(2), 103.

Ledger, S., Ure, C., Burgess, M., & Morrison, C. (2020). Professional Experience in Australian Initial Teacher Education: An Appraisal of Policy and Practice. Higher Education Studies, 10(4), 116-130.

López-Meneses, E., López-Catalán, L., Pelícano-Piris, N., & Mellado-Moreno, P. C. (2025). Artificial Intelligence in Educational Data Mining and Human-in-the-Loop Machine Learning and Machine Teaching: Analysis of Scientific Knowledge. Applied Sciences, 15(2), 772.

Masneri, S., Domínguez, A., Pacho, G. et al. A collaborative AR application for education: from architecture design to user evaluation. Virtual Reality 28, 42 (2024). https://doi.org/10.1007/s10055-024-00952-x

Mananay, J. A. (2024). Integrating Artificial Intelligence (AI) in Language Teaching: Effectiveness, Challenges, and Strategies. *International Journal of Learning, Teaching and Educational Research,* 23(9), 361-382.

Mitrakas, N., Tsihouridis, C., & Vavougios, D. (2024). Using Mixed Reality in Educational Practice: An Inquiry-Based Process of the Fluid Expansion–Contraction Phenomena by Pre-Service Teachers. Education Sciences, 14(7), 754.

Mkwizu, K. H., & Bordoloi, R. (2024). Augmented reality for inclusive growth in education: the challenges. *Asian Association of Open Universities Journal*, 19(1), 88-100.

Mnguni, L., Nuangchalerm, P., El Islami, R. A. Z., Sibanda, D., Sari, I. J., & Ramulumo, M. (2024). The behavioural intentions for integrating artificial intelligence in science teaching among pre-service science teachers in South Africa and Thailand. Computers and Education: Artificial Intelligence, 7, 100334.

Nikou, S. A., Perifanou, M., & Economides, A. A. (2024). Exploring Teachers' Competences to Integrate Augmented Reality in Education: Results from an International Study. TechTrends, 1-14.

Norabuena-Figueroa, R. P., Deroncele-Acosta, A., Rodríguez-Orellana, H. M., Norabuena-Figueroa, E. D., Flores-Chinte, M. C., Huamán-Romero, L. L., ... & Mollo-Flores, M. E. (2025). Digital Teaching Practices and Student Academic Stress in the Era of Digitalization in Higher Education. Applied Sciences, 15(3), 1487.

Ogegbo, A. A., Penn, M., Ramnarain, U., Pila, O., Van Der Westhuizen, C., Mdlalose, N., ... & Bergamin, P. (2024). Exploring pre-service teachers' intentions of adopting and using virtual reality classrooms in science education. Education and Information Technologies, 29(15), 20299-20316.

Paulsen, L., Dau, S., & Davidsen, J. (2024). Designing for collaborative learning in immersive virtual reality: a systematic literature review. Virtual Reality, 28(1), 63.

Sadykova, G., & Kayumova, A. (2024). Educators' Perception of Artificial Intelligence as Instructional Tool. *TEM Journal*, 13(4).

Schwaiger, M., Krajnčan, M., Vukovič, M., Jenko, M., & Doz, D. (2024). Educators' opinions about VR/AR/XR: An exploratory study. Education and Information Technologies, 1-20.

Shwedeh, F. (2024). Harnessing digital issue in adopting metaverse technology in higher education institutions: Evidence from the United Arab Emirates. *International Journal of Data & Network Science*, 8(1).

Silva Díaz, F., Carrillo Rosúa, J., Fernández Ferrer, G., Marfil Carmona, R., & Narváez, R. (2024). Assessment of immersive technologies and STEM focus in initial teacher training. [Valoración de tecnologías inmersivas y enfoque STEM en la formación inicial del profesorado]. RIED-Revista Iberoamericana de Educación a Distancia, 27(1), 139-162. https://doi.org/10.5944/ried.27.1.37688.

Sulistyanto, H., Prayitno, H. J., Narimo, S., Anif, S., Sumardjoko, B., & Wardhani, N. W. (2024). A Study of The Use of Augmented Reality in Learning: Impacts on Increasing Students' Critical Thinking Skills. *Asian Journal of University Education*, 20(2), 369-379.

Tafazoli, D. (2024). Exploring the potential of generative AI in democratizing English language education. Computers and Education: Artificial Intelligence, 7, 100275.

Tan, K. H., Naim, M. K., Wahi, W., Arham, A. F., & Yunos, N. (2024). Metaverse-Based Activities for Enhancing Communicative Competencies among Young Learners. *International Journal of Interactive Mobile Technologies*, 18(21).

Tuta, J., & Luić, L. (2024). D-Learning: An Experimental Approach to Determining Student Learning Outcomes Using Augmented Reality (AR) Technology. Education sciences, 14(5), 502.

Wu, D., Zhang, S., Ma, Z., Yue, X. G., & Dong, R. K. (2024). Unlocking potential: Key factors shaping undergraduate self-directed learning in ai-enhanced educational environments. Systems, 12(9), 332.

Yaseen, H., Mohammad, A. S., Ashal, N., Abusaimeh, H., Ali, A., & Sharabati, A. A. A. (2025). The Impact of Adaptive Learning Technologies, Personalized Feedback, and Interactive AI Tools on Student Engagement: The Moderating Role of Digital Literacy. Sustainability, 17(3), 1133.

Zouhri, A., & El Mallahi, M. (2024). Improving teaching using artificial intelligence and augmented reality. *Journal of Automation, Mobile Robotics and Intelligent Systems*, 57-61.