Using Immersive Augmented Reality (AR) or Virtual Reality (VR) in a Classroom Is as Effective as Traditional Classrooms in Higher Education: A Systematic Review

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Integrating immersive virtual and augmented reality (VR/AR) in higher education has gained significant attention as potential tools to enhance learning experiences. This systematic review aims to evaluate the effectiveness of using AR and VR in the classroom compared to traditional instructional methods. The analysis includes 42 studies, 17 focused on AR, 23 on VR, and 2 addressing both technologies. The research trend indicated a notable increase in studies after 2018. The review reveals that AR and VR can offer several advantages, such as enhancing students' understanding of complex concepts, improving engagement levels, and promoting interactive learning experiences.

Keywords: Augmented Reality (AR) in education, Virtual Reality (VR) in education, immersive learning, Technology-Enhanced Learning (TEL), higher education, learning outcomes, student engagement

INTRODUCTION

Augmented Reality (AR) and Virtual Reality (VR) represent two of the most cutting-edge technological advancements of these times. Their potential to revolutionize the education system is immense. Over the past few years, there has been a growing trend of incorporating AR and VR into education, opening up numerous opportunities for technology-enhanced learning (Tan, Xu, Li, & Chen, 2022). AR and VR bring forth immersive digital experiences that go beyond the capacity of traditional teaching methods (Phakamach, Senarith, & Wachirawongpaisarn, 2022). By utilizing these technologies, students can interact with complex subject matter in ways that surpass lectures and textbooks, fostering deeper engagement (Sun, Zhong, Qu, & Xiong, 2022). Moreover, educators can tailor content to cater to individual learning styles (Childs, et al., 2021). These technologies offer a more immersive educational experience and provide the possibility of simulations and virtual field trips without physical travel (Seidametova, Abduramanov, & Seydametov, 2021). By leveraging AR and VR, educators can create realistic and interactive learning scenarios that were previously unattainable.

AR and VR have the potential to bridge the divide between conventional classroom teaching and practical, real-world experience, offering concrete opportunities for learners' professional growth. Over the last decade, augmented reality (AR) has emerged as a highly promising domain within computer graphics. As technology advances, digital devices are increasingly being embraced for educational purposes, shaping the landscape of learning and instruction (Zawacki-Richter & Latchem, 2018).

According to (Le & Nguyen, 2020), incorporating AR in education offers a range of advantages such as portability, cost-effectiveness, stress reduction, and promising solutions applicable in various academic settings. (Chavez & Bayona, 2018) conducted a study exploring the use of VR and AR in the context of learning. They investigated the key factors contributing to the successful implementation of this technology and its positive impact on learning outcomes. The research revealed that the "movement" feature is crucial in understanding the body's reactions in specific subjects like medicine. In general education, "immersion interfaces" are commonly used to simulate "live experiences" that closely resemble reality. As AR and VR hardware costs decrease, these technologies are expected to become more accessible.

The integration of Augmented Reality (AR) and Virtual Reality (VR) in education is revolutionizing the learning process, allowing students to engage with the world in novel and interactive ways (Du, et al., 2020). These technologies also allow educators to create interactive simulations, enabling students to delve into complex subjects within a safe and captivating environment. Iorporating both techniques in the classroom has positively affected student engagement and learning (Sun, Zhong, Qu, & Xiong, 2022). Those who use these immersive technologies exhibit higher motivation levels and increased engagement, leading to enhanced performance in academic tasks (Alizadehsalehi, Hadavi, & Huang, 2021).

As the adoption of AR and VR in educational settings continues to gain momentum, schools and universities are investing in this technology. Moreover, the cost of AR and VR hardware has gradually decreased, making it more accessible even for those with limited budgets.

The systematic review aims to investigate AR's applicability and relevance in e-learning contexts, uncovering its challenges as reported in the published research. By analyzing AR's challenges in this context, the review seeks to identify trends, limitations, and opportunities for further research, providing a comprehensive outlook for the future of AR in education.

Research Question

The following question guided our analysis of the complete texts. It enabled us to gain a better understanding of how researchers and teachers in higher education conceptualize the enhancement of teaching and learning with Augmented and Virtual reality:

RQ: *Do AR/VR interventions enhance knowledge or learning outcomes in higher education?*

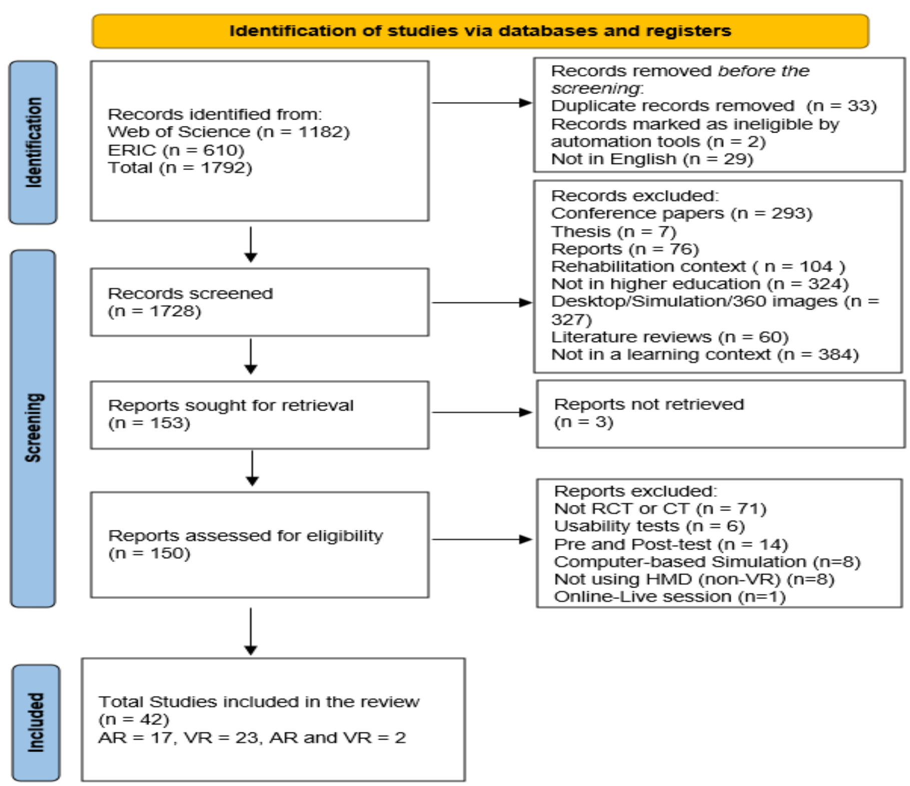
TABLE 1
APPLICATION OF THE POPULATION, INTERVENTION, COMPARISON, AND OUTCOMES (PICOS) FRAMEWORK TO THE RESEARCH QUESTION. TEL: TECHNOLOGY-ENHANCED LEARNING

Parameter	Details
Participants	Full-time higher education (university) students (Undergraduate or graduate)
Intervention	Using Augmented Reality (AR) OR Virtual Reality (VR)
Comparison	Traditional Classroom or Lab without AR or VR
Outcomes	Training effectiveness, learning outcomes, knowledge gain, and performance indicator
Study design	Both empirical and theoretical research published in English from peer-reviewed journals
Context	Classroom or Laboratory setting with VR HMDs or AR-enabled mobile devices.
Type	Randomized controlled trial (RCT) or Controlled trial (CT)

METHODS

This systematic review has been performed according to the preferred reporting items for systematic reviews and Meta-analyses (PRISMA) (Page, et al., 2021), recommendations for systematic reviews and meta-analyses. Figure 1 depicts the steps taken to arrive at a final analytical set of research papers for the study.

FIGURE 1
DIAGRAM FROM PRISMA SHOWING THE RESULTS OF THE INITIAL SEARCH



Research Strategy

A comprehensive scientific literature search was conducted using Web of Science and Education Resources Information Center (ERIC) databases. The search covered articles up to November 18, 2022, and utilized three primary sets of keywords: "university students," "augmented and virtual reality," and "randomized controlled trials." The full search for each database is reported in Appendix 1 but broadly includes the following:

TS=("augment reality" OR "virtual reality") AND TS=("higher education" OR "university" OR "graduate") AND TS=("evaluation" OR "performance" OR "intervention" OR "RCT" OR "randomized controlled trial" OR "randomized controlled trial").

The initial search retrieved 1792 articles: 1182 from Web of Science and 610 from ERIC. Of these, 33 were duplicates, and Zotero's automatic screen removed two additional articles after applying a language filter to include only those published in English. Of these 1792 records, 29 were identified as non-English studies and removed using automated duplication detection, yielding 1728 for further screening and eligibility.

Using Zotero Reference Manager (cite), a further 1575 records were excluded by hand using the following exclusion criteria: conference papers (n=293); theses (n=7); reports (n=76); rehabilitation context but experiments were conducted on university students (n=104); not in a higher education context (n=324); non-immersive (Desktop/Simulation) and used 360° images (n=327); and literature reviews (n=60) and not in learning context (n=384). Next, the remaining 153 screened reports were sought for retrieval. There were only three reports which were not retrieved; this resulted in a total of 150 reports.

Inclusion / Exclusion

Table 2 shows the inclusion and exclusion criteria. The criteria used to select the articles for this review were as follows: if they were: i) published in peer-reviewed journals; ii) included learning outcomes of students (such as grades or engagement); iii) randomized controlled trials or controlled trials; iv) laboratory or classroom context; and v) HMD (Head mounted display) is used for VR; vi) and were written in English.

Articles that did not evaluate a program or intervention were excluded; only usability or acceptance tests, pilot or exploratory studies, non-immersive, non-VR, and pre-and post-tests were included.

TABLE 2
INCLUSION AND EXCLUSION CRITERIA FOR THE PROPOSED STUDY BASED ON A PICO FORMAT

Parameters	Inclusions	Exclusions
Participants	University Students (graduate/undergraduate)	School Students, Teachers, Medical Staff, Patients, Mixed Audience, Adults
Intervention	AR and VR as a medium, in the case of VR, it must be HMD (Head mounted display)	3D simulation, Desktop VR, non-immersive/non-VR, VR Simulation
Comparison	Laboratory or Classroom	Online, Distance Learning, or e-Learning
Outcomes	Learning Outcomes, Effectiveness, Knowledge Gain	Usability, Acceptance, Motivation, or Affordance
Study design	Empirical Qualitative and Quantitative, Survey, Questionnaire, etc.	Reviews, Opinions, Pilot Study
Context	AR/VR in the Classroom or Laboratory	Rehabilitation, Therapy, and all studies outside the classroom

Type	Randomized Controlled Trials (RCT) or Controlled Trials	An Exploratory Study, Pilot Studies
Language	English	All languages other than English

Of the 150 remaining articles, 110 were not Randomized controlled trials or controlled trials (n=71); Usability tests (n=6); Pre- and Post-test (n=14); Computer-based Simulation (n=8); Not using HMD (non-VR) (n=8) and 1 was an online-live session. After applying the complete set of criteria, we were left with a final analytical sample of 41 studies for extraction and analysis. There were 17 articles related to Augmented Reality (AR), 23 related to Virtual Reality (VR), and 2 for both AR and VR.

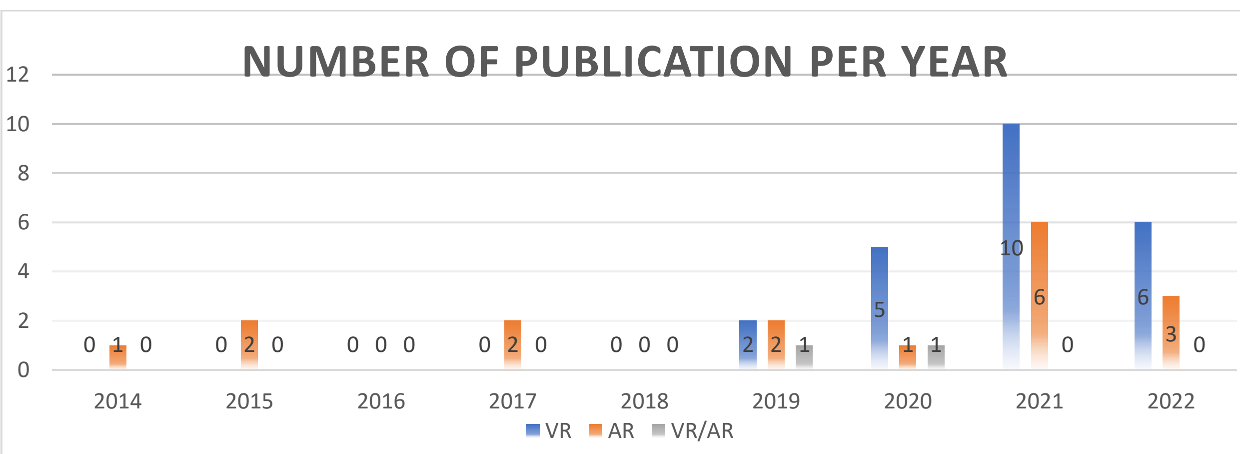
Extraction and Analysis

A systematic review has been conducted to locate all relevant literature on the benefits and advantages of implementing AR and VR in education, specifically focusing on classrooms. A concise scoping review was performed to facilitate this research, evaluating critical studies on AR in various sectors to identify common terminology and enable a more comprehensive search. The research adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations, as outlined by Nagendrababu in 2019. For each article included in the systematic review, the following information was extracted: author details, publication year, country of origin, study design, participants' characteristics, teaching model attributes, number of lessons received, instruments used to evaluate the impact of the teaching model, and the obtained results.

RESULTS AND THEMATIC ANALYSIS

The analysis revealed that using AR and VR in academic environments brought diverse advantages and obstacles. Of the 42 articles we examined, 17 focused on AR, 23 on VR, and 2 discussed both technologies. Figure 2 illustrates a significant increase in research studies, particularly after 2014, with the majority of them (n=16) being published in 2021.

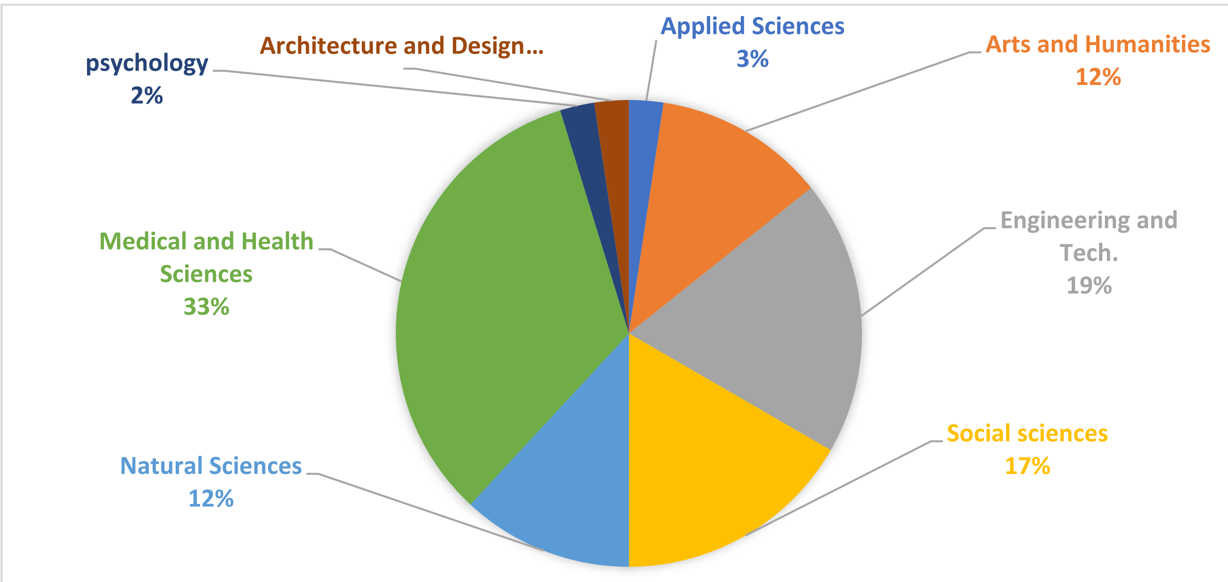
FIGURE 2
DEMOGRAPHIC DESCRIPTION; CLASSIFICATION OF THE 41 SELECTED PAPERS BY PUBLICATION YEAR



The Figure 3 shows published research works within the scope of the research given the related academic fields. It can be observed that the largest proportion of publications falls within the category of Medical and Health Science (33%), followed by Engineering and Technology publications (19%), Social

Sciences (17%) and Natural Sciences (12%). Smaller proportions of the publication landscape are accounted for by other disciplines, which include, for instance, Arts and Humanities (12%), Applied Sciences (3%), Psychology (2% and Architecture and Design (2%). This distribution illustrates the multidisciplinary character of the topic with a slight concentration on medical and technical fields.

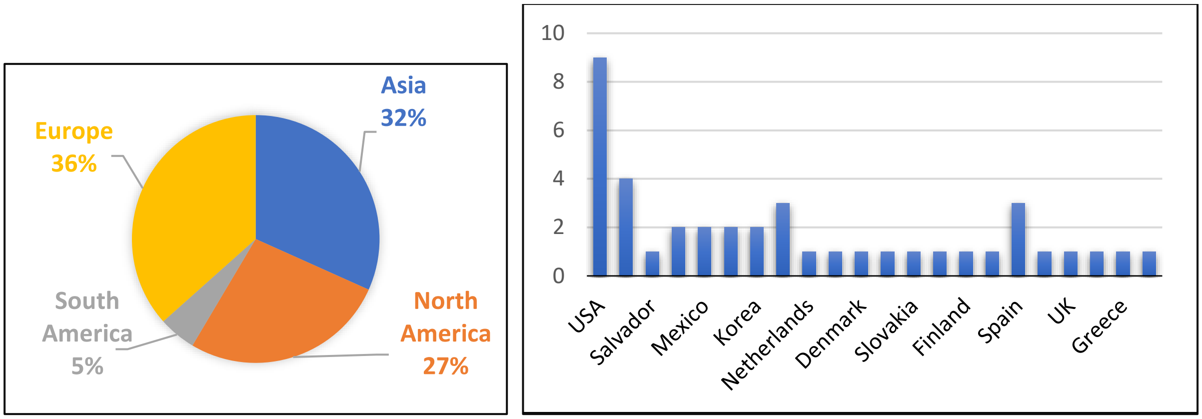
FIGURE 3
DEMOGRAPHIC DESCRIPTION; CLASSIFICATION OF THE 41 SELECTED PAPERS BY FIELD OF STUDY



The geographical distribution of the studies was diverse, as shown in Figure 4, including Asian countries (n=16), Europe (n=12), and North America (n=11). About one-quarter of the studies were among university students in the allied health sciences (n=13), followed by engineering (n=7) and social sciences (n=7) (see also Figure 3 for a disaggregation by field).

The apparatus used for VR varied among studies, with HTC (n=8) and Oculus (n=5) being the most used. Other studies used VR Box with a smartphone, Gear VR, and Google Cardboard. For AR, most studies used mobile devices as the primary tool, with only three studies using Microsoft HoloLens and 1 using Vuzix M300 smart glasses. Methodologically, these studies drew heavily upon randomized control trials as their study design (n=21), whereas the others performed trials without randomization.

FIGURE 4
DEMOGRAPHIC DESCRIPTION: NUMBER OF PUBLICATIONS CLASSIFIED BY REGION AND COUNTRY



Five main themes emerged from the analysis: i) Learning outcomes and academic performance; ii) Student engagement randomization and motivation; iii) Reducing anxiety and stress; iv) Skill development and experiential learning; and v) Knowledge gain and retention. Table 3 summarizes how each article fits into these five themes.

TABLE 3
THEMES USED FOR DATA EXTRACTION AND IDENTIFIED CATEGORIES IN DATA SYNTHESIS

Themes	Virtual reality (VR)	Augmented reality (AR)	Augmented & Virtual reality (AR/VR)
Learning outcomes and Academic performance, Cognitive load	(Bacca Acosta, Tejada, Fabregat, Kinshuk, & Guevara, 2022); (Baceviciute, Terkildsen, & Makransky, 2021); (Campos, Irving, & Zavala, 2022); (Davis, Linvill, Hodges, Costa, & Lee, 2020); (Dunnagan, et al., 2020); (Gao, et al., 2021); (Han, Kim, Kong, & Cho, 2021); (Lamb, Etopio, Hand, & Yoon, 2019); (Lopez, Arriaga, Juan Pablo Nigenda Álvarez, & José Antonio Elizondo-Leal, 2021); (Mansoory, Azizi, Mirhosseini, Yousef, & Moradpoor, 2022); (Miller, Castillo, Medof, & Hardy, 2021); (Wang, Guo, Wang, Tu, & Liu, 2021)	(Chu, Chen, Hwang, & Chen, 2019); (Gutiérrez & Fernández, 2014); (Nuanmeesri, Kadmateekarun, & Poomhiran, 2019); (Özcan et al., 2017); (Shirazi & Behzadan, 2015); (Wolf, et al., 2021)	(Gabajová, et al., 2019)

Student engagement and motivation, Collaborative learning	(Valencia, Rivas, Palmero, & Gámez, 2022); (Wang, Guo, Wang, Tu, & Liu, 2021)	(Bork, et al., 2021); (Ferrer-Torregrosa, Torralba, Jimenez, Garcıía, & Barcia, 2015); (Kandasamy, Bettany-Saltikov, Cordry, & McSherry, 2021); (Rodríguez-Abad, Rodríguez-Gonzaleź, Martínez-Santos, Josefa-del-Carmen, & Fernandez-de-la-Iglesiá, 2022); (Södervik, et al., 2021)	(Gabajová, et al., 2019)
Reducing anxiety and stress, Cognitive load	(Sarpourian, Samad-Soltani, Moulaei, & Bahaadinbeigy, 2022); (Wang, Guo, Wang, Tu, & Liu, 2021)	(Rodríguez-Abad, Rodríguez-Gonzaleź, Martínez-Santos, Josefa-del-Carmen, & Fernandez-de-la-Iglesiá, 2022)	--
Skill development and experiential learning	(Berg & Steinsbekk, 2021); (Boetje & Ginkel, 2021); (Chiu, Hwang, & Hsia, 2022); (King, Dzenga, Burch, & Kennedy, 2021); (Kurul, Ögün, Narin, Avci, & Yazgan, 2020); (Wells & Miller, 2020)	(Borgen, Ropp, & Weldon, 2021); (Han, Zhao, & Zhao, 2022); (Södervik, et al., 2021)	--
Knowledge gain and retention	(Baceviciute et al., 2021; (Gabajová, et al., 2019); (Kim, et al., 2019); (Ruan, 2022)	(Borgen, Ropp, & Weldon, 2021); (Chin & Wang, 2021); (Dukalskaya & Tabueva, 2022); (Södervik, et al., 2021)	(Srinivasa et al., 2021)

Theme 1: Learning Outcomes and Academic Performance (n = 19)

Multiple studies evaluated the impact of VR and AR on learning outcomes and academic performance. These applied to diverse fields of scholarly research, including health sciences, psychology, and engineering. Starting with the VR studies, as one example, Wang et al. (2021) performed a controlled trial to teach English as a foreign language (EFL) using three approaches to VR. One group used VPS-VR strategies, which provided explanatory and supplementary information while reading in the VR environments. Another watched the VR videos without VPS strategies, in which a word was flashed on the screen for 6 to 8 seconds. The final control group watched the video on the computer. Their analysis revealed that a VPS-based strategy significantly improved learning outcomes such as reading skills and reading comprehension, such as information location and text comprehension.

Similarly, another study (Miller, Castillo, Medof, & Hardy, 2021) focused on using VR to teach organic chemistry, finding that immersive VR improved academic performance and student grades. Interestingly, it also found that the impact of VR was more significant on the students, who traditionally had lower success rates in STEM (science, technology, engineering, mathematics) courses. Other studies that investigated the effectiveness of VR technology in specific fields, such as dentistry (Mansoory, Azizi, Mirhosseini, Yousef, & Moradpoor, 2022), human neuroanatomy (Lopez et al., 2021), neurology (Han, Kim, Kong, & Cho, 2021), and Physics (Campos, Irving, & Zavala, 2022). These studies also found VR to be an effective tool to enhance learning outcomes and academic performance.

Turning to the AR studies, Wolf et al. (2021) compared the effectiveness of AR-based and conventional instructions during cannulation training. They found that AR-based instructions were more effective in improving trainees' performance. Shirazi and Behzadan (2015) investigated the use of AR for content delivery in building design and assembly projects and found that AR-enhanced the student's understanding and performance of the project. Özcan et al. (2017) used AR to teach Ottoman Turkish readings to high school students and found that AR positively affected the students' performance in reading and comprehending Ottoman texts.

Nuanmeesri et al. (2019) performed a CT comparing AR with traditional methods such as notes, pictures, and videos for teaching human heart anatomy to nursing students. The training lasts for 3 hours and includes pre-and post-tests. The results showed that the learning results of the AR group were better than that of the control group at the statistical significance of p-value > 0.001 (how learning outcomes are measured). Gutierrez and Fernandez (2014) applied AR in engineering education and found that it improved academic performance and student motivation. Chu et al. (2019) investigated the effects of formative assessment by employing an AR approach to conducting ubiquitous learning activities for architecture courses. They found that AR-based formative assessment improved students' learning outcomes.

Theme 2: Student Engagement and Motivation (n=8)

Multiple studies evaluated the impact of VR and AR on students' engagement and motivation, with all eight studies finding significant improvements compared with conventional teaching approaches. AR and VR enable the development of educational aids that enhance interactions, adaptability, and creative engagement among learners. According to these researchers, these techniques are effectively utilized in various learning settings to establish innovative pedagogical approaches that cultivate human-centered learning environments.

Almost all studies were in the allied health sciences (n= X). In a survey by Bork et al. (2021), the researchers investigated the effectiveness of collaborative augmented reality in gross anatomy teaching using HoloLens. The study found that the use of collaborative AR increases the understanding of topographic anatomy, enhances student engagement, and leaves a positive impact on fun and motivation. Similarly, Ferrer-Torregrosa (2016) developed and assessed ARBOOK, a tool based on augmented reality for anatomy learning for medical students. The author found that using ARBOOK significantly improved the students' engagement and motivation and promoted their self-learning and their working autonomously.

Kandasamy et al. (2021) conducted an exploratory study to investigate the use of vision-based augmented reality (VBAR). They found that the students' learning of the spine and spinal deformities was improved. These findings show that augmented reality integration results in several learning gains, such as increased student engagement and motivation. Rodríguez-Abad et al. (2022) investigated the effectiveness of augmented reality in learning about leg ulcer care in nursing students. The results showed that using AR improves students' knowledge, skills, perceptions, and expectations towards the teaching-learning process.

Södervik, et al., (2021) explored using mobile augmented reality glasses such as Vuzix M300 to foster performance in hands-on work in a microbiology laboratory. The results showed that augmented reality glasses significantly increased students' engagement, motivation, and learning outcomes. Finally, Valencia et al. (2022) explored university students' perceptions of virtual reality as a didactic resource. The authors conducted a pre-experimental study with a control and experimental group and found that virtual reality significantly increased students' engagement and motivation.

Theme 3: Reducing Anxiety and Stress (n=3)

Technology-based solutions such as virtual and augmented reality have been found effective in reducing anxiety and stress levels in students. Anxiety and stress are common issues that many individuals experience in various situations, including academic settings. The potential of AR and VR technologies in reducing anxiety and stress levels among students presents a promising opportunity for improving academic performance.

Sarpourian et al. (2022) investigated the effect of virtual reality therapy and counseling on students' public speaking anxiety. The study utilized a virtual reality exposure therapy (VRET) program, which exposed students to simulated public speaking situations in a controlled environment. The results showed that the VRET program significantly reduced students' public speaking anxiety levels compared to that of the control group, who received traditional counseling methods. Similarly, Wang et al. (2021) found that the virtual reality approach was effective in reducing anxiety levels and stress among EFL learners.

A study by Rodríguez-Abad et al. (2022) investigated the effectiveness of augmented reality in learning about leg ulcer care among nursing students. The study utilized an augmented reality application that allowed nursing students to interact with 3D models of leg ulcers and learn about their care procedures. The results showed that the augmented reality application effectively reduced students' anxiety levels and improved their learning outcomes.

Theme 4: Skill Development and Experiential Learning (n=9)

The AR/VR creates an immersive and interactive environment that allows individuals to practice and improve their abilities realistically and engagingly. Further, it enhances learners' hands-on skills and engagement. Virtual and augmented reality have demonstrated outstanding potential in skill development and experiential learning across various fields, including healthcare, soft skills, engineering, and art. Virtual reality and augmented reality are practical in skill development and experiential learning.

Berg and Steinsbekk (2021) conducted a randomized controlled trial to investigate the effect of self-practicing systematic clinical observations in a multiplayer, immersive, interactive virtual reality application versus physical equipment. The results showed that the virtual reality application was as practical as physical equipment in improving clinical observation skills. This finding implies the potential of virtual reality in healthcare training.

Kurul et al. (2020) proposed an immersive virtual reality method for anatomy training, revealing its potential to provide an engaging and practical learning experience for medical students. Similarly, Borgen et al. (2021) and Han et al. (2022) investigated the impact of augmented reality technology in aeronautical engineering technology education and mechanical assembly courses, respectively, demonstrating the potential of augmented reality in engineering education. Wells and Miller (2020) investigated the effect of virtual reality technology on welding skills, bringing out the potential of virtual reality in vocational training.

Boetje and van Ginkel (2021) examined the added benefit of virtual reality in developing presentation skills. The study showed that the extra practice session significantly improved presentation skills, indicating the potential of virtual reality in education and professional training. Finally, Chiu et al. (2022) used experiential learning based on virtual reality to promote the students' artwork. The study showed that the virtual reality approach significantly improved the students' appreciation and engagement with artwork.

Theme 5: Knowledge Gain and Retention (n=9)

Virtual reality (VR) and augmented reality (AR) technologies allow students to visualize and manipulate complex concepts and information, making it easier to understand and remember them. These technologies improve knowledge gain and retention among students by furnishing interactive, immersive, and engaging learning experiences. These technologies have been shown to significantly enhance knowledge gain and retention in various educational settings. Knowledge gain and retention have been studied in multiple fields to find more effective ways of improving learning outcomes.

The studies such as those by Södervik, et al. (2021) and Srinivasa et al. (2021) have examined AR and VR technologies in laboratory settings. These studies found that AR and VR technologies can improve student knowledge, self-efficacy, and attitude toward laboratory work. Similarly, Gabajova et al. (2019) and Kim et al. (2019) have explored VR and AR for medical education and biochemistry, respectively. These studies found that VR and AR technologies provide learners with an immersive and interactive learning environment and thus can enhance knowledge gain and retention.

The findings of Borgen et al. (2021) and Dukalskaya and Tabueva (2022) also support the positive impact of AR technology on learning outcomes. Borgen et al. (2021) investigated the use of AR technology in aeronautical engineering education, while Dukalskaya and Tabueva (2022) explored the use of AR technology for teaching English to non-native students in higher education. Bacca-Acosta et al. (2022) used eye-tracking technology in VR to provide personalized scaffolding to English language learners, leading to improved comprehension and retention of the language.

DISCUSSION

The analysis conducted on the use of Augmented Reality (AR) and Virtual Reality (VR) in academic environments revealed a range of advantages and challenges. The examination of 41 articles revealed that 15 focused on AR, 22 on VR, and 2 discussed both technologies. The research trend indicated a notable increase in studies, particularly after 2014, with a significant number published in 2021.

Based on the analysis of various studies included in this review, it is concluded that employing VR/AR as a teaching tool yields greater effectiveness than traditional teaching methods regarding learning satisfaction and academic performance. As no systematic review or meta-analysis is available for VR/AR use in classroom teaching, these findings will be compared to other systematic reviews and meta-analyses in different educational disciplines.

Zhao et al. (n.d.) reported that medical students trained in VR technology rose to a higher pass rate and demonstrated better acquisition of specialized knowledge than those taught through traditional methods. Rickel (2001) suggested that integrating VR-based teaching models into the university education system would necessitate significant financial investment to provide the required infrastructure in various teaching centers. Moreover, substantial efforts would be necessary to adequately train and instruct university teaching staff using these new technologies. Virtual learning environments should also be continuously adapted to meet the needs of both teaching staff and students. The significant challenges identified in these studies are categorized into pedagogical, learning, and technological issues. Pedagogical issues pertain to teachers' resistance and lack of AR technology skills, training, and experience.

CONCLUSION

The promising potential of Augmented Reality (AR) and Virtual Reality (VR) technologies can transform the field of education by offering students a highly immersive and encaptivating learning experience. By leveraging these technologies, students can be fully immersed in diverse visuals, audio cues, and simulations, thus enhancing their interest and engagement in the subject matter. The research concluded that VR/AR-based teaching models are just as effective as traditional teaching methods, serving as a valuable complement rather than a complete replacement for conventional approaches.

Future Directions

Educators can harness the capabilities of Augmented and Virtual Reality technologies to replicate real-life situations, create immersive learning environments, and offer students hands-on experiences that bridge the gap between theoretical knowledge and practical application. The ongoing advancements in these technologies are expected to revolutionize how we approach teaching and learning. Therefore, it is highly encouraged for educational institutions to allocate more time, resources, and training toward integrating these technologies into their curricula. Augmented reality has the potential to animate textbooks with interactive diagrams. In contrast, virtual reality can produce immersive simulations that enable students to experience real-world scenarios in a safe and controlled setting. Instructors have recognized that students value practice-oriented learning over mere memorization of facts. This leads to an understanding that instructors have positive experiences with VR in their teaching sessions. It is anticipated that they can further explore advanced applications to make teaching even more practice-oriented. In this study, most articles describe VR applications for teaching procedural knowledge. The use of AR in the classroom setting brings academic advantages. However, further research is required to ascertain the effectiveness of this approach, particularly in distance and remote learning scenarios.

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