Education and Information Technologies
https://doi.org/10.1007/s10639-024-12602-5

# Virtual, augmented reality and learning analytics impact on learners, and educators: A systematic review

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Received: 17 March 2023 / Accepted: 26 February 2024


**Abstract**
Virtual and Augmented Reality technologies have emerged as promising tools in the education sector, offering new possibilities for immersive learning experiences. Many researchers have focused their research on examining the potential of these technologies in education from different perspectives. However, it was discovered that there are research gaps in current systematic reviews regarding the examination of the impact of Virtual, Augmented Reality and Learning Analytics utilization on various types of learners and educators across different educational systems, including K-12 Education, Higher Education, Vocational, and Industrial Training, in addition to the educational systems' research tendencies and their adoption of these technologies. Therefore, our study aims to address these gaps by searching various studies in Google Scholar, Scopus, and the IEEE Xplore databases. By following the PRISMA protocol, 150 research papers were selected for analysis, and our findings show that improving motivation and attention, improving learners' understanding & performance, and increasing knowledge retention are the most significant impacts on all types of learners. For educators, we found that these technologies have a prominent effect on assisting educators in teaching and training and reducing the burden. Furthermore, we discovered that Higher Education and Augmented Reality were the dominant educational system and the technology type in the selected studies. We also found that most Virtual and Augmented reality researchers preferred to use questionnaires and online surveys for data collection. We further identified that analyzing learners' traces when interacting with Virtual and Augmented Reality applications can improve learners' performance and learning experience. Our review offers valuable insights into how integrating these technologies with Learning Analytics can benefit learners and educators and how educational institutions and industrial organizations can take advantage of adopting these technologies.

**Keywords** Virtual and augmented reality · Technology enhanced learning · Educational technology · Learning analytics · Learners and educators

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# 1 Introduction

Virtual Reality (VR) and Augmented Reality (AR) technologies have shown great educational potential by providing immersive learning experiences. These tools offer interactive and engaging environments that can enhance students' knowledge and learning experience. Learning through VR and AR technologies allows learners to discover environments and situations that might be difficult to visit (e.g., the abstract—non-Euclidean geometry, or the physically impossible—the surface of Venus). They also can aid in creating more immersive and experiential learning experiences by promoting self-based learning through sensible and immersive construction assignments, which is not feasible with the existing Learning Management Systems (LMSs) (Kavanagh et al., 2017; Scavarelli et al., 2020). VR and AR technologies allow learners to integrate diverse creative technologies to expand their real-world and virtual surroundings (Eigen et al., 2020). The adoption of VR and AR seems to have a promising future in learning and training within various educational systems, such as K-12 education (K-12) (Degli Innocenti et al., 2019), Higher Education (HE) (Samosorn et al., 2020), Vocational Education (VE) (Babu et al., 2018), and Industrial Training (IT) (Delgado et al., 2020). Integrating VR and AR as a medium to educate various learners has gained significant interest from many researchers (Babalola et al., 2023; Bacca-Acosta et al., 2021; Mazzuco et al., 2022; McCloskey et al., 2023). VR technology as a learning medium has proved its effectiveness in terms of increasing immersion, collaboration, enjoyment, and motivation in learning, and several domains have shown an explicit adoption of such technology, including health applications (e.g., surgical education, physical education, nursing education, rehabilitation), engineering (e.g., robotics, architecture, mining, construction, mechanical engineering), and science (e.g., computer science, astronomy, energy education, geometry) (Kavanagh et al., 2017). AR, on the other hand, is another learning medium that provides seamless interaction between the natural environment and virtual objects as it combines aspects of ubiquitous computing, tangible computing, and social computing. Its application in education has enhanced the learner's perception and interaction with the real world. The effectiveness of AR educational apps was evident in various domains, such as military, medicine, engineering design, robotics, telerobotics, manufacturing, maintenance, and repair applications. It also enhances collaboration and improves the understanding of real objects (Kesim & Ozarslan, 2012). Akçayır and Akçayır (2017) have also affirmed that AR improves learner's laboratory skills with evident improvement of positive attitude and enhanced learning performance.

## 1.1 Technologies background

Although VR and AR technologies share some characteristics, it is better to provide their definitions and a synopsis of each technology's history to help the reader differentiate between them. VR can be depicted as a computer-generated three-dimensional (3D) simulation of real-world scenarios. It allows users who wear a particular electronic device on their heads (HMD: Head Mounted Display) to fully immerse themselves in a virtual environment. VR has recently become increasingly popular in various industries, including gaming, healthcare, education, and military training, able to transport users to different worlds and experiences. (Babalola et al., 2023). The setup of VR can be categorized into three categories (Bamodu & Ye, 2013):

a) Non-immersive: this category provides the least immersive experience through the utilization of a desktop screen.
b) Semi-immersive: this type offers a more immersive experience while keeping the ease of use of a desktop VR. It is commonly referred to as a hybrid or AR system.
c) Immersive: this category provides the highest level of immersion to the user, eliminating the real world. For further clarity, fully immersive VR is a synthetic computer-generated environment transforming the user from the real world to a fully isolated imaginary environment.

Even though VR has been around for quite some time, it has not been widely used in education. The first digital VR system was created in 1966 as a United States Air Force flight simulator. However, VR applications were mainly limited to the public sector until 1991. Virtuality Group released some specialized arcade games, but these games were unsuccessful and paused after a couple of years. A Virtual Reality HMD was designed by SEGA in 1993, but it was never released despite several game studios creating software for it. Nintendo also released its VR-based game system, the Virtual Boy, in July 1995 with both a controller and a monochromatic HMD. Unfortunately, it was a commercial failure and was stopped less than six months after its initial release date (Kavanagh et al., 2017). AR technology, on the other hand, can be described as an interactive experience that depends on superimposing a digital layer on a real environment to enhance the user's understanding of real objects, and handheld devices and wearable components can view the content of AR. This technique enhances user perception and helps extract information from the virtual environment to the real world (Babalola et al., 2023). AR has been developed since the 1960s and was first debuted in interactive films featuring 3D animated objects. It is now recognized as a powerful and valuable tool, especially in education. The "father" of modern user interfaces, Sutherland (1968), has credited a VR and AR helmet called the "Sword of Damocles". However, because of its weight and size, it was constantly mounted above the user, making it challenging to move around. For more than 30 years, research in this area was restricted to laboratories due to the need for more mobility of AR technologies. It was only with the emergence of mobile devices in the 1990s that the technological prerequisites were met to allow the use of AR technology outside of specialized laboratories in the mobile space of the internet user. The concept of AR was initially introduced by Caudell and Mizell in 1992, who collaborated with engineers at Boeing to develop a transparent headset to assist aircraft engineers with complex wiring diagrams. The aim of implementing AR was to reduce costs and increase efficiency in various operations involving human participation in aircraft construction. The terms "augmented reality," "AR," and "augmentative reality" are interchangeable. Most people became acquainted with AR technology in 2016 following the release of Pokémon Go, and since then, interest in AR has continued to grow (Gurevych et al., 2021).

### 1.2 Research objectives

Many studies focused on investigating the integration of VR and AR in education. However, despite the abundance of published VR and AR studies, we found research gaps in existing systematic reviews concerning the impact of VR, AR and Learning Analytics integration on various types of learners and educators across different educational systems. For further clarity, it was challenging to find comprehensive research that discusses the impact of integrating VR and AR across various educational systems, considering both learners and educators. Furthermore, finding a paper that succeeded in identifying the dominant technology used for each educational system and investigating the data collection tools was difficult. The educational systems' research tendencies and their degree of adoption of VR and AR technologies were also found to be a research gap. Moreover, finding a systematic review that discussed the effect of applying Learning Analytics techniques with VR and AR educational applications was challenging. Therefore, in this study, we aim to provide a comprehensive systematic review of the impact of integrating VR and AR on various educational systems, including K-12 education, higher education, vocational education, and industrial training. The study's main contributions are as follows: First, the study focuses on understanding the most frequently identified effects of VR and AR technologies integration on learners and educators. Secondly, data collection tools are applied in educational systems utilizing VR and AR technologies. Thirdly, we aim to identify the educational systems' research tendencies and the adoption of the available educational systems for VR and AR technologies. Lastly, we focus on understanding the relationship between adopting these technologies and learning analytics. These contributions can be translated into the following research questions:

RQ1: What is VR and AR studies distribution for the educational systems during the selected timeframe?
RQ2: Which educational system has benefited most from VR and AR technology integration and the dominant technology in each educational system?
RQ3: What data collection tools are VR and AR educational researchers using?
RQ4: Which are the most frequently identified effects when learners and educators use VR and AR technologies across various educational systems?
RQ5: How do VR and AR educational applications relate to Learning Analytics?

## 2 Literature review

Studies have shown that implementing VR and AR remarkably impacts education regarding learners and educators. For instance, in K-12, VR and AR offer many advantages when teaching STEM (Science, Technology, Engineering, and Mathematics) subjects (Leighton & Crompton, 2017; Zawadzki et al., 2020). It also acts as a medium that assists educators in delivering the learning material (Sharma et al., 2021; Zikky et al., 2018). In HE, VR and AR make learning more interesting (Alfalah, 2018; Frasson, 2021) by converting theoretical concepts into practical ones (Cowling & Birt, 2016; Zhong & Cui, 2021). Thus, it raises self-confidence, reinforcing learning outcomes

(Divekar et al., 2021). Further, it provides a great feature to educators by allowing them to design the course without costly laboratory upgrades (Syed et al., 2019). In VE, VR and AR facilitate the transmission and training of vocational knowledge, boost knowledge retention, and allow learners to master complex processes. As a result, learning quality improves for learners (Fehling et al., 2016; Kamińska et al., 2017a, b). It also decreases the teaching load for educators. VR and AR apps act as a guide through the learning process (Bacca et al., 2015; Wei et al., 2020). While in IT, these technologies facilitate the training process and give trainees boundless training sessions if demanded (Carruth, 2017), without the persistent presence of trainers during the training process (Bosch et al., 2020). Furthermore, it raises awareness of hazardous situations. Ultimately, it boosts the safety level of trainees (Eiris et al., 2020; Ting et al., 2021).

In the literature, VR and AR technologies proved by experiments that learning gains were higher than those of conventional educational resources (Garzón & Acevedo, 2019). In K-12, VR and AR have succeeded in improving learning and teaching processes for various subjects, such as learning programming (Segura et al., 2020), science (Nasharuddin et al., 2021), and foreign languages (Alfadil, 2020). VR and AR technologies have also contributed to enhancing the HE domains. For instance, computer science (Srimadhaven et al., 2020), medical education (Kleinert et al., 2015), and engineering (Allcoat et al., 2021; Molnár et al., 2018). Integrating these technologies also positively impacted VE and IT educational systems. It assisted in clarifying the learning of plastic surgery training (Mughal et al., 2020), car maintenance and assembly (Gavish et al., 2015; Santamaría-Bonfil et al., 2020), and manufacturing (Pilati et al., 2020; Yildiz et al., 2019). Construction (Shi et al., 2020), mining (Liang et al., 2019), and nursing (Chang & Lai, 2021) domains have also benefited significantly from integrating such technologies into both VE and IT educational systems.

It has also been found that various studies have used questionnaires and surveys as a single data collection tool for conducting their studies (Eder et al., 2020; Kowalski et al., 2020; Scaravetti & Doroszewski, 2019). In contrast, Bacca-Acosta et al. (2021) have used a combination of data collection tools, including eye-tracking, a questionnaire, and a semi-structured interview. Several data collection tools have been employed in VR and AR studies. Therefore, it is crucial to investigate these tools to guide future research of recent methods and tools to provide accurate results. Undoubtedly, the purpose of using any novel educational intervention tool is to enhance the learning and teaching process. For this enhancement, analyzing the resultant data of VR and AR apps is required, and here comes the role of Learning Analytics (LA). LA (Abdullah & Sakr, 2021) collects and analyses learners' data to enhance the learning process and learner performance. Birt et al. (2019) have applied LA in their research using an analytical dashboard to evaluate clinical anatomy. This tool has helped educators monitor what the learners do during the examination. It also provides them with a detailed report of the summative assessment.

### 2.1 Contemporary studies

Examining previous and current literature in the field is crucial, as it investigates the field's current state and guides other researchers in searching for appropriate themes to discuss. In addition, to identify the subjects that have continuous significance (Akçayır & Akçayır, 2017; Davies et al., 2010; Höffler & Leutner, 2007). Various systematic review studies investigated VR and AR integration within the education sector. In these studies, researchers have directed their research to investigate one of these technologies in one discipline at one or more educational systems. For instance, the systematic review of (McCloskey et al., 2023) summarizes the use of VR and AR technologies in surgical education by analyzing 48 studies concerning spinal surgery. Some other reviews, such as (Babalola et al., 2023), have focused their investigation on using immersive technologies (VR, AR, and Mixed Reality (MR) for occupational safety and health training in the industrial sector by analyzing 67 studies. Another systematic review conducted by (Baysan et al., 2023) has analyzed 12 studies to show the impact of using 360-degree VR applications in nursing education. Marougkas et al. (2023) have also presented a systematic review of VR integration in education. However, the study's main focus was on the personalization strategies used in immersive VR for educational objectives in the classroom, limitations and advantages of using VR in education, and part of this study's findings has mentioned the most subjects that adopted VR technology, such as Chemistry, Engineering, and Biology.

Further, the review of (Juliana et al., 2022) has discussed the use of VR in business education, and the study of (Rahman et al., 2022) has investigated the impact of VR integration in laboratory education. In terms of engineering education, the research conducted by Alvarez-Marin and Velazquez-Iturbide (2022) has investigated the integration of AR, and the authors have addressed among the research questions the impact of AR from the perspective of students and instructors on the related domain. The review by (Huang et al., 2018) discussed the implementation of VR and AR technologies in dentistry for higher education students. Furthermore, (Mazzuco et al., 2022) have searched for the usage of AR technology in higher education in the Chemistry domain, and the studies of (Choi et al., 2022; Moussa et al., 2022; Radianti et al., 2020) have investigated the adoption of VR technology in higher education. While (Zweifach & Triola, 2019) study has demonstrated VR and AR adoption in medical training in higher education. In contrast, Akçayır and Akçayır (2017) research has discussed the educational impact of AR at various levels of education, including K-12, higher education, and industrial training. However, finding one comprehensive review that investigated and combined the VR and AR technologies' impact from learner and educator perspectives across various disciplines and within all the available educational systems to identify the most frequently identified effects was difficult. In addition, it was challenging to find a paper that investigated the impact of Learning Analytics integration with VR and AR learning environments and identified the educational systems' research tendency and the adoption of these educational systems to such technologies among the available systematic reviews in the field. Therefore, there is a need to review the benefits of implementing these technologies within various educational systems from different perspectives and investigate the data collection tools that were applied, the educational systems' research tendencies and their adoption of VR and AR technologies. Also, to investigate the advantages of merging Learning Analytics with VR and AR to reach the maximum capacity to use such technologies, in addition to helping direct future research, educational institutions, and industrial organizations around using these technologies for educational and training purposes. To bridge these gaps, in this study, we identified and analyzed 150 research articles examining the impact of integrating VR and AR technologies in various educational systems, published from 2015 to 2021.

## 3 Study method

This systematic literature review was conducted by pursuing the PRISMA instructions (Moher et al., 2009) and following the practical guidelines (Weidt & Silva, 2016) provided to search, collect, assess, and epitomize research articles related to the research questions. One hundred and fifty research papers from three different databases were analyzed. To demonstrate the impact of VR, AR, and Learning Analytics on the educational systems, the data collection tools that were applied, and the educational systems' research tendency and their adoption of these technologies. Below, we provide detailed information on the following procedures.

### 3.1 Research article selection process

To identify the research articles to answer the research questions, we searched for VR and AR studies in three bibliometric databases: Google Scholar, Scopus and IEEE Xplore, which might provide comprehensive coverage of the research topic (Harzing & Alakangas, 2016; Tomaszewski, 2021). As the mentioned databases offer a search engine, we searched the following keywords: VR and AR, combined with Education, Higher Education, K-12 Education, Vocational Education, Industrial Training, and Learning Analytics. The search was conducted from January 2020 to November 2021.

The period from 2015 to 2021 was selected as a primary target for the studies selection. As shown in Table 1, the search yielded many articles that were exported using the Export feature found on the Scopus and IEEE Xplore websites. At the same time, dedicated software was used to export Google Scholar's search results. Later, all results were screened based on the title and keywords. Finally, the titles and keywords of the derived studies were scanned manually to eliminate irrelevant research articles.

Next, we examined the abstracts of the remaining research articles. This process resulted in 239 studies that might be suitable. The derived articles were then assessed by reading each publication independently by one researcher to determine their eligibility for the study. The examination process was based on inclusion and exclusion criteria, as shown in Table 2. Finally, the studies that did not fulfil the eligibility criteria were eliminated. After applying the eligibility criteria, 150 research articles, as shown in Fig. 1, were found to be relevant to the study, as shown in Table 6 (See Appendices).

**Table 1** Database research results

| Keywords | Database | Results |
|---|---|---|
| "Virtual Reality", "Augmented Reality", "education", "higher education", "K-12 education", "vocational education", "industrial training", and "Learning Analytics" | Scopus | 5488 |
| | Google Scholar | 2177 |
| | IEEE Xplore | 2823 |
| | Total | 10,488 |

**Table 2** Inclusion and exclusion criteria

| Inclusion criteria | Exclusion criteria |
|---|---|
| • Publications should include VR and/or AR technologies as a main component. | • Non-English articles |
| • Publications should be about using VR and/or AR technologies for educational purposes. | • Publications contain the use of VR and AR for non-educational purposes. |
| • Publications can include a comparison between VR and/or AR technologies and conventional learning methods. | • Publications that will not serve the research questions. |

### 3.2 Data coding and analysis of the included publications

One researcher coded and analyzed all the selected studies using an MS Office Excel document. The extracted data (raw data) has been collected in an Excel sheet including the following information: year of publication, title, citation, data collection methods, research design, participants type, number of participants, the technology used, educational system, domain name, advantages of VR and AR technologies, impact on the learner, impact on educator, and Learning Analytics.

The first research question (RQ1) addresses the VR and AR studies' publication year within the educational systems. The year in the conducted study means the study's indicated date, which is mentioned in the selected research article. Some studies (Garzón & Acevedo, 2019; Pellas et al., 2021; Segura et al., 2020) combined more than one educational system. In such papers, more than one code was applied for the published year. The second question (RQ2) addresses the most selected educational system and the common technology type chosen for the published studies. Systems include Higher Education (HE) (college, university students, and teaching staff), K-12 education (K-12) (primary, middle, secondary learners, and teachers), vocational education (VE) (vocational learners and teachers), and industrial training (IT) (operators, experts, and technicians). In some studies, such as Segura et al. (2020), more than one educational system was utilized, such as undergraduate and K-12 learners. In such papers, more than one code was applied to the educational system. In terms of the technology type, these technologies were divided into two categories: VR (using HMDs, Non-immersive VR (one study) and AR (mobile devices such as tablet PCs and smartphones, AR headsets). In the results process, we found that more than one technology was used in some studies, such as (Barteit et al., 2021; Guilbaud et al., 2021; Ong et al., 2021). In this

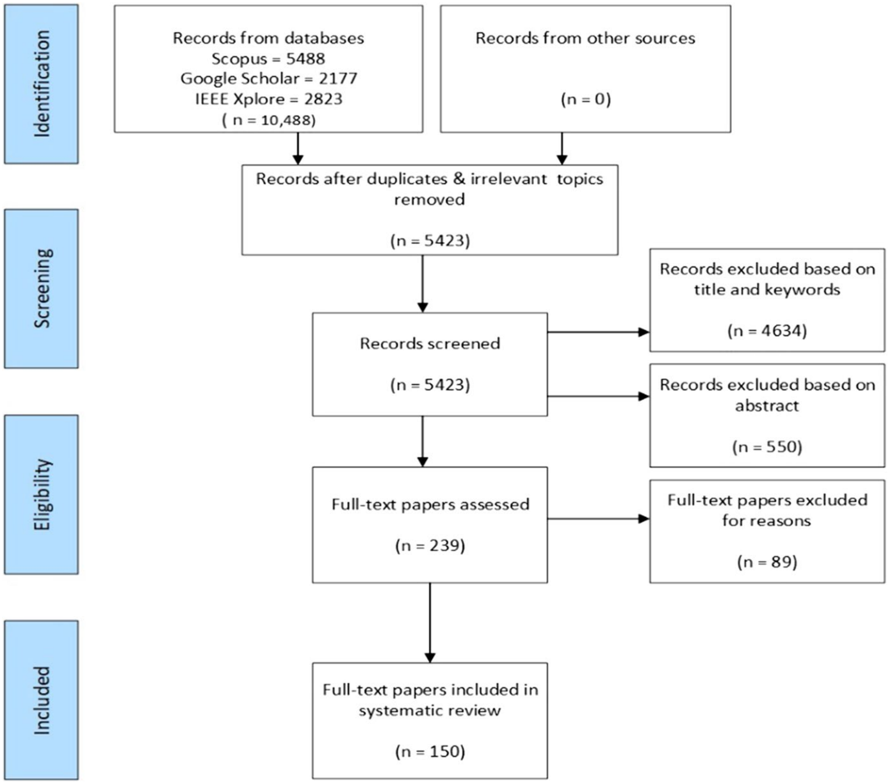


**Fig. 1** Studies selection process following PRISMA guidelines

case, more than one code was applied for the VR and AR technologies. Then, the collected data was analyzed to demonstrate the distribution of VR and AR technologies across the educational systems to identify the most technology employed. We examined code terms to determine the data collection tools (RQ3) used in VR and AR studies. The resultant data were then collected in one spreadsheet. The fourth research question (RQ4) addresses the most frequently identified effects of VR and AR technologies' integration within various educational systems. Critical reading of the selected 150 studies was accomplished to determine the effects of these technologies, which divided the effects into two main categories: learner and educator. We searched for code terms to identify VR and AR technologies' most frequently identified effects. The resultant data were collected in separate spreadsheets (learner-coding and educator-coding). The data collected from the studies was then analyzed using the content analysis method "as a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding" (Berelson, 1952). The fifth question (RQ5) is about the impact of integrating Learning Analytics with VR and AR technologies. This question followed the same procedures as the third and fourth questions (RQ3 and RQ4) regarding coding and analysis.

No pre-defined templates were utilized to find the most frequently identified effects of VR and AR integration within the educational systems, the data collection tools used in the selected studies, or the impact of Learning analytics integration on VR and AR technologies. The reason behind this was to ensure the accuracy of the coding process. Pre-created forms can unduly direct researchers while coding and can be misleading for the intended purpose (Akçayır & Akçayır, 2016).

## 4 Results and analysis

This section depicts the results and analysis of the systematic review based on the research questions mentioned. Of the 150 studies (e.g., surveys, reviews, systematic reviews, meta-analysis, experimental, and case studies) included in the following analysis, 64% were published in journals, while 32% and 4% originated from conferences and book chapters.

### 4.1 RQ1: What is VR and AR studies distribution for the educational systems during the selected timeframe?

When the distribution of the studies investigating VR and AR integration in education was analyzed across the years of publication, we found that starting from 2015 to 2020, the number of research articles has steadily increased over time, as shown in Fig. 2 for three levels of education, including, higher education, K-12, and industrial training. However, in 2021, the number of K-12 publications witnessed a sharp rise that exceeds the number of industrial training publications, which has fallen in the number of published studies compared to 2020. Furthermore, considering the vocational educational system, the educational system has experienced fluctuation in the published studies across the identified period.

Experts predict that the global VR and AR market will witness a significant rise in adopting these technologies by 2024. Furthermore, experts suggest that improvements in VR and AR hardware coupled with developments in software applications and connectivity will expedite the adoption of these technologies for education and training, in addition to other sectors (Statista, 2021a, b). A report by IndustryARC (2023) also affirmed that the VR and AR market size for the education industry is estimated to reach \$22.4 billion by 2027, growing at a Compounded Annual Growth Rate (CAGR) of 14.6% from 2022 to 2027.

Figure 2 also shows that the higher education VR and AR studies have the highest number of published studies during the specified timeframe, in contrast to other educational-level studies, which suggests that most of the research focus during these six years was on the integration of VR and AR technologies at the higher education system. However, this focus was transformed into other educational systems over time.

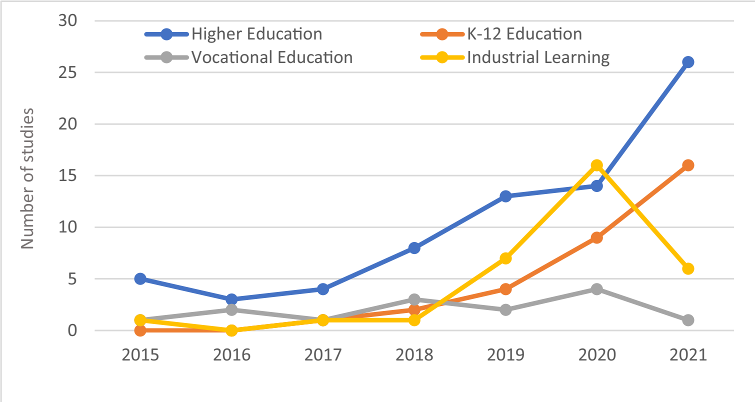


**Fig. 2** Distribution of VR and AR studies

### 4.2 RQ2: Which educational system has benefited most from VR and AR technology integration and the dominant technology in each educational system?

This research question will discuss the educational systems that adopted VR and AR technologies and each system's predominant technology type. The following subsections will provide the related results.

#### 4.2.1 Educational systems

After investigating VR and AR educational studies to identify the most educational systems, we found that 48% (73 studies) of the studies were correlated to the HE level (see Fig. 3). While both the IT and K-12 levels (roughly 20% (32 studies) for each level) shared second place. VE (nearly 9% (of 14 studies)) was the third educational system to adopt these technologies. 3% (5 studies) of the VR and AR studies had no evidence of the educational type. These studies came in fourth place.

Research findings demonstrated that the research tendency during the identified period was to investigate VR and AR integration at higher education over other levels. The possible explanation for this finding might be that several domains at this level require linking between the curriculum's theoretical and practical sides to boost learners' understanding (Katajavuori et al., 2006). Also, the ability of VR and AR technologies to provide practical experience to undergraduates can qualify them for the labor market upon graduation. Work experience is considered a key differentiator for obtaining employment, and graduates with work experience are expected to secure an appropriate level of work within a short time upon graduation (Brooks & Youngson, 2016). This work experience can now be gained with the assistance of VR and AR technologies, which might explain the massive adoption of these technologies at the higher education level.

Industrial trainees, particularly novice ones, also require practical experience in their work field to identify their weaknesses and improve their performance. A study

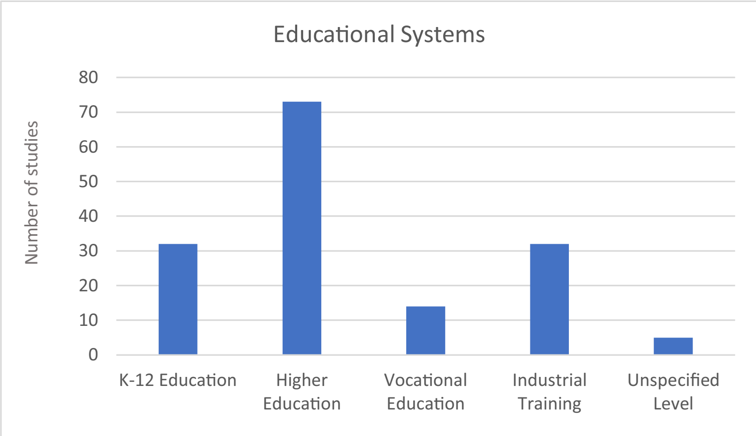


**Fig. 3** Educational systems distribution

by (Zawadzki et al., 2020) with a participant number of 20 operators in industrial production line training showed that VR training helped trainees improve identification tasks for simple assembly operations performed on the production line. VR could also improve qualified products' number and products meet quality requirements. VR and AR provide an excellent opportunity for IT trainees to explore and repeatedly practice on industrial equipment safely without paying attention to any potential hazards or facing severe consequences to their interactions, as might occur when interacting with physical equipment (Santamaría-Bonfil et al., 2020; Venkatesan et al., 2021). Hence, this could explain why the IT educational system embraced VR and AR technologies.

On the other hand, Piaget's theory of cognitive development affirms that children at the concrete operational stage (the age of 7 years old until 11 years old) and early adolescents that fall under the formal operational stage (the age of 12 years and up), use their senses to explore and learn (Babakr et al., 2019). In addition, early adolescents at this stage improve their thinking as scientists think (Babakr et al., 2019). VR and AR apps offer a significant opportunity for interaction and perception of learning material. Hence, learners who fall under these stages will undoubtedly benefit from learning through such technologies. VR and AR learning content enabled K-12 learners to interact and explore the learning material. It also helped them to understand and analyze the problem scenarios when these technologies were integrated with science subjects by promoting the development of logical thinking (Fidan & Tuncel, 2019; Liu et al., 2021a ; Osypova et al., 2021). Thus, this may be the reason behind the K-12 adoption of VR and AR technologies as a new learning method, as they assist in developing the cognitive abilities of children and early adolescents.

Almost nine per cent (14 studies) of the research focused on VR and AR implementation at the vocational education level. VR and AR were discovered as potentially effective tools for training vocational learners on various equipment and tools they may work with after graduation. Results showed that (Al-Adawi & Luimula, 2019) VE learners prefer to use VR and AR technologies as an educational medium in learning about safety issues instead of using conventional methods, as it helps understand how learners act in dangerous situations efficiently. Also, VR and AR provide learning resources when required (Chang & Lai, 2021; Weng et al., 2021). Thus, it creates an independent and stress-free learning environment. Furthermore, it provides both theoretical explanations and hands-on activities for VE learners. As a result, this could be the reason behind the integration of VR and AR in this educational system.

### 4.2.2 Dominant technology

Examination of the VR and AR studies identified that different educational systems have benefited from integrating VR and AR technologies but to varying degrees. The research concluded that AR was the dominant technology across three educational systems, except for industrial training, as shown in Fig. 4.

This study discovered that the total number of VR utilization across all the educational systems was 86 (see Fig. 4). HE (45% (39 studies) was the highest among other educational systems, as shown in Fig. 5, followed by IT (27% (23 studies) educational system, K-12 (15% (13 studies) and VE (7% (6 studies) levels, respectively. In comparison, AR utilization reached 88 (see Fig. 4). Figure 6 shows that HE (48% (42 studies) was also the highest educational system for these technologies' adoption. The second educational system was K-12 (26% (23 studies). IT (15% (13 studies) and VE (8% (7 studies) were the third and fourth, respectively. There is no evident or identifiable type of educational system. These studies have demonstrated (6% (5 studies) VR utilization (see Fig. 5) and (3% (3 studies) AR usage (Badge, 2021; Fernandez, 2017; Guilbaud et al., 2021; Kavanagh et al., 2017). VR and AR industry experts reported that immersive and interactive digital content is expected to be the major application in education within the next two years (Statista, 2021a, b).

In this research, the authors also identified that AR technology adoption at the K-12 level was higher than VR technology adoption (see Fig. 4). AR technology does not require expensive hardware and sophisticated equipment like VR technology. It can be utilized with computers or handheld devices, making AR technology used easily at every level of K-12 (Akçayır & Akçayır, 2017). The available educational VR content is often designed for stand-alone learning experiences. Further, it was not designed as a tool to be utilized in different educational systems and with different pedagogical approaches. Learning the functionality of VR devices and understanding each application's logic can also consume time for educators and learners. Thus, it makes the VR content less suitable for classroom use (Fransson et al., 2020; Jensen & Konradsen, 2018). Accordingly, this may explain why AR technology reached a high level of adoption compared to VR technology in the K-12 educational system.

It was observed in this study that VR technology integration was noticeably higher in the industrial training educational system in contrast to AR. VR technology is more immersive and attractive via spatial presence than AR apps (Huang et al., 2019). That was evident in the mining industry (Liang et al., 2019) and safety training in the construction industry (Hoang et al., 2021). VR training was engaging, raised user awareness, and changed attitudes toward safety in the construction industry (Hoang et al., 2021). It creates a new reality that allows participants to be part of it by interacting and practicing the same activities as if participants were in a real environment. Accordingly, this might explain the high proportion of VR adoption in the industrial training educational system.

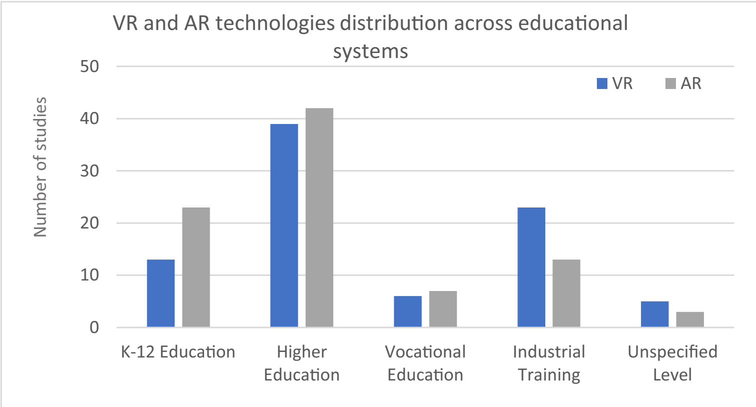


**Fig. 4** VR and AR technologies distribution

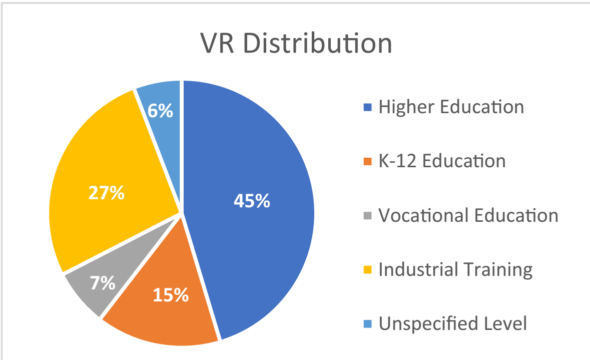


**Fig. 5** VR distribution

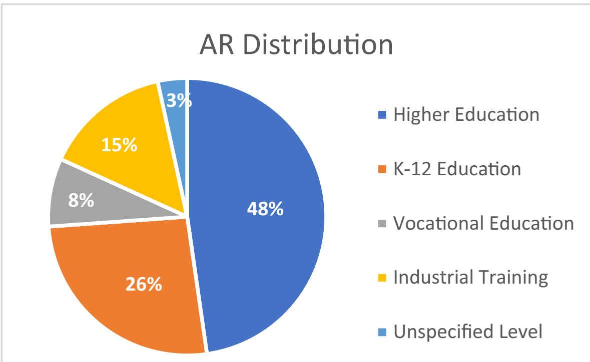


**Fig. 6** AR distribution

### 4.3 RQ3: What data collection tools are VR and AR educational researchers using?

Concerning the data collection tools, questionnaires/online surveys (Bacca et al., 2016; Hsu & Liu, 2021; Remolar et al., 2021) were the popular methods as they were iterated 79 times across the VR and AR studies, as shown in Table 3. User testing (39) (Chernosky et al., 2021; Lacko, 2020) and Interviews (26) (Daling et al., 2021; Liu et al., 2021a) were the 2nd and the 3rd most preferable methods for VR and AR educational researchers for collecting learners' data. The content analysis (19) was the 4th selected approach (Moro et al., 2021). For instance, Nowlan et al. (2018) study depended on collecting activity-based basic metrics extracted from Virtual Learning Environment (VLE) log files for analysis. (9) of the studies, such as (Logothetis et al., 2021; Stork et al., 2020), have utilized the Observation technique to collect learners' data. Other (6) data collection methods have been discovered in VR and AR studies. Each method has been used once, such as student traces in the 3D environment (Stefan et al., 2016), Microsoft Kinect data collection tool (Gorham et al., 2019), Video recording (Birt et al., 2019), log data and lab report (Jiang et al., 2021), and brainwave detecting (Xiao et al., 2019) for obtaining attention and emotion data. Participants' comments (3) (Stork et al., 2020) and Assessment & evaluation (2) (Gunn et al., 2018) were also among the utilized methods. This study also discovered a novel method for data collection, the Eye tracking technique (Bacca-Acosta et al., 2021; Shi & Worthy, 2020). This technique depends on collecting learners' gaze movement when interacting with 3D objects in VR environments.

Although VR and AR researchers in the collected studies have depended mainly on traditional data collection methods, they must also pay attention to novel data collection tools as they provide insight into new learning data. For instance, detecting learners' movements, brain waves, and gazes might refer to the easiness and acceptance of the learning application and the possible decisions that learners might make. (Mikhailenko et al., 2022) have reported that "in predicting decision making, gaze fixation, fixation duration, and the number and duration of visits are of great importance". Using these tools can also provide more accurate data than conventional tools. For example, learners might provide non-accurate data on

**Table 3** Data collection tools in VR and AR studies

| Data collection tools | f |
|---|---|
| Questionnaire & Survey | 79 |
| User testing | 39 |
| Interviews | 26 |
| Content analysis | 19 |
| Observation | 9 |
| Other | 6 |
| Comments | 3 |
| Assessment & evaluation | 2 |
| Eye tracking technique | 2 |
| No method applied | 18 |

questionnaires, and this provided data may deceive the researchers. However, using novel data collection tools (e.g., brain waves and gazes) may work to limit data falsification. Consequently, it provides rigorous research. Finally, (18) papers had no explicit or recognizable data collection method (Bistaman et al., 2018).

### 4.4 RQ4: Which are the most frequently identified effects when learners and educators use VR and AR technologies across various educational systems?

After completing the coding process, the identified effects of VR and AR in the available educational systems were classified into two categories, as shown in Table 4, which encompasses Leaner and Educator. The following sub-sections will present the related results.

#### 4.4.1 Technology effects on learners

Regarding the most identified effects on learners, improved motivation and attention levels had the highest impact noticed across all the educational systems (Büth et al., 2020; Eduardo et al., 2021; Khan et al., 2019; Palmas & Klinker, 2020; Tilhou et al., 2020; Willicks et al., 2018; Yengui & Stechert, 2021), (see Table 4). VR and AR learning content can be viewed as enjoyable activities that motivate learners to engage with the content and invest their time and effort. As a consequence, it works on reducing their constant questioning related to the learning or training materials. Furthermore, VR and AR-based material helps learners understand the learning content was the second noticed impact as it makes the content more simply (Bouaoud et al., 2021; Gisler et al., 2020; Huisinga, 2021; Liang et al., 2021; Randeniya et al., 2019; Stromberga et al., 2021; Sugiura et al., 2021; Turkan et al., 2017; Valdez et al., 2017; Zhou et al., 2018), and it works on increasing knowledge retention for higher education, K-12, vocational, and industrial educational systems' learners (Meyer et al., 2019; Weeks et al., 2021). A study by Allcoat et al. (2021) affirmed that these technologies as a learning medium for engineering learners produced better retention than conventional learning techniques. As a result, enhancing learning achievement, which was evident in the higher education, K-12 education, and industrial training educational systems (Alfadil, 2020; Alhalabi, 2016), and promoting the learners' self-confidence (Dhimolea et al., 2021; Iqbal et al., 2020). Nevertheless, this confidence was challenging to find in K -12 learners in the collected studies. Further, this research has found that a self-directed three-dimensional learning experience effectively decreases the cognitive load for learners (Lee, 2020). It improves the learners' learning performance and enhances their satisfaction with the learning process (Fajrianti et al., 2021; Henssen et al., 2020). However, we observed that satisfaction with using VR and AR technologies requires more investigation in industrial training.

It also develops a positive attitude during the learning experience (Bursali & Yilmaz, 2019; Papakostas et al., 2021). VR and AR educational-based experiences are vivid experiences that attract different types of learners, whether young or adult learners, and indirectly raise concentration levels, especially for young learners during the learning

**Table 4** VR and AR technologies effects on Learner and Educator

| Main categories | VR & AR effects | f | Educational system |
|---|---|---|---|
| Learner | Improve motivation and attention | 47 | HE, K-12, VE, IT |
| | Improve learners 'understanding & performance | 44 | HE, K-12, VE, IT |
| | Increase knowledge retention | 23 | HE, K-12, VE, IT |
| | Improve technical skills | 15 | HE, VE, IT |
| | Enhancing learning achievement | 12 | HE, K-12, IT |
| | Develop positive attitude | 10 | HE, K-12, VE, IT |
| | Improve inventive thinking | 9 | HE, K-12 |
| | Improve experimental education | 9 | HE, K-12 |
| | Allow learners to learn in a safe environment | 9 | HE, K-12, VE, IT |
| | Decrease cognitive load | 8 | HE, K-12, VE, IT |
| | Promote self-confidence | 8 | HE, VE, IT |
| | Raise the interactivity level | 8 | HE, K-12 |
| | Enhancing satisfaction | 7 | HE, K-12, VE |
| | Increase collaboration between learners | 7 | HE, K-12, VE, IT |
| | Raise awareness of hazardous situations | 5 | HE, K-12, IT |
| | Decrease the learner's need to learn on physical elements | 4 | HE, K-12 |
| | Reduce error and task time for fulfilling complicated tasks | 4 | HE, VE, IT |
| | Increase concentration level | 3 | K-12 |
| | Develop imagination & communicative skills | 2 | HE, K-12 |
| | Help to transform learners into workplace workers | 1 | HE |
| Educator | Assist in teaching | 26 | HE, K-12, VE |
| | Reduce the burden on educators and trainers | 15 | HE, K-12, VE, IT |
| | Increase collaboration between educators and their learners | 8 | HE, K-12, VE |
| | Act as a personalized tutor or trainer | 4 | HE, VE, IT |
| | Help in evaluating and observing learners' interaction with learning content | 4 | HE, K-12 |
| | Reimburse the lack of conventional teaching techniques | 1 | HE |

process (Ting et al., 2021). The findings of (Gargrish et al., 2020) study on secondary education students showed that immersive capabilities aid young learners in raising their concentration level and memorizing concepts for a long time. Further, it has been found that VR and AR assist in developing imagination and communicative skills (Khan et al., 2021b; Schott et al., 2021) for K-12 and HE learners, respectively. Unleashing the imagination, especially among curious young learners, is crucial as it develops creativity and problem-solving skills. Imagination can also lead to establishing young scientists with the help of VR and AR technologies as it allows them to perform dangerous and complicated tasks that are difficult to execute in a real environment. It also assists in boosting social and communicative skills. Armah and Landers-Potts (2021) have affirmed that children with imagination are more social compared to other children who do not possess such skills. Imagination skills have been positively linked to cognitive skills, which are usually considered beneficial for social development.

VR and AR apps also boost collaboration between learners (Wang et al., 2018; Zhu et al., 2021). It can allow many learners to interact with the same app simultaneously across various educational systems, which enables them to share their suggestions and opinions. As a result, this will improve inventive thinking (Badge, 2021; Lamb et al., 2018). This collaboration will not only assist learners in sharing and acquiring knowledge from other learners. However, it can also prepare and qualify learners for complicated tasks and estimate the task's success if it is executed in a real environment. It also can predict what might be faced if the same procedures are followed in a real environment. In the medical industry, Venkatesan et al. (2021) stated that VR allows medical learners and participants to practice the required procedures before performing surgery on an individual to address the required issue. For example, a group of surgeons in separate countries specializing in conjoined twin separations have collaborated through VR for months to trial techniques to perform one of the most complex separation processes. The surgeons have collaborated using VR projections of the twins based on CT and MRI scans. For the first time, VR technology has enabled surgeons to wear headsets and operate in the same Virtual Reality room (McCallum, 2022). VR collaboration increased the success rate of complex separation processes while removing the risk factor and facilitating sharing knowledge and opinions on such operations. Further, it makes surgeons predict what they might encounter during the real separation processes. Consequently, sharing knowledge is not the only gain from collaboration via VR and AR. However, raising prediction and success levels, especially for critical tasks, may be considered new gains.

This study also discovered that VR and AR learning content raises the interactivity level with the learning materials (Ahmed et al., 2021). Furthermore, it allows participants to learn and work in a low-risk and safe environment (Doolani et al., 2020). This is considered a great feature for young learners, such as K-12 and adult learners, such as vocational and industrial learners. Working in a safe environment is crucial since it enables industrial trainees and vocational learners to learn and practice the necessary tasks numerous times without concern. Consequently, it aids in the transformation of learners into workplace workers (Guo, 2019).

The safe environment provided by VR and AR educational-based applications helped reduce errors and task time for accomplishing complicated tasks (Radosavljevic et al., 2020; Zhang et al., 2021). It allows learners to feel more comfortable when learning with virtual 3D machines, and learners who use the VR and AR app outperform those who use traditional methods to accomplish the same tasks. VR and AR apps have improved technical skills for higher education, vocational education, and industrial training learners (Guo et al., 2020; Nikitin et al., 2020; Shamsuzzoha et al., 2021). In addition, it aids in identifying hazards in safety training, thus raising awareness of hazardous situations (Hoang et al., 2021). Such a feature significantly improves safety training as it helps save workers who are used to working in dangerous sites. For instance, in the mining industry (Liang et al., 2019). In this research, the authors also found that VR and AR educational apps can decrease the learners' need for learning with physical elements (Liu et al., 2021a).

#### 4.4.2 Technology effects on educators

The most noticeable effect on educators was "Assist in teaching" (see Table 4) (Coimbra et al., 2015; Sahin & Yilmaz, 2020; Scavarelli et al., 2020; Sharma et al., 2021;

Vázquez-Cano et al., 2020). With the integration of VR and AR, the role of educators will witness a radical change. Educators will transform from content delivery to content facilitators. The 3D virtual elements in VR and AR apps can deliver the learning content effectively with excellent guidance. Also, integrating virtual avatars with VR and AR apps can become a private educator (Harborth & Kümpers, 2021; Wei et al., 2020), as it plays the role of the educator in guiding learners during the learning experience. As a result, the burden on educators and trainers is reduced (Abidi et al., 2019; Bistaman et al., 2018). Reducing the burden on educators depends on setting their goals from using VR and AR as teaching assistance tools and identifying learners' needs before using technology. To clarify, educators should fully grasp what resources, tools, and technology types will serve learners' needs and help them understand the learning content better. For instance, it is wise to select VR resources with minimum motion if most learners experience some VR-related health issues (e.g., nausea). Sagnier et al. (2020) have reported that the intention to utilize VR in learning is negatively affected by cybersickness. Consequently, selecting an appropriate resource will encourage learners to benefit better from the VR content, allowing educators to increase their dependency on technology as an assistance tool. Also, suppose a learner is a huge gamer. In that case, the educator could utilize VR or AR learning games to ignite the learner's excitement. Accordingly, a positive correlation will be established between employing VR and AR resources and the dependency on technologies as teaching assistance tools. For further clarity, this means that a better selection of VR and AR resources that serve learner needs will increase the dependency level on the technology from the educator's side.

This study also discovered that VR and AR apps will not only reduce educators' efforts but also compensate for the lack of conventional teaching techniques (Li et al., 2021). VR and AR technologies have also increased collaboration between educators and learners (Bistaman et al., 2018; Bourguet & Romero-Gonzalez, 2021; Lee, 2020). It enables educators to assign responsibilities to learners, allowing them to make their own decisions. Then, discuss the decision with the educator and receive feedback. Consequently, collaboration increases. Furthermore, it helps educators evaluate and observe learners' interactions with learning content (Yue et al., 2021). This study also discovered that some educators prefer to use one of these technologies in their teaching over another, such as AR technology (Alalwan et al., 2020). The reasons lie in the ease of observing learners' interactions and providing guidance and advice to their learners when using handheld AR compared to VR. In addition, those educators believe that VR educational apps are extremely broad and cannot help monitor their learners' interactions. Nevertheless, in this study, the authors found that educators affirmed that VR and AR educational-based apps have great potential to change learning and teaching positively.

### 4.5 RQ5: How do VR and AR educational applications relate to Learning Analytics?

Immersive experience has the potential to accumulate a vast amount of data that can be analyzed through Learning Analytics. This analysis can reveal valuable insights into learner interaction, engagement, and performance with the learning content. The extracted data can then be utilized to improve educational experiences by enabling personalized instruction ensuring learning outcomes are attained (Carter & Egliston, 2023). After an extensive investigation of the relationship between Learning Analytics (LA) and VR and AR technologies, research yielded that few articles (11) had applied the LA technique with VR and AR educational-based applications. This integration resulted in significant advantages. Using LA attempts to comprehend learner interactions and the VR and AR learning environment (Birt et al., 2019).

This study discovers that assisting in improving teaching and learning (Gorham et al., 2019; Qvist et al., 2015) and helping in recognizing the learners' performance (Jiang et al., 2021; Maiti et al., 2021; Santamaría-Bonfil et al., 2020), were the 1st and the 2nd features correlated to applying Learning Analytics with immersive technologies respectively, as shown in Table 5. While allowing the understanding of learners' behavioral characteristics in the learning environment (Jiang et al., 2021; Xiao et al., 2019); and providing customized support (Maiti et al., 2021; Qvist et al., 2015) were the 3rd features found through investigation. Analyzing immersive data can provide insights into learner behaviour, engagement, and performance, allowing educators to personalize instruction and improve learning outcomes. By analyzing the extracted data, educators can identify areas where learners may struggle and provide targeted interventions to address those challenges. This data can also help educators assess the effectiveness of instructional strategies and make data-driven decisions to optimize the learning experience (Carter & Egliston, 2023). Table 5 also demonstrated other discovered advantages during the investigation, encompassing raising motivational level (Qvist et al., 2015), helping in assessing learning outcomes (Birt et al., 2019), aiding in understanding the cognitive level of learners, competency skills, emotions of the learners of accepting VR technology (Srimadhaven et al., 2020), and helping in assessing learners' participation (Alalwan et al., 2020). Applying analytics to immersive data can facilitate a learning process that adjusts learning based on individual needs, leading to more personalized and efficient learning experiences. This data can track learner progress by capturing and analyzing the learner interactions and performance within virtual environments. By monitoring learner actions and decisions in immersive simulations, educators can assess their progression and identify

**Table 5** The advantages of integrating learning analytics with VR and AR

| Advantages | f | Educational system |
|---|---|---|
| Aids in improving teaching and learning | 4 | HE |
| Helps in recognizing learners' performance | 3 | IT, HE, K-12 |
| Allows understanding of the behavioral characteristics of learners in the learning environment | 2 | K-12 |
| Provides customized support | 2 | HE |
| Raises motivational level | 1 | HE |
| Helps in assessing learning outcomes | 1 | HE |
| Aids in understanding the cognitive level of learners | 1 | HE |
| Helps in assessing learners' participation | 1 | K-12 |
| Aids in understanding the learners' competency skills | 1 | HE |
| Aids in understanding learners' emotions | 1 | HE |

areas of improvement. Further, it can provide quantitative metrics such as completion time, accuracy, and efficiency, which can be used to measure learner's progress. It can also track learner engagement and motivation, providing insights into their level of interest and involvement in the learning process (Carter & Egliston, 2023). It was also noticed that higher education was the most educational system implementing the Learning Analytics technique, followed by K-12 and industrial training educational systems.

# 5 Discussion

In the following section, we discuss the current challenges that traditional learning and training methods might face and how VR and AR technologies address those challenges. We also discuss the effects of these technologies on learners, educators, and the impact of applying Learning Analytics with VR and AR learning-based applications. Further, we discuss the barriers that limit the adoption of VR and AR in education. Finally, we placed the practical implications of this study by the end of this section.

## 5.1 Challenges and solutions

Conventional learning methods sometimes fail to convey complex concepts and theories to learners. However, VR and AR technologies have effectively addressed this issue by providing learners with immersive experiences of such concepts. This approach can enhance their understanding and enable them to comprehend the tasks better. VR and AR have many educational benefits, including increasing learner motivation, engagement, and retention, which were sometimes challenging to accomplish by traditional methods, and this can be achieved using realistic and interactive scenarios stimulating curiosity and creativity (Liu et al., 2021a). Additionally, these technologies allow learners to explore costly different sites and perspectives that may be challenging or unattainable to experience in the real world, such as historical events, cultural sites, and scientific phenomena (Bourguet & Romero-Gonzalez, 2021; Akçayır & Akçayır, 2017). This feature given by these technologies is challenging to execute using traditional learning methods. Accordingly, using VR and AR will help overcome time and cost constraints. VR and AR can also address the material shortage required for learning. For instance, the lack of chemical substances in real labs may force educators to postpone practical sessions. However, with the use of VR and AR, virtual substances are always available, and educators will not also have the same concern when teaching these critical sessions as with traditional methods because both learners and educators are using a safe environment (Marougkas et al., 2023; Ting et al., 2021). Consequently, VR and AR will help overcome the lack of learning materials. Furthermore, traditional safety training methods, such as reading manual instructions, can be complicated for beginner operators to comprehend, particularly for complex operational procedures, and this is especially true in situations where traditional safety training is not feasible. Nevertheless, with the use of VR and AR technologies, this training can be a safe, efficient, and cost-effective solution due to the immersive nature of the technology (Hoang et al., 2021). Traditional training in some domains, such as manufacturing training, might be costly, and in some cases, such as in medical training, may negatively influence the patients. However, implementing VR and AR technologies in such domains can decrease or nearly eliminate such issues. For further clarity, with these technologies, manufacturing trainees will be trained on virtual machines instead (Liu et al., 2021b). Also, a medical trainee can virtually observe the consequences of any failure resulting from medical mistakes, eliminating any risk that might impact the patients (Zweifach & Triola, 2019).On the other hand, (Badge, 2021) argued that using VR and AR technologies eliminates distractions from the surrounding environment, allowing educators to ensure that their learners are entirely focused on the learning tasks, and this means that there is no longer a need to repeat specific points during the training time, as was necessary with traditional teaching methods. VR and AR technologies have significantly reduced educators' time to prepare for their classes due to their immersive nature (Chang and Lai, 2021), making it easier for learners to understand the task. With these technologies, educators will not spend time thinking about how to teach complex concepts. These technologies offer excellent visualization, allowing educators to bridge the gap between theoretical and practical concepts and help learners better understand the task and consolidate their knowledge. To sum up, implementing VR and AR technologies in learning and training will aid in overcoming numerous issues encountered by traditional teaching and training techniques.

### 5.2 Impact on learners

Concerning the identified effects on learners, (Li et al., 2021) have reported that VR and AR play an essential role in raising the retention level compared to conventional learning techniques. A perception of the learning and training materials will be formed by allowing learners and trainees to interact and experience learning resources several times. As a result, and across various educational systems, VR and AR create confident learners who can retain knowledge for a long time and apply what they have learned during the learning course (Abidi et al., 2019; Gargrish et al., 2020). This confidence can qualify higher education learners to compete in the labour market and create new opportunities for vocational and industrial learners to master the functionalities of sophisticated systems.

VR and AR also decrease the cognitive load during the learning process. Thus, it enhances performance and satisfaction levels with the learning course, which leads to a positive attitude during the learning process (Maiti et al., 2021; Lee, 2020). The correlated interaction feature of VR and AR can also transform learners from passive receivers into active participants. The vivid feature of VR and AR experience attracted learners to gain more knowledge. As a result, their concentration level will improve throughout the learning process. Boosting concentration was evident in this study with the K-12 learners when employing these technologies. This increased concentration has enhanced their understanding of the learning concepts and accelerated the learning process. Consequently, the required time previously required for learning such concepts will decrease. Therefore, it expands the time for exercising the understood concept, ultimately providing a learner who completely understands the learning content (Gargrish et al., 2020; Ting et al., 2021; Zhu et al., 2021).

Furthermore, VR and AR learning content raise the interactivity level with the learning materials, allowing learners to explore, train, and interact without paying attention to financial or ethical problems. Collaboration between learners can also be boosted by employing VR and AR technologies. VR and AR allow several learners to interact with the same educational resource concurrently (Zhu et al., 2021). As a result, they can share their ideas and opinions, which leads to improved inventive thinking (Fernandez, 2017). Collaboration with adult learners via these technologies can also improve the prediction and success levels of sophisticated processes. VR and AR hands-on-based applications make learners more comfortable learning complicated tasks with virtual 3D machines. Results proved that learners who used the VR and AR apps outperformed those who used traditional methods to accomplish the same tasks (Shi et al., 2020). The VR and AR 3D simulation apps are very close to the physical elements found in real life. The interaction mechanism with virtual elements attached to previous features makes learners feel they are interacting with an actual physical element. However, in a safe environment without facing any dangerous consequences. As a result, the need for physical learning might be reduced with consistent practice on virtual elements (Alalwan et al., 2020; Daling et al., 2021; Liu et al., 2021a). Learning with caution in dangerous situations or sites and dealing with critical substances (e.g., chemical substances) in real life may not allow learners to obtain complete knowledge because learners' concentration may be divided between learning and avoiding dangerous actions. However, with VR and AR technologies, learners will learn perfectly with an absolute elimination of the hazardous consequences. Consequently, knowledge gains will be improved, alongside numerous other benefits. VR and AR technologies will increase knowledge absorption compared to conventional methods (Tilhou et al., 2020). It will also encourage learners to study and train for extra time beyond the course requirements (Bujdosó et al., 2017). This increase in practice may prepare learners for their profession and improve the required skills for trainees, positively impacting productivity. All the mentioned benefits and more will be delivered to learners if they receive appropriate training on using VR and AR applications that satisfy the learning and learners' requirements. VR and AR technologies will radically change learners' learning methods.

### 5.3 Impact on educators

Educators will also benefit from using VR and AR technologies in their teaching. VR and AR apps are remarkable helpers in clarifying the learning material; they also assist in overcoming the deficiencies of traditional teaching techniques (Li et al., 2021). Educators will no longer have to spend additional time and effort illustrating learning resources, and this is due to the impressive descriptive visualization of learning and training courses provided by VR and AR (Birt et al., 2019; Zweifach & Triola, 2019). Additionally, VR and AR applications, combined with instructional guidance or avatars, will reduce the burden of teaching as they convert the conventional learning process, which depends mainly on the educators' presence for delivering learning content, into a self-paced learning process (Maiti et al., 2021; Qvist et al., 2015; Sahin & Yilmaz, 2020). VR and AR experiences also offer an excellent opportunity for educators. It increases collaboration between educators and their learners. By sharing the same learning experience with learners or trainees, educators can monitor learners' interactions with the VR and AR learning content, assign responsibilities to learners, and provide instant feedback (Qvist et al., 2015). Consequently, the collaboration level will be boosted. Eventually, to receive adequate benefits from integrating VR and AR technologies and Learning Analytics, educators and trainers should receive technical support and training in using such technologies. In addition, educators and trainers should also identify which technology (VR or AR) will ideally assist in delivering the learning content to meet their learners' expectations.

### 5.4 Impact of learning analytics

Learning Analytics are the traces learners leave behind when engaging with VR and AR content. For instance, the tracking feature connected to VR devices allows educators to track learners' gazes and collect information about learning environment parts that attract learners' attention (Santamaría-Bonfil et al., 2020). Collecting and analyzing the learner's gaze data is also crucial in understanding the complexity degree of the VR app's tasks and comprehending the learner's knowledge gains. To clarify, a learner might have a long gaze at one of the tasks while giving a short gaze at other tasks, indicating that the learner hardly grasps the required knowledge of that task. As a result, these analytics assist in measuring learners' cognitive load and concentration levels. Ultimately, it facilitates the transmission of personalized learning. Analyzing eye-tracking data can offer new scope for examining learners' attention and motivation, probably expediting and making learning more effective (Asish et al., 2023).

Furthermore, Learning Analytics provides a unique perspective on how learners interact with VR and AR content. Learning Analytics combined with Virtual learning experiences will enhance learning since educators and trainers can view learners' performance, participation, and learning outcomes. For instance, it can identify learners' motivation and persistence to learn, and this will be done by identifying the frequency of learners' engagement with the learning content. Thus, this helps educators recognize learners' performance and provide feedback to learners (Krikun, 2017; Santamaría-Bonfil et al., 2020). Consequently, engagement and motivation levels will be positively impacted, eventually boosting performance. It will also allow educators and trainers to identify the number of attempts made to complete the learning experience and how many times learners have replayed the experience. As a result, this will assist in understanding the cognitive level of learners, thus providing customized support to learners who need help (Carter & Egliston, 2023).

Further, it can indicate any weaknesses in the immersive learning app that might negatively impact the learning gains; as a result, improving the app to meet the learning requirements. This will also lead to the enhancement of the learning process. On the other hand, the capturing of data of each learner individually from body position and movement, eye-tracking, and biometric feedback can inform about the behavioural characteristics of learners in the learning environment. It monitors learners' movements around the immersive environment, what they are looking at, and how learners feel at a specific moment during their interaction with the VR and AR experience. Analyzing immersive learners' data will aid educators in transforming their conventional teaching style into a new one, providing better support and more personalized feedback to their learners (Christopoulos et al., 2020).

### 5.5 VR/AR technology barriers in education

While VR and AR have shown significant potential in enhancing educational experiences, they also come with several limitations that need to be considered. One of the main limitations of the technologies in education is the cost associated with implementing and maintaining the technology (Alfalah, 2018; Qvist et al., 2015; Venkatesan et al., 2021). For instance, purchasing and maintaining wearable VR and AR equipment for each learner, including headsets and controllers, can be burdensome for organizations and educational institutions. Further, the software cost and availability can be another significant barrier limiting the adoption of these technologies in education. Developing VR and AR applications is usually time-consuming and costly as it requires a high level of programming (Kavanagh et al., 2017; Gavish et al., 2015). Developing such content requires an expert with the necessary skills and expertise in 3D modelling, programming and a comprehensive understanding of the subject matter to create VR and AR content (Alfalah, 2018). On the other hand, the limited availability of content specifically designed for educational purposes is another challenge. Unfortunately, the available content is not aligned with the curriculum but is developed based on experiences that are supposed to be interesting for learners (e.g., K-12 learners). Moreover, insufficient realism was also found to be another barrier (Kavanagh et al., 2017). For further clarity, some learning experiences (e.g., industrial training) require more realistic than others, such as surgical simulations. These learning experiences should be close to the physical ones because if the surgical simulations fail to provide a realistic experience, it could result in a weakened learning experience and negatively impact the students. The high-quality realism of the content is essential for adult learners compared to young learners at schools, as immersive technologies will be an alternative training tool to the physical ones. The purpose of using immersive technologies in K-12 education is to convey and facilitate knowledge and allow learners to perceive the complicated theories in the curriculum (Leighton & Crompton, 2017). However, the situation with adult learners will be completely different, as establishing a high level of immersion is crucial to ensure the effectiveness of virtual training.

Usability is another limitation of VR and AR in education. Immersive technologies can often be complex and challenging to navigate, especially for younger learners or individuals needing to be more technologically proficient (Kavanagh et al., 2017). Learners exploring experiences with inadequate interface design and poor interaction quality may lose the aimed educational benefits in such an environment. Also, if learners encounter frustration or have a negative experience while using the technology, it can impact their motivation to continue using it for learning purposes. Further, VR and AR educational apps with excessive multimedia can lead to a cognitive overload issue. To clarify, when learners engage with multimedia tasks requiring multiple sights and sounds, they often experience cognitive overload. Therefore, an appropriate design focusing on pedagogical aspects with simple utilization of multimedia would be better (Delello et al., 2015). These aspects are crucial and should be considered when implementing new technologies such as VR and AR in education. Additionally, the complexity of immersive technologies can pose a challenge for both educators and learners. For educators, learning and navigating new software and hardware systems may require additional training and resources (Cowling & Birt, 2016). On the other hand, educators may need to allocate time to train their learners on immersive technologies, which may reduce the time available for teaching. In addition to the mentioned obstacles, the potential for isolation and lack of social interaction can limit the adoption of immersive technologies (Fernandez, 2017; Qvist et al., 2015; Venkatesan et al., 2021). VR creates an entirely immersive experience, which can be isolating for students as they are fully immersed in the virtual environment. This isolation can limit opportunities for collaboration and social interaction with peers, which are essential aspects of the learning process in various educational systems.

Further, there may be concerns about potential adverse side effects of prolonged use of immersive technologies, such as motion sickness or eye strain. Ensuring learners can only use technology until they feel comfortable with it is crucial. Also, it is essential to recognize that some learners may feel discomfort rapidly. Therefore, it is necessary to consider the duration of the immersive learning experience because the prolonged exposure may put the learner at a greater risk of experiencing discomfort (Venkatesan et al., 2021; Yoon et al., 2021). Other significant concerns, including privacy, security, and ethics, should also be considered. For instance, AR browsers installed on mobile devices can be hijacked by unauthorized parties, leading to manipulation of AR content by accessing the device's camera and GPS. Furthermore, complex input sensors such as cameras, microphones, and GPS can pose serious security and privacy challenges that must be addressed. In collaborative immersive experiences, attackers may copy virtual content, which puts intellectual property and user rights at risk. In addition, attackers may impersonate legitimate users and influence other users to reveal sensitive information or behave in a specific manner (Venkatesan et al., 2021). Integrating VR and AR in education has great potential. Nevertheless, it is recommended that an appropriate plan is set to overcome the mentioned obstacles before implementing VR and AR technologies in education.

### 5.6 Practical implications

The insufficiency of existing systematic reviews that investigate the effects of using VR, AR, and Learning Analytics on different types of learners and educators within diverse educational systems has inspired this study to present a range of practical implications which could assist learners, educators, organizations, and educational institutions as follows:

- Immersive technologies promote enhanced learning achievement, suggesting that integrating VR and AR into educational practices can establish confident learners with high-quality skills that may lead them to compete in the labor market.
- Our findings suggest that reducing the training and learning on physical elements and using real substances (e.g., chemical substances) due to the integration of VR and AR is expected to reduce the costs to educational institutions and organizations.

- VR and AR interventions in the learning and training process are anticipated to reduce the teaching burden and improve teaching and training methods.
- VR and AR produce vast amounts of data that can be valuable to the context of educational practices. Learning Analytics is expected to positively impact the learners' progress, achievements, and performance. It is also expected to improve teaching methods.

## 6 Study limitations

VR and AR with Learning Analytics integration can provide countless advantages in case educational institutions and industrial organizations grant support, whether funds, training, or technical support, to learners and educators alongside the adequate implementation and application of the technologies. Further, educational institutions and industrial organizations should consider the correlated health issues that VR applications can cause. Therefore, utilizing such applications within a limited time is recommended to avoid future health problems for learners, as these problems might negatively impact the learning process.

This research has analyzed studies published in Google Scholar, Scopus, and IEEE Xplore databases within a particular time frame and concrete criteria. We invite future researchers to investigate other bibliometric databases using this study's themes to identify the impacts of other Learning Analytics and VR and AR technologies on education and training. In this study, we decided to make our research comprehensive, including various studies such as empirical studies, reviews, conference proceedings and book chapters. This approach aimed to understand better the impact of integrating such technologies within different educational systems from different perspectives. Also, to extend on what has been provided by other systematic reviews. However, this study included a few numbers of conference proceedings and book chapters and excluded dissertations, which can be a valuable source of research. Thus, we advise future researchers to consider including conference papers, book chapters, and dissertations in their future systematic reviews on the impact of Learning Analytics, VR and AR on education. Further, we focused on research articles centred on the effects of VR, AR and Learning Analytics on learners and educators, in addition to the research tendency of the available educational systems and their adoption of these technologies. We felt that those crucial aspects correlate to improving the learning process and help identify which educational systems require extra investigation, and this has distinguished our study from other systematic reviews.

## 7 Conclusion and future research

Available systematic reviews have investigated the impact of VR and AR integration. However, this investigation was limited to one of the VR and AR technologies in one discipline or investigation within one or two educational systems. Nevertheless, we could not find a paper investigating the impact of VR and AR technologies from learner and educator perspectives across various disciplines and within all the available educational systems. Further, it discusses the impact of Learning Analytics integration with VR and AR applications, in addition to identifying the applied data collection tools, the educational systems' research tendency and their adoption of VR and AR technologies. Therefore, we decided to address this research gap because combining all these aspects in one study will inform different educational institutions and industrial organizations of the prospective advantages to learners and educators when deciding to adopt VR and AR with Learning Analytics technologies and how these technologies will advance education and training.

By examining 150 studies, our results show that investigating these technologies has increased over time and searching about VR and AR integration within K-12 seems to attract future researchers. In this study, we also found that VR and AR can improve motivation and attention, reducing the burden of teaching and training and additionally making up for the deficiency of conventional teaching methods. We also found that Learning Analytics can provide valuable information to organizations, educational institutions and educators about learners' performance, any weaknesses in the VR and AR applications, and which learners need customized learning techniques. Furthermore, we affirmed that Higher education was the dominant educational system and that AR was the most popular technology within the identified period. Also, questionnaires and online surveys were preferred data collection tools by VR and AR researchers. This research has also affirmed that VR and AR integration will radically change various educational systems, and researchers can take advantage of the extracted VR and AR learning data to provide improvement and assistance to learners, educators, educational institutions, and the learning environment. Integrating these technologies will establish an independent and confident learner who previously used to receive knowledge at a particular time from educators. In addition, it can perfectly prepare learners for their future careers, which undoubtedly will positively impact the economy. Educators will also find extra time to develop learning content since these technologies will reduce the burden of teaching. Further, Learning Analytics will assist in overcoming any possible learning issues before they occur. Educational institutions and organizations will also save money and protect their learners and equipment as the VR and AR simulation reduces the dependence on physical equipment and avoids potentially dangerous consequences.

Nonetheless, despite the potential benefits, there are limitations to VR and AR in education that must be considered, including technology cost (hardware and software), usability, lack of the appropriate content, cognitive overload, training, isolation and lack of social interaction, and motion sickness. These limitations can hinder the widespread adoption and implementation of such technologies across various education systems. Learning Analytics also still lacks adequate investigation, and researchers need to target their research to investigate more Learning Analytics impacts on VR and AR technologies. Also, novel data collection tools are required to be used to provide results from other perspectives. Further research on VR integration within industrial training and K-12 is required, and the VR and AR research in the vocational education system is still low and requires extra examination.

## Appendix

**Table 6** Systematic review papers

| No | Reference | Technology | Domain | Research Results |
|---|---|---|---|---|
| 1 | (Jamali et al., 2015) | AR | Human anatomy | Improve motivation and attention. |
| 2 | (Delello et al., 2015) | AR | Education, Human Resource Development, and Marketing | Improve motivation and attention. |
| 3 | (Gavish et al., 2015) | VR, AR | Industrial maintenance and assembly | Reduction in the error rate compared to the traditional methods - increase retention. |
| 4 | (Bacca et al., 2015) | AR | Car maintenance | Improve motivation and attention, promote self-confidence, enhancing satisfaction, act as a personalized tutor or trainer, reduce the burden on educators and trainers. |
| 5 | (Kleinert et al., 2015) | VR | Medical | Improve the procedural knowledge to the learners, consolidate the understanding of the domain. |
| 6 | (Qvist et al., 2015) | VR | Biological sciences and Chemistry | Improve motivation and attention, allow learners to learn in a safe environment, improve experimental education, assist in teaching, Learning Analytics aids in improving teaching and learning, Learning Analytics provides customized support, LA raises motivational level |
| 7 | (Coimbra et al., 2015) | AR | Math | Assist in teaching. |
| 8 | (Cowling & Birt, 2016) | AR | Computer Science (Networking) | Improve motivation and attention, reduce the burden on educators and trainers. |
| 9 | (Stefan et al., 2016) | AR | Engineering, Arts | Learning Analytics can aid in improving teaching and learning. |
| 10 | (Fehling et al., 2016) | AR | N/A | Improve learners 'understanding & performance, increase knowledge retention, Assist in teaching |
| 11 | (Bacca et al., 2016) | AR | Car maintenance | Improve learners 'understanding & performance. |
| 12 | (Alhalabi, 2016) | VR | Engineering | Enhancing learning achievement |
| 13 | (Bujdosó et al., 2017) | VR | Computer Science | Improve motivation and attention, Improve inventive thinking. |

**Table 6** (continued)

| No | Reference | Technology | Domain | Research Results |
|---|---|---|---|---|
| 14 | (Fernandez, 2017) | VR, AR | N/A | Improve inventive thinking, improve technical skills, Raise the interactivity level, Decrease the learner's need for learning on physical elements, assist in teaching, Increase collaboration between educators and their learners |
| 15 | (Leighton & Crompton, 2017) | AR | N/A | Improve experimental education, improve motivation and attention, Increase knowledge retention, |
| 16 | (Kavanagh et al., 2017) | VR | N/A | Improve motivation and attention, increase collaboration between learners, assist in teaching, Reduce the burden on educators and trainers |
| 17 | (Valdez et al., 2017) | VR | Engineering | Improve learners 'understanding & performance. |
| 18 | (Carruth, 2017) | VR | Manufacturing | Allow learners to learn in a safe environment, Reduce the burden on educators and trainers |
| 19 | (Kamińska et al., 2017a, b) | VR | Mechanical and Electrical Engineering | Improve learners 'understanding & performance, improve technical skills, increase knowledge retention, Assist in teaching |
| 20 | (Turkan et al., 2017) | AR | Engineering (Civil Engineering) | Improve learners 'understanding & performance. |
| 21 | (Kamińska et al., 2017a, b) | VR | Engineering -Mechatronics | Improve learners 'understanding & performance, improve technical skills, increase knowledge retention, |
| 22 | (Alfalah, 2018) | VR | IT Education | Improve experimental education, improve motivation and attention, promote self-confidence, assist in teaching, Increase collaboration between educators and their learners |
| 23 | (Babu et al., 2018) | VR | Motorcycle maintenance | Improve motivation and attention, Increase knowledge retention. |
| 24 | (Aebersold et al., 2018) | AR | Nursing | Improve experimental education, assist in teaching. |
| 25 | (Lucas, 2018) | VR | Construction | Improve learners 'understanding & performance, Improve technical skills. |

**Table 6** (continued)

| No | Reference | Technology | Domain | Research Results |
|---|---|---|---|---|
| 26 | (Bistaman et al., 2018) | AR | N/A | Improve motivation and attention, improve learners 'understanding & performance, increase knowledge retention, assist in teaching, Reduce the burden on educators and trainers, Increase collaboration between educators and their learners |
| 27 | (Wang et al., 2018) | VR | Construction | Improve learners 'understanding & performance, Increase collaboration between learners. |
| 28 | (Gunn et al., 2018) | VR | Medical | Improve technical skills. |
| 29 | (Zikky et al., 2018) | VR | Science (solar system learning) | Improve motivation and attention, Assist in teaching. |
| 30 | (Molnár et al., 2018) | AR | Engineering | Improve motivation and attention. |
| 31 | (Lamb et al., 2018) | VR | Life Sciences | Improve motivation and attention, Improve inventive thinking. |
| 32 | (Willicks et al., 2018) | AR | Engineering and Computer Science | Improve motivation and attention. |
| 33 | (Zhou et al., 2018) | VR | Computer hardware assembly | Improve learners 'understanding & performance. |
| 34 | (Bottani & Vignali, 2019) | AR | Several Industries | Reduce error and task time for fulfilling complicated tasks. |
| 35 | (Zweifach & Triola, 2019) | VR, AR | Medical training | Improve technical skills, Assist in teaching. |
| 36 | (Andrews et al., 2019) | VR, AR | Medical | Improve motivation and attention, improve learners 'understanding & performance |
| 37 | (Birt et al., 2019) | AR | Medical | Decrease cognitive load, help in evaluating, and observing learners' interaction with learning content Learning Analytics aids in improving teaching and learning, LA helps in assessing learning outcomes |
| 38 | (Bursali & Yilmaz, 2019) | AR | Language Learning | Improve motivation and attention, Develop positive attitude. |
| 39 | (Garcia et al., 2019a, b) | VR | Oil & Gas field | Improve technical skills. |
| 40 | (Garcia et al., 2019a, b) | VR | Engineering | Improve learners 'understanding & performance, Assist in teaching. |
| 41 | (Gorham et al., 2019) | VR | Learning foreign language | Learning Analytics aids in improving teaching and learning |
| 42 | (Acosta et al., 2019) | AR | Chemistry | Improve motivation and attention |

**Table 6** (continued)

| No | Reference | Technology | Domain | Research Results |
|---|---|---|---|---|
| 43 | (Cabero-Almenara et al., 2019) | AR | Educational Technology | Improve motivation and attention. |
| 44 | (Xiao et al., 2019) | AR | Training K-12 teachers | Learning Analytics allows understanding the behavioral characteristics of learners in learning environment |
| 45 | (Liang et al., 2019) | VR | Mining Industry | Increase knowledge retention, improve learners 'understanding & performance |
| 46 | (Yildiz et al., 2019) | VR | Industrial assembly operation | Increase collaboration between learners. |
| 47 | (Abidi et al., 2019) | VR | Assembly operation | Promote self-confidence, develop positive attitude, increase knowledge retention, Reduce the burden on educators and trainers |
| 48 | (Al-Adawi, & Luimula, 2019) | VR | Fire safety training | Enhancing satisfaction, improve learners 'understanding & performance, allow learners to learn in a safe environment |
| 49 | (Randeniya et al., 2019) | VR | Maintenance Training | Improve learners 'understanding & performance. |
| 50 | (Shamsuzzoha et al., 2021) | VR | Industrial maintenance | Improve technical skills. |
| 51 | (Garzón & Acevedo, 2019) | AR | Engineering, Arts and Humanities | Improve learners 'understanding & performance. |
| 52 | (Degli Innocenti et al., 2019) | VR | Music | Improve motivation and attention. |
| 53 | (Fidan & Tuncel, 2019) | AR | Physics | Improve learners 'understanding & performance. |
| 54 | (Meyer et al., 2019) | VR | Science | Increase knowledge retention. |
| 55 | (Guo, 2019) | VR | Accounting | Help to transform learners into workplace workers |
| 56 | (Syed et al., 2019) | VR | Engineering-mechanical | Improve learners 'understanding & performance, assist in teaching, Reduce the burden on educators and trainers. |
| 57 | (Huang et al., 2019) | VR, AR | Science | Improve motivation and attention, Increase knowledge retention. |
| 58 | (Scaravetti & Doroszewski, 2019) | AR | Engineering (Mechanical design) | Enhancing learning achievement |
| 59 | (Khan et al., 2019) | AR | Health Science | Improve motivation and attention. |
| 60 | (Segura et al., 2020) | VR | Computer Science | Improve learners 'understanding & performance. |

**Table 6** (continued)

| No | Reference | Technology | Domain | Research Results |
|---|---|---|---|---|
| 61 | (Tilhou et al., 2020) | VR | Science | Improve motivation and attention, improve learners 'understanding & performance, enhancing learning achievement, assist in teaching, reduce the burden on educators and trainers |
| 62 | (Santamaría-Bonfil et al., 2020) | VR | Maintenance training | Allow learners to learn in a safe environment, Learning Analytics helps in recognizing learners' performance |
| 63 | (Eiris et al., 2020) | VR | Construction | Improve learners 'understanding & performance, raise the awareness of the hazard situations |
| 64 | (Alalwan et al., 2020) | VR, AR | Science | Improve experimental education, improve motivation and attention, improve learners 'understanding & performance, decrease the learner's need for learning on physical elements, develop positive attitude, assist in teaching, reduce the burden on educators and trainers, help in evaluating, and observing learners' interaction with learning content, Learning Analytics helps in assessing learners' participation. |
| 65 | (Scavarelli et al., 2020) | VR, AR | N/A | Improve experimental education, improve motivation and attention, improve learners 'understanding & performance, assist in teaching. |
| 66 | (Palmas and Klinker, 2020) | VR | Industries | Improve motivation and attention. |
| 67 | (Guo et al., 2020) | VR | Various industries (maintenance - aerospace) | Improve technical skills. |
| 68 | (Bosch et al., 2020) | AR | Assembly in manufacturing companies | Improve motivation and attention, improve technical skills, Reduce the burden on educators and trainers. |
| 69 | (Pellas et al., 2020) | AR | Various subjects | Improve motivation and attention, improve learners 'understanding & performance |
| 70 | (Srimadhaven et al., 2020) | VR | Computer Science | Improve motivation and attention, assist in teaching, Learning Analytics aids in understanding the cognitive level of learners, LA aids in understanding the learners' competency skills, LA aids in understanding learners' emotions |

**Table 6** (continued)

| No | Reference | Technology | Domain | Research Results |
|---|---|---|---|---|
| 71 | (Vázquez-Cano et al., 2020) | AR | Social Education | Improve learners 'understanding & performance, assist in teaching. |
| 72 | (Samosorn et al., 2020) | VR | Nursing | Improve learners 'understanding & performance, Improve technical skills. |
| 73 | (Delgado et al., 2020) | VR, AR | Architecture, Engineering and Construction | Improve learners 'understanding & performance, raise the awareness of the hazard situations |
| 74 | (Bouaoud et al., 2020) | VR | Medical | Improve learners 'understanding & performance. |
| 75 | (Chang and Lai, 2021) | VR | Nursing | Develop positive attitude, reduce the burden on educators and trainers. |
| 76 | (Mughal et al., 2020) | AR | Plastic surgery training | Enhance satisfaction. |
| 77 | (Zawadzki et al., 2020) | VR | Production line | Increase knowledge retention. |
| 78 | (Gisler et al., 2020) | VR | Industrial assembly task | Improve learners 'understanding & performance. |
| 79 | (Nikitin et al., 2020) | VR | Maintenance Training | Improve technical skills. |
| 80 | (Lacko, 2020) | VR | Health Safety Training | Develop positive attitude, increase knowledge retention. |
| 81 | (Doolani et al., 2020) | VR, AR | Manufacturing Training | Allow learners to learn in a safe environment, increase knowledge retention. |
| 82 | (Lee, 2020) | VR | Furniture manufacturers | Decrease cognitive load, increase collaboration between educators and their learners, allow learners to learn in a safe environment. |
| 83 | (Henssen et al., 2020) | AR | Medical | Decrease cognitive load. |
| 84 | (Gargrish et al., 2020) | AR | Science | Improve learners 'understanding & performance, increase concentration level, increase knowledge retention. |
| 85 | (Wei et al., 2020) | AR | Learning foreign language | Raise the interactivity level, develop positive attitude, increase knowledge retention, Reduce the burden on educators and trainers, Act as a personalized tutor or trainer. |
| 86 | (Duarte et al., 2020) | VR, AR | Anatomy | Assist in teaching, increase knowledge retention. |

**Table 6** (continued)

| No | Reference | Technology | Domain | Research Results |
|---|---|---|---|---|
| 87 | (Eder et al., 2020) | AR | Manufacturing (maintenance) | Improve learners ‘understanding & performance. |
| 88 | (Doolani et al., 2020) | AR | Medical | Improve learners ‘understanding & performance, Increase knowledge retention |
| 89 | (Alfadil, 2020) | VR | Learning foreign language | Enhancing learning achievement. |
| 90 | (Pilati et al., 2020) | AR | Assembly | Enhancing learning achievement. |
| 91 | (Iqbal et al., 2020) | VR | Medical | Promote self-confidence. |
| 92 | (Shi et al., 2020) | VR | Construction | Decrease cognitive load, Enhancing learning achievement. |
| 93 | (Büth et al., 2020) | AR | Manufacturing | Improve learners ‘understanding & performance. |
| 94 | (Zawadzki et al., 2020) | VR | Assembly | Improve technical skills. |
| 95 | (Kowalski et al., 2020) | VR | Architectural History | Improve motivation and attention, Assist in teaching. |
| 96 | (Stork et al., 2020) | AR | Literacy Education | Assist in teaching. |
| 97 | (Radosavljevic et al., 2020) | AR | Engineering | Reduce error and task time for fulfilling complicated tasks. |
| 98 | (Sahin & Yilmaz, 2020) | AR | Science | Develop positive attitude, enhancing learning achievement, Assist in teaching. |
| 99 | (Schez-Sobrino et al., 2020) | AR | Programming | Improve motivation and attention. |
| 100 | (Allcoat et al., 2021) | VR, AR | Engineering | Increase knowledge retention. |
| 101 | (Bacca-Acosta et al., 2021) | VR | Learning foreign language | Improve motivation and attention. |
| 102 | (Liang et al., 2021) | AR | Nursing | Improve learners ‘understanding & performance. |
| 103 | (Ong et al., 2021) | AR | Ophthalmology | Promote self-confidence, improve learners ‘understanding & performance, improve technical skills, allow learners to learn in a safe environment |
| 104 | (Gurevych et al., 2021) | AR | Humanities and natural sciences | Improve motivation and attention. |
| 105 | (Venkatesan et al., 2021) | VR | Biomedical | Allow learners to learn in a safe environment. |
| 106 | (Barteit et al., 2021) | VR, AR | Medical training | Improve motivation and attention. |
| 107 | (Kumar et al., 2021) | AR | Medical training | Increase knowledge retention. |

**Table 6** (continued)

| No | Reference | Technology | Domain | Research Results |
|---|---|---|---|---|
| 108 | (Moro et al., 2021) | VR, AR | Medical | Improve learners ‘understanding & performance. |
| 109 | (Liu et al., 2021a) | AR | Physics | Improve learners ‘understanding & performance, enhancing learning achievement, Improve motivation and attention |
| 110 | (Yengui & Stechert, 2021) | AR | Mechanical Engineering | Improve motivation and attention. |
| 111 | (Guilbaud et al., 2021) | VR, AR | Science | Promote self-confidence, improve inventive thinking, increase knowledge retention |
| 112 | (Daling et al., 2021) | VR, AR | Mining Engineering | Decrease the learner’s need for learning on physical elements, increase collaboration between educators and their learners, Reduce the burden on educators and trainers, Assist in teaching. |
| 113 | (Osypova et al., 2021) | VR, AR | Mathematics and Computer Science | Improve motivation and attention, Improve inventive thinking. |
| 114 | (Stromberga et al., 2021) | VR, AR | Medical | Improve learners ‘understanding & performance. |
| 115 | (Divekar et al., 2021) | VR | Foreign Language | Promote self-confidence. |
| 116 | (Nasharuddin et al., 2021) | VR | Science | Enhancing satisfaction, |
| 117 | (Chernosky et al., 2021) | AR | Engineering | Improve motivation and attention. |
| 118 | (Badge, 2021) | VR, AR | Training | Improve inventive thinking, Increase collaboration between learners. |
| 119 | (Maiti et al., 2021) | AR | Networking | Assist in teaching, improve motivation and attention, decrease cognitive load, Learning Analytics helps in recognizing learners’ performance, Learning Analytics provides customized support |
| 120 | (Jiang et al., 2021) | AR | Science | Improve experimental education, Learning Analytics helps in recognizing learners’ performance, Learning Analytics allows understanding the behavioral characteristics of learners in learning environment |
| 121 | (Frasson, 2021) | AR | Computer Science and Engineering | Improve motivation and attention, improve learners ‘understanding & performance, decrease cognitive load |

**Table 6** (continued)

| No | Reference | Technology | Domain | Research Results |
|---|---|---|---|---|
| 122 | (Remolar et al., 2021) | VR, AR | History | Improve motivation and attention, enhancing satisfaction, Increase knowledge retention |
| 123 | (Harborth & Kümpers, 2021) | VR, AR | Training | Act as a personalized tutor or trainer. |
| 124 | (Dhimolea et al., 2021) | VR | English Language | Promote self-confidence. |
| 125 | (Papakostas et al., 2021) | AR | Engineering | Improve motivation and attention, improve learners 'understanding & performance, develop positive attitude, Enhancing learning achievement. |
| 126 | (Matome & Jantjies, 2021) | VR | N/A | Assist in teaching, increase collaboration between educators and their learners, raise the interactivity level. |
| 127 | (Pellas et al., 2021) | VR | N/A | Improve inventive thinking, improve learners 'understanding & performance, develop positive attitude, enhancing learning achievement, reduce the burden on educators and trainers |
| 128 | (Li et al., 2021) | VR | Dental | Reduce the burden on educators and trainers, Reimburse the lack of conventional teaching techniques, Raise the awareness of the hazard situations. |
| 129 | (Weng et al., 2021) | AR | Civil Engineering | Enhancing satisfaction, reduce error and task time for fulfilling complicated tasks, Act as a personalized tutor or trainer |
| 130 | (Logothetis et al., 2021) | AR | Literature and Language Education | Improve inventive thinking. |
| 131 | (Hsu & Liu, 2021) | AR | Learning Foreign Language | Improve motivation and attention, enhancing satisfaction, Develop positive attitude. |
| 132 | (Khan et al., 2021a) | VR | Safety Training | Improve inventive thinking, allow learners to learn in a safe environment, develop imagination & communicative skills. |
| 133 | (Dakeev et al., 2021) | AR | STEM | Raise the interactivity level, Increase knowledge retention. |
| 134 | (Khan et al., 2021a) | VR, AR | Science | Enhancing learning achievement. |
| 135 | (Zhang et al., 2021) | AR | Engineering | Reduce error and task time for fulfilling complicated tasks. |
| 136 | (Nicolaidou et al., 2021) | VR | Learning foreign language | Improve motivation and attention. |

**Table 6** (continued)

| No | Reference | Technology | Domain | Research Results |
|---|---|---|---|---|
| 137 | (Zhu et al., 2021) | AR | Chemistry | Increase collaboration between educators and their learners, help in evaluating, and observing learners' interaction with learning content, increase collaboration between learners, Increase concentration level. |
| 138 | (Huisinga, 2021) | AR | History | Improve learners 'understanding & performance. |
| 139 | (Ting et al., 2021) | AR | Chemistry | Improve experimental education, improve motivation and attention, Raise the awareness of the hazard situations, decrease cognitive load, increase concentration level. |
| 140 | (Bourguet & Romero-Gonzalez, 2021) | VR, AR | Materials Science | Increase collaboration between educators and their learners. |
| 141 | (Yue et al., 2021) | VR | Medical | Improve technical skills, help in evaluating, and observing learners' interaction with learning content. |
| 142 | (Schott et al., 2021) | VR, AR | Medical | Improve motivation and attention, decrease cognitive load, Develop imagination & communicative skills. |
| 143 | (Sharma et al., 2021) | AR | Science | Assist in teaching. |
| 144 | (Zhong & Cui, 2021) | AR | Geography | Raise the interactivity level. |
| 145 | (Eduardo et al., 2021) | AR | Learning Foreign Language | Improve motivation and attention, Raise the interactivity level, increase collaboration between learners, enhancing learning achievement, Increase knowledge retention. |
| 146 | (Ahmed et al., 2021) | AR | Chemistry | Raise the interactivity level, Increase collaboration between learners. |
| 147 | (Liu et al., 2021a, b) | AR | Mechanical Engineering | Improve experimental education, raise the interactivity level, decrease the learner's need for learning on physical elements. |
| 148 | (Sugiura et al., 2021) | AR | Medical | Improve learners 'understanding & performance. |
| 149 | (Hoang et al., 2021) | VR | Construction/ Safety training | Raise the awareness of the hazard situations. |
| 150 | (Fajrianti et al., 2021) | AR | Medical | Enhancing satisfaction, improve learners 'understanding & performance. |

**Acknowledgements** This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

**Author contributions** Asmaa Sakr: Conceptualization, Methodology, Data Curation, Formal Analysis, Visualization, Validation, Writing- Original draft preparation, Investigation, Resources, Writing- Reviewing and Editing. Tariq Abdullah Conceptualization, Supervision, Validation, Writing- Reviewing and Editing.

**Data availability** Data sets used and/or analyzed during the current study are available from the corresponding author under reasonable request.

## Declarations

**Conflict of interest** The authors declare that they have no conflicting interests.



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