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Review Article

Analyzing augmented reality (AR) and virtual reality (VR) recent development in education

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ABSTRACT

Augmented Reality (AR) and Virtual Reality (VR) technologies have revolutionized learning approaches through immersive digital experience, interactive environment, simulation and engagement. Yet, these technologies are in developing stage and require massive investment and mass customization to meet the high demand in education. This comprehensive review aims to frame AR and VR development in education during the last twelve years. By adopting text mining and topic analysis approaches, a total of 1536 articles were selected for further analysis. These articles were selected from Scopus database based on specific criteria where titles, keywords and abstracts were extracted for analysis by WordStat. Hypotheses were formulated based on the prior works of AR and VR in education and being processed and evaluated to unveil state of art of AR and VR literature development, applications, advantages and future directions. Results reveal that adoption of AR and VR in education have exponential growth during recent years where wearable device have gain the large portion of this development. Based on secondary data, results also reveal the gap in implementing and customizing these technologies quickly in educational institutions. As AR and VR technologies rapidly develop and become mature, more educational applications emerge in learning process. Researchers are recommended to keep in pace to discover gaps of AR and VR transition to education and create effective adaptability approaches to gain more benefits of these technologies development.

1. Introduction

Augmented and virtual reality (AR & VR) are two of the most innovative technology advancements in the world today, and their potential for improving the education system is massive. The use of Augmented Reality (AR) and Virtual Reality (VR) in education has been on the rise in recent years and provides a wealth of opportunities to leverage technology-enhanced learning (Tan et al., 2022). AR and VR introduces students to immersive digital experiences that cannot be replicated through traditional teaching methods (Phakamach et al., 2022), enabling them to better engage with complex material beyond just lectures and textbooks (Sun et al., 2022), while enabling lecturers to customize content for individual learning styles (Childs et al., 2021). Not only can these technologies create a more immersive experience, but also offer the potential for educators to provide simulations and step into virtual field trips without the physical travel implications (Seidametova et al., 2021). Additionally, the use of innovative technologies such as AR and VR can bridge the gap between traditional classroom instruction and real-world experience, providing tangible benefits for learners' professional development.

Augmented Reality (AR) is a technology that enhances the real-world environment around us by overlaying computer-generated content onto it (Hantono, Nugroho, & Santosa, 2018, Julyeral professional applications across various fields, including healthcare, manufacturing, education, and retail (Antonioli et al. 2014). Organizations now use AR to improve employee safety by providing virtual training simulations and visualizing how equipment can function before it is manufactured. On the other hand, Virtual Reality (VR) is an advanced technological innovation that has revolutionized the way we experience and interact with digital environments (Velev & Zlateva, 2017). By leveraging cutting-edge computer graphics, motion sensors, and display technologies, VR enables users to immerse themselves in vividly realistic

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simulations of real or imaginary worlds. VR has proved to be invaluable in various industries such as Gaming, Education, Healthcare, Real Estate and many more (Kamińska et al., 2019). Although AR and VR might sound similar, but they are two distinct technologies with different purposes. VR immerses users in a completely new digital environment, providing an interactive experience through the use of headsets or glasses. AR complements the real-world environment by overlaying digital objects onto it, augmenting it with extra information or enhancing its functionality.

Furthermore, AR and VR technologies offer a range of benefits to online learning, m-learning and mixed learning such as providing immersive learning experiences and a more engaging learning environment. AR and VR can be used to create virtual worlds and simulations that allow students to explore and interact with real-world environments without leaving the classroom (Young et al., 2020). Additionally, AR and VR can be used to create interactive and engaging content, such as 3D images and videos, which can help to keep students engaged (Gargrish et al., 2020).

This research analyzes recent literature development and gives more understanding of AR and VR evolution in education in last twelve years indicating the researches trends, gaps, advantages, challenges and recent developments. Research hypotheses supported by prior studies of AR and AR in education are raised and validated by a noticeable research growth in recent years in education. By revealing the state of art in the prior literature, the contribution of this research lies on providing further directions for AR and VR in education and their developments.

1.1. State of art

The use of AR and VR technologies in education is becoming more and more common. Students are able to interact with their environment in a more immersive way, increasing engagement and providing a greater understanding of concepts (Zhang et al., 2022). As the cost of AR and VR hardware continues to decrease, the technology will likely become even more accessible in the future. Augmented Reality (AR) and Virtual Reality (VR) technologies in education are revolutionizing the way students learn and interact with the world around them (Du et al., 2020). AR and VR offer new opportunities for students to interact with 3D objects, explore their environment, and gain a greater understanding of concepts. AR and VR can also be used to create interactive simulations, allowing students to explore complex concepts in a safe and engaging environment.

Furthermore, integration of AR and VR in the classroom has been shown to have a positive effect on student engagement and learning (Sun et al., 2022). Students who use AR and VR technologies have been found to have higher levels of motivation and engagement, as well as better performance on academic tasks (Alizadehsalehi et al., 2021). This is likely due to the fact that AR and VR provide a more immersive learning experience, allowing students to explore, discover, and interact with their environment. The use of AR and VR in the classroom has been gaining traction in recent years, with schools and universities beginning to invest in the technology. The cost of AR and VR hardware has also been steadily decreasing, making it more accessible to those on a tighter budget.

AR and VR technologies have also been used in a variety of other educational settings, such as museums, libraries, and science centers. By using AR and VR, students can explore and interact with objects in a way that would not be possible in the physical world. This type of learning can be particularly beneficial for younger students, who may not be able to fully grasp complex concepts without the assistance of visual aids. This analysis will indicate the engagement and ability of prior and recent researches to further understand the challenges and gain the advantages of AR and VR in education.

1.2. Related works

According to the main purpose of this research, reviewing existing literature during last 10 years of VR and AR in education and its recent developments and directions, related works have been summarized in the same area including multiple objectives and investigating specific usage of VR and AR in learning have been reviewed in Table 1. Key words used in searching for related works included variables of this title focusing in the most comprehensive studies in education. Recently during Covid-19 pandemic, some researches have been published

Table 1
Related works to VR & AR in Education in recent years.

Reference	Subject	Method	Findings
Zwoliński et al. (2022)	Extended reality in management education	Case Studies	Creating a modal for XR-based educational environment by utilizing different XR technologies
Scavarelli et al. (2021)	VR and AR in Social Learning	Literature Review	Exploring the recent developments of VR & AR in Social space and several learning theories.
Patel et al. (2020)	VR, AR & mixed Reality in education	Survey	Overview VR, AR and Mixed Reality in education and ability of people adaptation of these technologies.
Boyles (2017)	VR & AR in Education	Review	Describing usage of AR & AR in enhancing learning and reviewing advantages and disadvantages.
Olbina and Glick (2022).	Integration of AR & VR in Construction Management	Physical model	Improving visualization, improvement in understanding of construction material and improved student communications skills.
Sirohi et al. (2020)	Augmented & Virtual Reality applications	Survey	An interdisciplinary review of integration of VR & AR in different area and directions.
Huang et al. (2019)	AR & VR in Education	Exploratory Study	Virtual reality is more inclusive of spatial presence while augmented reality is more effective in dealing with auditory information
Guo et al. (2021)	Extended Reality (XR) in Education	bibliometric analysis	Exploring the overall productivity of XR and recent development and trends in educational field.
Solmaz and Van Gerven (2022)	Integration of extract-based CFD of AR & VR	A architecture Modal	Proposing a component-oriented system architecture and Data simulation with AR/VR.
Nguyen and Dang (2017, October)	Setting up VR & AR learning environment	Designing Model	Designing 3D framework for curriculum based on VR &AR presetting real world objects
Cieri et al (2021)	Visual and Augmented Reality	Descriptive & case studies	Describing recent VR/AR software, hardware and techniques in pedagogy.
Rau et al. (2018)	Speed reading on VR & AR	Survey	Exploring performance on VR & AR where response time was longer on VR and AR than desktop
Remolar et al. (2021)	Learning throughout VR & AR	Several Experiments	Supporting gameplay and attractiveness and increasing student's interest to learn.
Beck (2019)	Immersive learning	Special issue	Integration of technologies including AR & VR to enhance learning environments.

including literature reviews and surveys on VR & AR in education. Scavarelli et al. (2021) explored VR and AR integration in social learning including classrooms and museums based on learning theories. Patel et al. (2020) and Boyles (2017) investigated characteristics of virtual, augmented and mixed reality, advantages and disadvantages in education and people experience of using these technologies in real life. Furthermore, some researches included virtual reality or augmented reality only in education. Other researches also investigated the developments of VR and AR in different fields including education. Sirohi et al. (2020) investigated the innovative integration of VR and AR in different businesses including education. Moreover, some of studies were conducted during Covid-19 pandemic which included valuable information and showed the significance of VR and AR in overcoming exogenous threats in education. Table 1 included sample of pervious researches that investigated different aspects of virtual and augmented reality in addition to mix and extended reality. This research differs of previous researches through investigated comprehensive researches indexed in Scopus database during 2011–2022 concentrating more on researches, trends and recent developments in VR and AR in education during Covid-19 pandemic and beyond based on hypotheses testing.

2. Literature review and hypotheses development

2.1. Characteristics and recent researches

Virtual Reality (VR) and Augmented Reality (AR) are the two sides of the same coin of emerging technologies sharing some of characteristics mostly but also they have some distinguished features. According to Maunder (2018) website, integration of VR and AR in education market is expected to reach 19.6 billion with annual growth rate equals 16.2% by 2023.

According to Krüger et al. (2019), Kim et al. (2018) and Javornik (2016), Virtual reality main characteristics represented in imaginary space, immersion in virtual space, sensory feedback and interactivity while augmented reality includes contextuality, which means combination of virtual and actual world simultaneously, interactivity at the same time and spatiality in the 3D world. These features enabled virtual and augmented reality in learning and created new significant educational approaches during outbreak of Covid-19 pandemic. Recently, virtual and augmented reality have gained increasing popularity due to a quantum leap in the development of VR and AR technologies (Beck, 2019; Chen et al., 2017; Gudoniene & Rutkauskiene, 2019). However, some of recent researches were conducted in AR, VR and XR in educational area exploring quality change in learning environment during Covid-19 Raja and Lakshmi Priya (2022); social learning space Scavarelli et al. (2021); utilization among primary school teachers Alalwan et al. (2020); myth and reality Elmqaddem (2019); science knowledge retention Huang (2019); Oral & Maxillofacial Surgery Ayoub and Pulijala (2019); challenges in present and future learning methods Al-Azawi (2018); meta-analysis Hantono, Nugroho, and Santosa (2018, July) and panel Zhu (2016).

Researches in VR and AR were limited due to the huge development of these technologies in different aspects. This research focuses on the integration of AR and VR in education in recent twelve years including period of Covid-19. Based on the literature review, the first and second hypotheses are formulated as follows.

H1. Virtual Reality (VR) and Augmented Reality (AR) researches in education have increased dramatically in the past ten years.

H2. VR and AR adoption in education have exponential growth during the outbreak of Covid-19 pandemic.

2.2. Opportunities and challenges

Regardless the limitless of potential opportunities and advantages of using VR and AR in learning environments, the current and actual usage is represented through enhancing the communication, motivation and interaction among educators and students. AR and VR have positive impact on learning effectiveness (Garzón et al., 2019). Augmented and virtual reality (AR and VR) are two of the most innovative technology advancements and their potential for improving the education system is massive. AR and VR allow teachers to take students on virtual field trips and offer interactive, engaging lessons that can be accessed from anywhere (Kumar et al., 2022). AR and VR can also be used to create immersive learning experiences, with students able to complete exercises in a virtual world and receive feedback on their work. Furthermore, the use of AR and VR in education can help to reduce the costs associated with learning materials and travel, making it more accessible and affordable for everyone (Shibata, 2019). By using these technologies, teachers can deliver lessons in a much more effective and engaging way, allowing them to get the best out of their students.

AR and VR can also be used to create dynamic and interactive lessons that are tailored to each student's individual needs, providing a more personalized learning experience. With AR and VR, students can also explore virtual worlds and replicate real-world experiences to gain a better understanding of concepts (Oberdörfer et al., 2021). Furthermore, AR and VR can help to improve collaboration between students and teachers. Students can work together with their peers in a virtual space, engaging in collaborative activities and learning together. Teachers, too, can use AR and VR to gamify their lessons, making them more entertaining and engaging (Mystakidis et al., 2021). AR and VR can also be used in the assessment process by providing students with interactive tests and challenges that are tailored to their individual learning level, teachers can measure their understanding of a topic more accurately and provide feedback in a timely fashion.

The use of augmented reality (AR) and virtual reality (VR) in education is becoming increasingly popular, as it offers a unique and immersive learning experience. However, these technologies come with a variety of challenges that must be addressed before they can be successfully implemented. One of the major challenges of AR and VR in education is the cost (Nguyen et al., 2019). The hardware and software required for these technologies can be expensive, and schools may not have the budget to purchase them. Additionally, the software used to create the immersive experiences must be regularly updated, which can lead to additional costs.

Another challenge is accessibility (Biswas et al., 2021). Not all students have access to the necessary hardware and software, so educational institutions must find ways to provide them to all learners. Furthermore, the use of AR and VR in education can be overwhelming for some students, depending on their age and experience with the technology. In addition, there is an issue with scalability (Scavarelli et al., 2019). As AR and VR become more commonplace, educational institutions must find ways to update their content and develop more immersive experiences that keep up with the latest technology.

While AR and VR offer many benefits for education, there are still challenges that must be overcome before they can be successfully implemented. With the right resources and strategies, however, the use of AR and VR in education can be a powerful tool for engaging and educating students. Based on this literature, we formulated the third hypothesis as.

H3. VR and AR have enhanced communication and students-educators interaction in e-learning.

2.3. Mobile applications and platforms

In recent years, mobile applications have become increasingly popular in the field of education (Criollo-C et al., 2022; Poláková & Klímová, 2019). The ubiquity of smartphones and tablets has enabled the development of a wide variety of educational apps, ranging from language learning programs to educational games (Huang et al., 2019). Mobile apps offer a number of benefits for education, such as providing

anytime, anywhere access to learning materials, increasing student engagement and motivation, and allowing students to learn at their own pace (Criollo-C et al., 2021).

M-learning, which stands for mobile learning, has revolutionized the way education is delivered (Bernacki et al., 2020). M-learning allows for anytime, anywhere access to learning materials and online courses, helping students to learn at their own pace and from any location (Klimova & Polakova, 2020). In recent years, the introduction of Augmented Reality (AR) and Virtual Reality (VR) technologies have further enhanced the capabilities of mobile learning.

Mobile apps and platforms offer a number of benefits for education, such as anytime, anywhere access to learning materials, increased student engagement and motivation, and allowing students to learn at their own pace. In addition, mobile apps can be used to track student progress and provide real-time feedback, helping teachers to better understand their students and adjust their teaching methods accordingly. Based on this facts, we proposed the fourth hypothesis as follows.

H4. Mobile applications and platforms are dominating the VR and AR landscape in education.

2.4. AR & VR during and beyond Covid-19 pandemic

The Covid-19 pandemic has had a drastic effect on the way people live, work, and learn (Al Ansi & Al-Ansi, 2020). Social distancing and other safety protocols have forced businesses and educational institutions to adapt quickly and find new ways to keep things running smoothly (Garad, Al-Ansi, & Qamari, 2021). Augmented Reality (AR) and Virtual Reality (VR) technologies have emerged as powerful tools for staying connected and continuing education during this difficult time. One of the ways AR and VR have been used during the pandemic is to enable remote learning (Ali, 2020). VR and AR allow students to explore and interact with their environment in a more immersive way, without having to be present in the physical classroom. This can be especially beneficial for younger students, who may have difficulty with traditional online learning methods. Additionally, AR and VR can be used to create virtual simulations (Lavrentieva et al., 2020), allowing students to explore and understand complex concepts in a safe and engaging environment. Based on this literature, we formulated the fifth hypothesis of this research as follows.

H5. Adopting of VR and AR in education have been significant during Covid-19 pandemic.

2.5. Recent AR & VR developments

Recent developments in Augmented Reality (AR) and Virtual Reality (VR) technologies are having a major impact on the world of education. AR and VR can be used to create immersive learning experiences, helping students to better understand and engage with the subject matter (Vretos et al., 2019). AR and VR applications can be used to create virtual simulations of a variety of scenarios, which can be useful for teaching students about subjects such as history, science, and economics (Li et al., 2018). For example, a student studying physics can use an AR or VR simulator to explore the properties of a black hole, or a student studying history can explore a recreated ancient city.

Furthermore, AR and VR can also be used to create interactive learning experiences, allowing students to explore and interact with 3D objects in a way that would not be possible in the physical world (Van Nguyen et al., 2022). Students can use AR to view a 3D model of an object and explore it from different angles, or use VR to explore an interactive environment (Al-Ansi & Fatmawati, 2023). AR and VR technologies have also been used to create experiences for special needs students, providing them with a safe and engaging learning environment (Köse & Güner-Yildiz, 2021). For example, AR and VR can be used to create simulations of challenging tasks such as crossing a busy street or visiting a grocery store, allowing students to practice and gain confidence in a safe environment. The rapid change and development of technologies including AR and VR increased adoptions of them in different markets including education and created more jobs (Verma et al., 2021). Based on this facts, we have proposed the six hypothesis of this research as follows.

H6. Recent researches on VR and AR in education include trends related to market and businesses for future jobs.

3. Method and results

Based on the fact that there are several databases providing access to scientific researches available in hundreds of international journals specifically in education, this research focuses on using Scopus database due to its excellence and accreditation in scientific research (Cortez et al., 2018).

3.1. Research settings

By adopting Scopus database, VR and AR in education or learning included 5122 documents of all times without any limitation. The following setting was executed to look for the related works between 2011 and 2022 (current year 2023 was excluded).

Distinct query: (TITLE-ABS-KEY (Virtual AND Reality) AND TITLE-ABS-KEY (Augmented AND Reality) AND TITLE-ABS-KEY (Education) OR TITLE-ABS-KEY (Learning)).

Furthermore, additional settings were applied to make research's cycle more effective including year of publication 2011–2022, document type: article 1454, review 252 and conference paper 35 documents in addition to notes, letters editorials and short surveys and source type included conference proceeding with 852, journals with 648 and book series with 283 documents while the language was only English. After execution all settings above, 1536 documents were the focus of this research and used for further analysis. Fig. 1 shows the distribution of documents in related year of VR & AR in education during last 12 years.

Virtual reality and augmented reality in education also include different area of science in all field. To be more specific, we need more clarification about the subject area of different science. Fig. 2 included the different field of science that encompassed VR and AR in their contents. It is important to mention that these different areas included education or learning only while discussing more about usage and employment of virtual and augmented reality in different fields and market is out of the scope of this research. The most dominant areas included computer science social sciences, engineering and medicine respectively.

One more step to finalize characteristics of selected papers in this research is to determine the related journals and contribution of each one of them to the education field. Table 2 included top 20 international journal indexed in Scopus as source of virtual and augmented reality in education sorted based on the number of articles respectively.

3.2. Documents analysis

According to Tables 2 and 527 articles included both AR & VR in education from different Scopus-based Journals from 2011 to 2022. To make the analysis more accurate and possible 84 documents were selected based on one criteria which is the document must include both AR and VR in education (Social Science) and limited to article only. These 84 documents were uploaded to WordStat application for further analysis. The outcome included word-cloud, keyword distribution, word frequency and topic analysis. Fig. 3 shows the Word Cloud Analysis for AR and VR in education.

Researchers adopted WordStat due to effective usage of this software in content analysis (Lewis, 1999). WordStat gives us more understanding about word frequency and keyword distribution. We have adjusted settings again to find the main keywords of AR and VR in education.

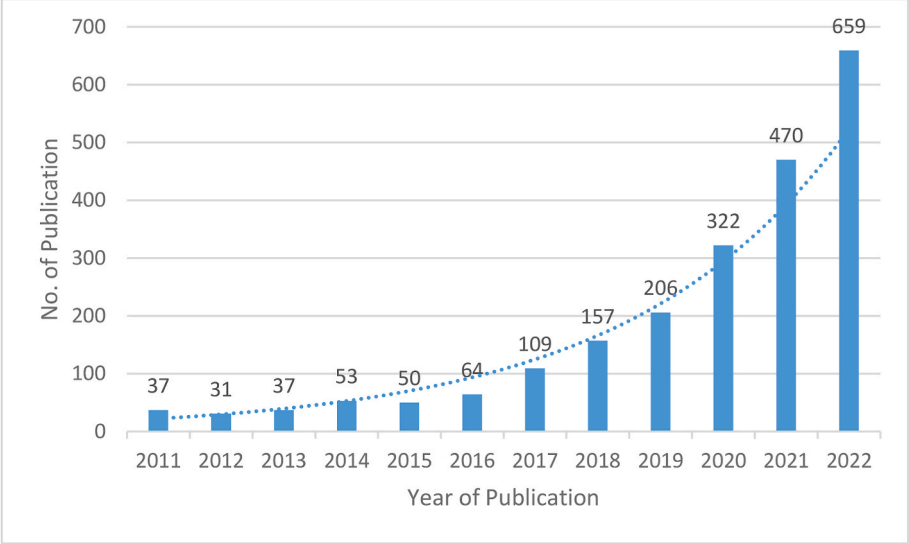

Fig. 1. Distribution of VR and AR throughout year of publication.

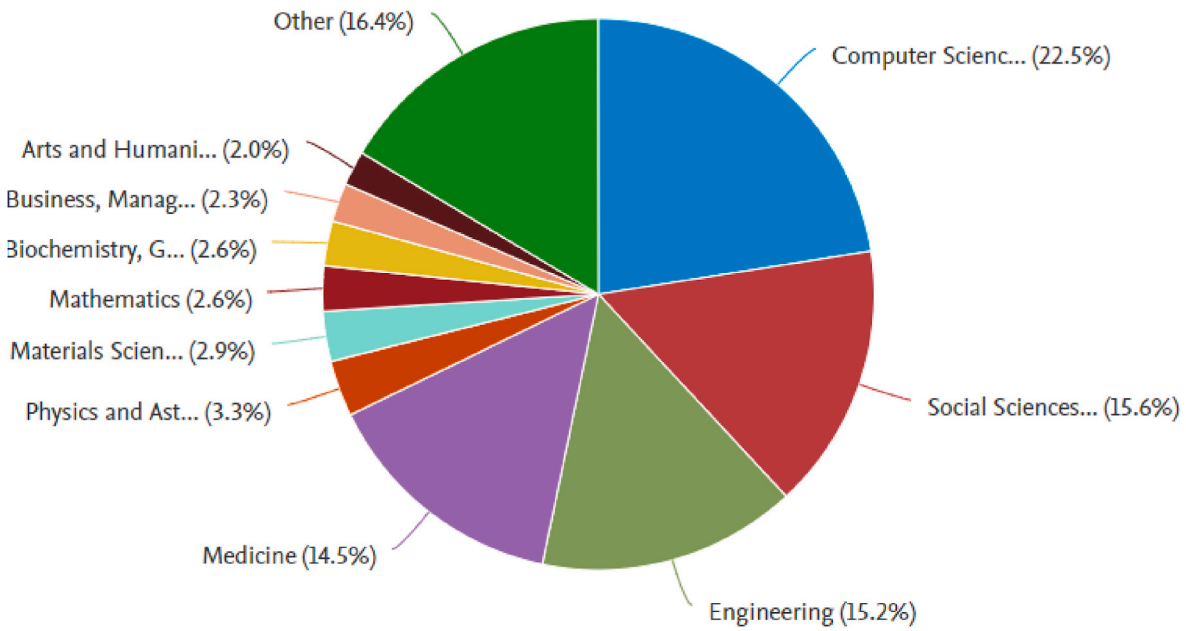

Fig. 2. Documents based on Subject area, Scopus 2023

Fig. 4 shows the keywords used in our documents which determine these documents are technology-based in their nature. These results reveal the concentration of research during last decade where AR, VR, Augmented, Virtual and technology were among the top 10 keywords with a high frequencies compared to other learning subjects.

Furthermore, we adjust WordStat settings to understand the word frequencies of AR and VR in education including the top 20 words. The results showed in Table 3 explain the most frequented words in selected documents. AR and VR in addition to the extension of these abbreviation were among the top five word frequency.

Final step for analysis includes topic analysis of AR and VR in education. The analysis settings included 20 top topics, after editing these topics to fit our criteria, 13 topics of them were selected based on serial number. Seven of these topics where excluded while the other topics explain coherence, eigenvalue, frequency and number of documents where these words were appeared. Table 4 illustrates this analysis.

4. Discussion and conclusion

In this part of paper, we examine the hypotheses as part of the discussion. Further, we concluded the main objective of this analysis and illustrate the theoretical and practical implications in addition to limitations of this work.

4.1. Discussion

Based on the results, AR and VR gain an important attention during last decade and more, especially from 2011 to 2022. We can divide this period into two part: each period includes 6 years. The first part include years 2011–2016 where AR and VR in education were growing slightly. The second period (2017–2022) where studies in AR and VR in education have grown exponentially. Fig. 1 illustrates this increased growth in amount of studies in last decade which reflects the confirmation of the first hypothesis $\mathbf{H_1}$. Furthermore, Fig. 1 also shows the dramatic change

Table 2
Top sources of VR & AR in education (2011–2022).

VR & AR in Education Sources	No. of Articles
Lecture Notes In Computer Science	130
Ceur Workshop Proceedings	56
ACM International Conference Proceeding Series	51
Communications In Computer And Information Science	33
Advances In Intelligent Systems And Computing	31
Procedia Computer Science	30
Computers And Education	26
Journal Of Physics Conference Series	19
ASEE Annual Conference And Exposition Conference Proceedings	17
Lecture Notes In Networks And Systems	16
Applied Sciences Switzerland	14
Studies In Health Technology And Informatics	12
Conference On Human Factors In Computing Systems Proceedings	11
International Journal Of Emerging Technologies In Learning	11
Sustainability Switzerland	11
2017 IEEE Virtual Reality Workshop On K 12 Embodied Learning Through Virtual And Augmented Raja & Lakshmi Priya, 2022	10
Education Sciences	10
IEEE Global Engineering Education Conference Education conference	10
IEEE Transactions On Learning Technologies	10
Proceedings IEEE Virtual Reality	10

Source: Scopus database

during Covid-19 pandemic. In last three years (2020–2022), the number of researches on AR and VR in education have increased exponentially and this confirm the second hypothesis **H_2**. Number of papers in these three years is more than papers since 2011 to 2019. Precisely, we could confirm H_2 partially, as the numbers of papers have been doubled yearly. These results, to our knowledge, were not studied before although Tan et al. (2022) corroborate this results partially.

The summarized body of knowledge according to Fig. 4 "keyword analysis" and Table 3 (word frequency) unveiled the role of AR and VR in learning. Learning and students were among top 10 keywords in Fig. 4 and also in the second and 12 in Table 3 of word frequency. In addition, topic analysis in Table 4 indicates student and teacher is in the top three topics with ($\beta = 2.52$) illustrating the relative correlation of student/teacher and AR & VR in the analysis. These results confirm the third hypothesis of our research **H_3**. This result is aligned with prior works in AR and VR in education. Commination and interaction between teachers and students are enhanced by using technology application and platforms (Cheng & Tsai, 2019; Gandedkar et al., 2021; Garad et al., 2021). Furthermore, m-leaning or mobile education gains a high recognition in AR and VR applications where in Fig. 4 was among the top 10 keyword distribution and also the eleventh in topic analysis in Table 4. In addition, Mobile was the eighth among word frequency and media platforms was the top second for AR and VR in education as in Table 3. These results confirm the fourth hypothesis **H_4** of our research indicating the dominant role of mobile applications and platforms in AR and VR adoption in education.

Although social media, e-learning and m-learning has positive and significant role during the covid-19 pandemic (Garad, Al-Ansi, & Qamari, 2021; Al-Ansi et al., 2021 & Al-Ansi, 2022), but according to the results of our study, the AR and VR technologies has limited usage. The

Table 3
Word frequency for AR & VR in education.

Word	Frequency
AR	684
Learning	661
Virtual	617
VR	557
Augmented	436
Technology	300
Research	261
Mobile	196
Design	170
Information	147
Construction	138
Teaching	132
Training	122
Content	121
Computer	119
System	107
Knowledge	104
Game	97
Application	96
Device	95

Fig. 3. Word cloud for AR & VR in education.

Table 4
Topics analysis for AR & VR in education.

No.	Topic	Coherence (NPMI)	Eigenvalue	FREQ.	Case
1	Infrastructure	0.627	4.12	788	84
2	Media & Content Knowledge	0.503	3.90	298	84
3	Teachers & students	0.382	2.52	116	56
4	Construction Engineering	0.402	2.72	535	84
5	Higher Education & ICT Integration	0.438	2.57	310	71
6	Mounted displays head	0.382	2.52	116	56
7	Learning Environments	0.433	2.43	871	71
8	Evaluations	0.466	2.41	450	86
9	Texting Mining	0.369	2.38	165	76
10	Augmented Reality	0.212	2.34	1196	84
11	Mobile Learning	0243	2.20	280	71
12	Online Learning	0.371	2.16	365	71
13	VR Technologies	0.404	2.14	674	84

results reveal no evidence to support fifth hypothesis. Tables and figures related to our analysis illustrate the recent researches that were conducted before and during pandemic, but there is no any relevant keywords or topic was mentioned for Covid-19 or pandemic. This confirms the rejection of the fifth hypothesis **H_5**. Finally, regarding the recent researches on VR and AR in education, Fig. 2 shows the most related researches area connected to AR and VR. The majority of these researches are related to computer science, engineering, medicine and social science. Some other researches are related to mathematics, physics, materials business and art. This result also confirm the sixth hypothesis of our research **H_6**. Several of prior researches of AR and VR have been conducted in different areas and market including healthcare (Eckert et al., 2019; Fu, Hu, & Sundstedt, 2022), engineering (Lai et al., 2020; Schiavi et al., 2022), businesses (Huang, 2019; Permanasari et al., 2022), agriculture (de Oliveira & Corrêa, 2020) and tourism (Wei, 2019) while our research was conducted in education.

4.2. Conclusion

Augmented Reality (AR) and Virtual Reality (VR) technologies have the potential to revolutionize the world of education and provide a more immersive and engaging learning experience for students. Through the use of these technologies, students can be immersed in a variety of different visuals, audio cues, and simulations, which can help to increase their interest in the subject matter. Additionally, these technologies can

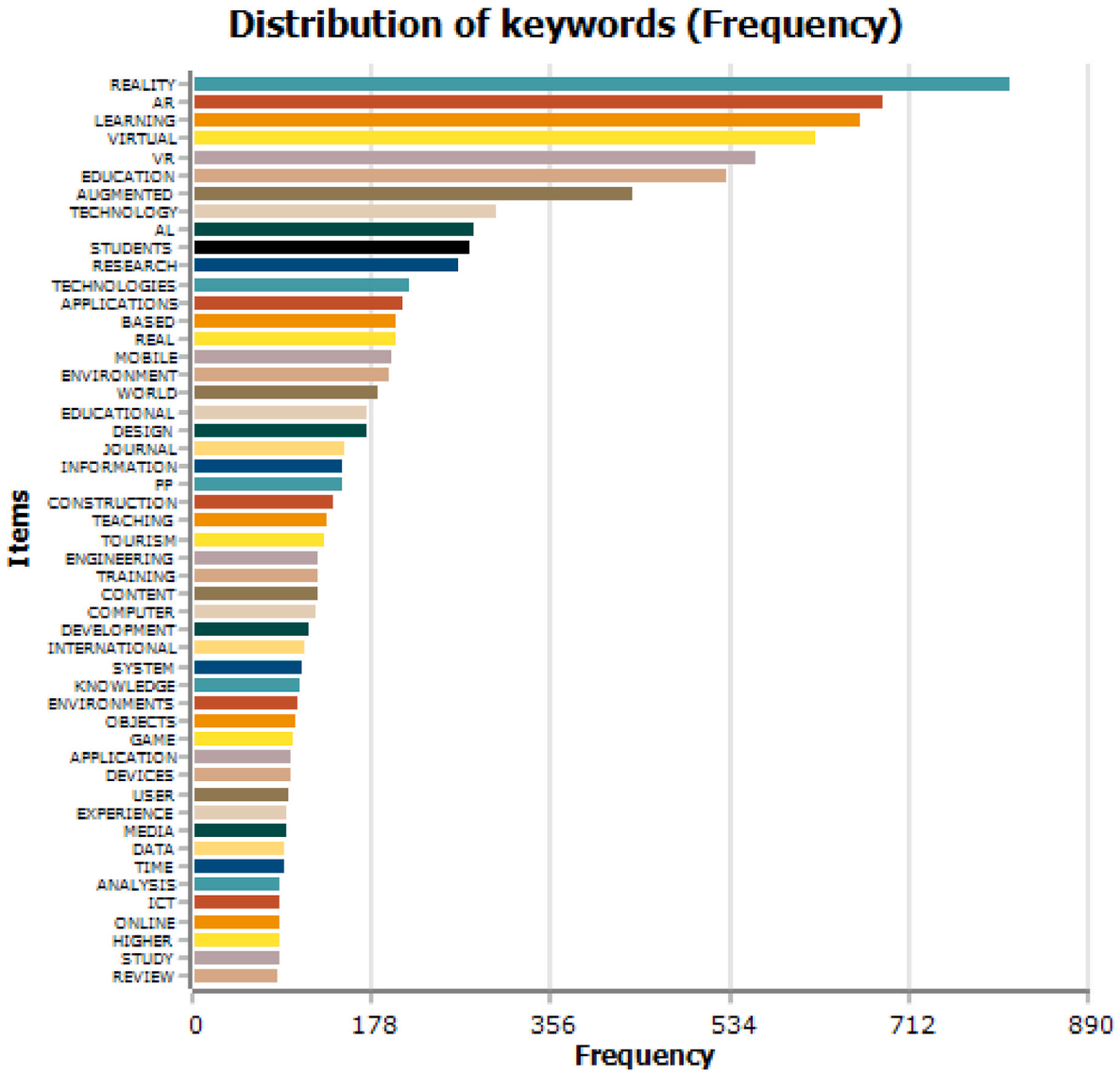

Fig. 4. Keywords distribution of AR & VR in education.

also be used to create more engaging virtual worlds, which can provide a more engaging and interesting learning experience. This paper analyzed the role of AR and VR in education from 2011 to 2022 and explored the main benefits and challenges, mobile applications and platforms, exponential growth during covid-19 pandemic and recent developments. Integration of AR and VR in education is still in the first stages, the potential of these technologies will change the nature of education and bring more benefits for students/teachers and educational institutions.

4.3. Theoretical implications

This research has reviewed the related researches and theories to AR and VR in education during the last 12 years. Firstly, a range of theoretical and surveys researches have been reviewed to explore the potential of AR and VR in education. This research illustrates Augmented/Virtual Reality Learning Environment Model (A/VRELM), which describes how these technologies can be used to facilitate learning. Secondly, this research describes the development area and future potential directions of AR and VR in education and its usefulness in different subjects. Finally, this research emphasizes the importance of AR and VR integration in education including e-leaning, m-learning and usage of educational applications and platforms.

In conclusion, numerous theoretical frameworks and empirical studies have been conducted to explore the potential of AR and VR in education. This study suggests that these technologies can provide a more immersive and engaging learning experience for students, and can also be used to support constructivist learning and reduce educational disparities.

4.4. Practical implications

Augmented Reality (AR) and Virtual Reality (VR) technologies have the potential to revolutionize the world of education and create a more immersive and engaging learning experience for students. Some of the practical implications could be as follows.

- AR and VR technologies can be used to provide a more immersive and interactive learning experience. By using these technologies, students can be exposed to a variety of engaging visuals and audio cues, which can help to increase their interest in the subject matter. Moreover, these technologies can also be used to create more engaging simulations and virtual worlds, which can provide a more engaging and interesting learning experience.
- AR and VR technologies can be used to increase the relevance of the content being taught. By allowing students to explore different environments and interact with content in a more realistic way, these technologies can provide a better understanding of the content being taught. In addition, these technologies can also be used to introduce new concepts and ideas in a more engaging way, which can help to increase student engagement and enthusiasm.
- AR and VR technologies can provide a more accessible learning experience for students with special needs. By allowing students to explore virtual environments at their own pace and on their own terms, these technologies can make learning more accessible for those with physical or cognitive impairments.

4.5. Limitations

Although Augmented Reality (AR) and Virtual Reality (VR) are powerful tools for enhancing education, they also come with some limitations. One of the main challenges with AR and VR is the high cost of the hardware, which can make it difficult for schools and universities to implement the technology. Another limitation of AR and VR is their complexity. Since these technologies are relatively new, it can be difficult for teachers and students to use them without any prior knowledge or experience. It can also be difficult to ensure the software and hardware are properly set up and maintained, and this can lead to technical issues and disruptions during classes. In addition, some of the immersive experiences created by AR and VR can be distracting for students, making it difficult for them to focus and retain information. There are still some limitations to the research on these technologies.

- The research on AR and VR in education is still in its early stages, and the lack of rigorous studies limits our understanding of their potential. Additionally, the complexity of implementing AR and VR technologies in a learning environment requires more research to understand their effects on student learning outcomes.
- The cost of implementing AR and VR technologies in a classroom environment can be prohibitively high, creating a barrier for some schools and institutions. Additionally, many schools and teachers may lack the technical knowledge to effectively implement these technologies in the classroom.
- There is also a lack of proper evaluation criteria for research on AR and VR in education. This can make it difficult to compare the effectiveness of different implementations, and make it challenging to accurately assess the benefits of these technologies.

There is still much to be done in order to fully understand the potential of AR and VR technologies in the world of education. With the right resources and evaluation criteria, however, these technologies can be harnessed to create a more engaging and immersive learning experience for students and educators.

4.6. Future direction

The future direction of augmented and virtual reality (AR/VR) is poised for significant growth as the technology continues to become more advanced and accessible. The integration of AR/VR in industries such as healthcare, education, gaming, and retail will likely continue to expand as it provides unique and innovative experiences for customers, patients, and students. With advancements in hardware such as wearable devices, head-mounted displays, and haptic technologies combined with improvements in software development tools including AI and machine learning algorithms, AR/VR has the potential to revolutionize the way people interact with digital content. Furthermore, the rise of 5G and 6G networks will enable faster processing speeds resulting in enhanced user experiences with reduced latency. As AR/VR becomes more mainstream across a broader range of industries worldwide; this trend is expected to continue into 2030 and beyond.

Furthermore, Augmented and virtual reality technologies allow educators to recreate real-life scenarios, employ immersive learning environments, and provide students with hands-on experiences that bridge the gap between theory and practice. With the continuous developments in these technologies, it is expected that they will fully transform the way we teach and learn. As such, schools are encouraged to invest more time, resources, and training towards implementing these technologies within their curriculum. Augmented reality can bring textbooks to life with interactive diagrams while virtual reality can create immersive simulations that enable students to experience real-world scenarios in a safe environment. These advancements aim to address the limitations of traditional classroom setups while also enhancing engagement levels amongst learners. Scholars and researches are encouraged to investigate more these development and approaches of deploying them in education.

Declaration of competing interest

Authors declare no any interest in this work.

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