



# “Next Generation Learning: Augmented Reality in Smart Education System”

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**Abstract:** Technology in education can influence students to learn actively and can motivate them, leading to an effective process of learning. Previous research has identified the problem that technology will create a passive learning process if the technology used does not promote critical thinking, meaning-making or metacognition. Since its introduction, augmented reality (AR) has been shown to have good potential in making the learning process more active, effective and meaningful. This is because its advanced technology enables users to interact with virtual and real-time applications and brings the natural experiences to the user. In addition, the merging of AR with education has recently attracted research attention because of its ability to allow students to be immersed in realistic experiences. Therefore, this concept paper reviews the research that has been conducted on AR. The review describes the application of AR in a number of fields of learning including Medicine, Chemistry, Mathematics, Physics, Geography, Biology, Astronomy and History. This paper also discusses the advantages of AR compared to traditional technology (such as e-learning and courseware) and traditional teaching methods (chalk and talk and traditional books). The review of the results of the research shows that, overall, AR technologies have a positive potential and advantages that can be adapted in education. The review also indicates the limitations of AR which could be addressed in future research.

Augmented reality (AR), a cutting-edge technology, has the potential to change the way students learn by superimposing virtual items and information onto the real environment. Through more immersive and interesting interactions with digital content, AR might help students better understand difficult concepts and boost their drive to learn. As a result of its contribution to student learning, AR has become increasingly appealing to educational researchers. This study aimed to descriptively explore the characteristics of AR studies in education and to qualitatively analyze the most influential ones indexed in the Web of Science (WoS) between 2000 and 2022. A scoping review was conducted to determine the sample of the AR studies in education based on the

inclusion criteria. Accordingly, descriptive analyses were conducted to identify the characteristics of the AR studies in education between 2000 and 2022 in terms of publication year, country, affiliations, journals, funding agencies, and citation trends. Then, the research methodologies and implications were found among the most influential AR studies in education between 2000 and 2022 by synthesizing qualitatively. The overall results indicated that AR studies in education have been conducted since 2008, with an increasing number of studies over time. Based on the implications of the most influential studies identified in terms of citation numbers, it was detected that AR has the potential to enhance education and training by providing interactive and engaging environments, linking real-world contexts with digital resources, and promoting efficiency and effectiveness in learning. [This paper was published in: "EJER Congress 2023 International Eurasian Educational Research Congress Conference Proceedings," Ani Publishing, 2023, pp. 273-291]

Augmented Reality has a positive impact in the world of education. Systematic review studies and article reviews have provided evidence of this positive impact. Augmented reality is an effective medium for learning, especially during a



pandemic. The keyword used to find the articles on the Scopus database was “augmented AND reality AND in AND science AND education,” which discovered 1153 publications, then screening found 68 articles that met the criteria for analysis were obtained by following the Preferred Reporting Items for Systematic Review procedure. The bibliometric finding in this study is the increasing trend of augmented reality research. Research trends consist of distribution year, research type, keywords, author nationality, and international collaboration. The findings reveal that there has been an increase in research from 2018-2023 on the theme of augmented reality. The research employed several methods, i.e., qualitative, quantitative, mixed-methods, and survey. The author publishes the theme of augmented reality from 28 countries, especially the Malaysia, China, Romania, Spain, Turkey. Furthermore, it was found that the number of collaborating publications (universities or countries) was higher than those not collaborating. The AR trend in education has benefits for students and teachers. The conclusions from the analysis of the article show that the theme of augmented reality is becoming a trend in education.

The study of augmented reality, also known as AR, is currently a high priority for multiple prestigious international universities and research institutions. This research paper explores the usage of augmented reality in the world of education. It has often been found that when presented visually, information is better understood by students in the classroom. AR is such a technology that can be used to provide interactive learning visual experience giving learners a sense of deeper immersion and significantly raising the learner’s appeal and interest. Augmented reality (AR) gaming can be utilized as an instructional tool, in addition to visual learning through animations and 3D models as it has been found a useful technique for improving understanding of new information. The purpose of this research is also to illustrate an educational application that uses AR and gaming to enhance conceptual understanding and adopts a different pedagogy from traditional methods. Blender and Unity3D were used to create the application that is discussed in the paper.

Keywords: Augmented Reality, Technology, Education, Student and literature review.

## 1. INTRODUCTION

Technology has become embedded in education and the results indicate a positive impact on learning and teaching styles.[32] According to Shapley et al. (2011), lessons that are supported by technology will lead to more innovative forms of teaching and learning. This is because the use of technology involves real-world problems, current informational resources, simulations of concepts, and communication with professionals in the field. [37] In addition, learning using technology is believed to complement the traditional forms of teaching and learning (Yasa Ket al., 2010).[31] The integration of technology tools into the curriculum is becoming part of good teaching (Pierson, 2001). Teachers not only have to spend a good deal of personal time working with computers but also should have a high level of innovation and confidence to use the new technologies that are embedded in contemporary education. The integration of technology also provides a means to enhance student learning and engagement in lectures. [27] Therefore, recent studies have aimed to better understand the applications adapted during lectures from the perspective of students, including multimedia, computer-based simulations, animations and statistical software (Neumann et al., 2011).[12] Research by Geer and Sweeney (2012) showed that the use of a variety of media applications to explain concepts increased the understanding and supported greater collaboration between students. Augmented reality (AR) is a new technology that has emerged with potential for application in education. While a lot of research has been conducted on AR, few studies have been conducted in the education field. The number of studies on AR is growing due to the effectiveness of this technology in recent years. [33] AR has been used in different fields in education. In particular, AR provides an efficient way to represent a model that needs visualization (Singhal et al., 2012). AR also supports the seamless interaction between the real and virtual environments and allows a tangible interface metaphor to be used for object manipulation (Singhal et al., 2012). Augmented Reality (AR) is “a system that enhances the real world by superimposing computer-generated information on top of it” (Furht, 2006) by overlaying digital information such as text, images, or videos, onto the real world to increase users’ perception of the environment. According to Azuma (1997), real-time interaction and precise 3D model registration of real and virtual objects are made possible by the fusion of the real and virtual worlds, which is called AR technology. Compared with virtual reality (VR), AR can be regarded as a more recent technology with an interdisciplinary application framework by “supporting learning [through] increasing on content understanding and memory preservation, as well as on learning motivation” (Cipres so et al., 2018). Therefore, AR has been applied and investigated in education to develop interactive learning experiences that can help students improve engagement and retention. The term “augmented reality” was first introduced by Tom Caudell in the early 1990s (Lee, 2012). Due to the advancements in mobile computing power and functionality, AR systems have been integrated into mobile devices, which accelerates its development and growth by providing access for a large group of users (Bower et al., 2014). Its innovative approach to learning has paved the way for AR use and research in the field of education.[9] Accordingly, AR technology is utilized for educational purposes due to its potential to enhance the learning experience by providing a more interactive and engaging environment for students. The AR technology blending real and virtual world experiences supports true inquiry in the real world for students because virtual



components including texts, videos, and photos serve as supplemental materials for them to perform investigations of their immediate environment (Dede, 2009; Klopfer & Sheldon, 2010). AR can make abstract concepts more tangible and accessible, which can aid in comprehension and retention. [36] Additionally, AR can offer students the opportunity to explore virtual objects and scenarios that may not be possible in real-life situations. Furthermore,

AR can facilitate collaborative learning and allow for personalized and adaptive learning experiences. Instead of only being dependent on the use of technologies, the educational benefits of using AR are closely related to how it is developed, put into use, and incorporated into both formal and informal learning environments (Wu et al., 2013). In this context, AR research in education significantly gains importance for improving student learning outcomes respectively. Therefore, this study aimed to descriptively explore the characteristics of the AR studies in education between 2000 and 2022 and to qualitatively analyze the most influential ones indexed in the Web of Science (WoS). Technology is increasingly into every aspect of life; education is also undergoing a significant transformation. One of the technological innovations that has changed the way we learn and teach is Augmented Reality (AR). AR combines the real world with interactive digital elements, creating immersive and engaging learning experiences. In an educational context, AR has opened the door to more immersive, visual and practical learning, helping students to understand complex concepts in ways that were previously difficult to access (K. Lee, 2012). In recent years, there has been a significant increase in the use of Augmented Reality (AR) technology in education (Garzón, 2021; Jaya Maha, 2024; Johnson & Westbrooks, 2021). AR has changed the way we view learning and is having a powerful impact on the way students learn and teachers teach. With the increasing sophistication of technological devices and the development of digital content, AR has become an increasingly popular and enthusiastic tool in various educational settings (H. Lee & Cho, 2020). This increase is not surprising considering the huge potential that AR has to offer. With the ability to blend the physical world with interactive digital elements, AR creates evocative and memorable learning experiences. Currently, students can explore abstract concepts in an attractive visual form, as well as face real-world situations that are enriched with additional information from the digital world. In this article, we will investigate how the increased use of AR has affected education. We will explore the reasons behind its increased popularity, as well as the impact it has seen in terms of quality of learning, student engagement and teaching effectiveness. Some examples of successful AR use cases will provide insight into the different ways in which this technology has been integrated in a variety of educational contexts, from elementary to tertiary levels. By looking at this trend, it is clear that AR has taken a significant role in changing the learning paradigm. This is an exciting time in which technology has not only been used as an auxiliary tool, but has become an integral part of the educational experience. With the continuous development of technology and emerging innovations, AR has great potential to bring education into a new era full of possibilities and opportunities.

With the advancement of emerging technologies, the ability to observe, interact, and hear virtual objects coexisting in the real-world environment is possible with the introduction of AR. Applications based on AR have proven quite an attention, interest, and attraction in many areas, including education, medical, automation, e-commerce, tourism, interior design, building architecture, and construction, as well as in entertainment [1],[2]. Traditional educational styles and classrooms have been replaced with more interactive methods of teaching and learning with the help of various AR-based applications. In the medical and healthcare sector, with the help of AR, the interactive study of human anatomy is possible; also, surgeons can perform medical procedures on the virtual body before actually performing the same procedures on real human bodies. A variety of medium scan explore educational material. Traditionally, students learn through interaction with peers and teachers, which use traditional face-to-face communication to understand the educational content and non-interactive mediums like video, notebooks, and images [3]. In the last few years, digital media has been continuously involved in learning and educational activities and provides opportunities to learn with educational games and interactive simulations.

## 2. BACKGROUND OF PROBLEM

In recent years, governments have implemented initiatives with the aim to improve the quality and effectiveness of the teaching and learning process. Thus, there is a philosophy named as 'Falsafah Pendidikan Kembangan' being created for the realization of this initiative. Besides, Malaysia is moving towards the title of a develop country and this needs a community which knowledgeable, progressive, innovative and can contributes in science and technology. These initiatives are motivated by the recognition that the traditional chalk and talk method and the use of static textbooks are failing to engage students and leading to poor learning outcomes.[35] In research conducted by Teoh and Neo (2007), for example, the respondents reported that it was boring to just hear the lecturer talking in front of them. The students believed that the integration of technologies would help them in their learning process. Therefore, educators have begun to seek technologies that have the potential to be integrated in education in order to help students learn actively and to improve their understanding especially in science subjects. The following sub-sections discuss the issues that have arisen in relation to the teaching and learning of Science and the ways in which technology such as AR can be applied to address these issues.



### 2.1 Decreasing Number of Students Interested in Science Subjects

[26] The study of science is a complex process that includes identifying a problem, investigating the problem, making hypotheses, planning the data collection method, testing the hypotheses, collecting the data and making the conclusion and results (Meerah, 1998). Participating in these processes helps the student to think critically in each step in order to gather the best results. Due to the popular perception among students that Science subjects are hard subjects; fewer students are interested in pursuing their education in the Science stream.

[30] According to Phang et al. (2012), the percentage of students pursuing their studies in the Science stream has never reached 60% and there was a worrying trend of decreasing student numbers in this stream. The Government of Malaysia has introduced a range of initiatives in order to address this problem but the target still has not been reached.[1] In the United Kingdom, there has also been a decrease in the number of students taking Mathematics, Physics and Chemistry subjects and a similar trend throughout Europe where young people are not choosing Science, Engineering and Technology subjects beyond compulsory subjects (Bevins, 2005).

Many studies have been conducted with the aim to learn from students about how to make them more interested to study Science. One suggestion made by students that an expert should be present in the classroom to provide them with the relevant context for the subject and make the classroom activities more exciting (Bevins, 2005). Students prefer to learn in interactive ways rather than the traditional teaching methods. [28] Research by Osman et al. (2007) found that students are less interested in studying Science because of their perception that it is a boring subject involving too many abstract concepts.

### 2.2 Students' Difficulties in Visualizing Abstract Concepts

[13] Students commonly find Science subjects to be abstract, requiring a depth of understanding and visualization skills (Gilbert, 2004). When students have difficulties in understanding the concept well, it leads to misconceptions.[29] According to Palmer (2001), misconception among students has to be taken into account because it can interfere with the students' learning of scientific principles and concepts. Thus, the selection of teaching method plays an important factor in avoiding or minimizing the students' misconception (Palmer, 2001).[15] Visualization technologies have exciting potential for facilitating understanding and preventing misconceptions in the scientific domain (Hay et al., 2000). [20] Kozhevnikov and Thornton (2007) found that is possible to improve students' visualization skills by presenting a variety of abstract visual images and allowing the students to manipulate and explore the images. There is a wide range of available technologies that can be used for the visualization of abstract concepts.

Examples of visualization technologies that have been examined in previous research include animation, virtual environments and simulation.[9] Dede et al. (1996) suggest that students can improve their mastery of abstract concepts through the use of virtual environments that have been designed for learning. Robertson et al. (2008) found that animation together with interesting data and an engaging presenter helps the audience understand the results of an analysis of information. These visualization technologies can be used to address the problem of misconception and help students understand better.

### 2.3 Potential Technologies for Visualization of Abstract Concepts

Scientific concepts can be categorized as theoretical and descriptive concepts. Examples of descriptive concepts can be found in Biology such as food chains and environmental factors. Theoretical concepts represent the concepts that cannot be seen with the eye such as air pressure (colliding molecules) and photosynthesis (Lawson www.ccsenet.org/ies International Education Studies Vol. 8, No. 13; 2015 3 et al., 2000). [7] Research has demonstrated the beneficial use of technology as a means of visualizing abstract concepts. Visualization technologies provide a means for making visible phenomena that are too small, large, fast or slow to see with the unaided eye (Cook, 2006).[36] For example, Wu et al. (2001) developed an animation to help students understand the abstract concepts in Chemistry. According to them, this type of technology allows students to visualize the interactions among molecules and to understand the related chemical concepts.[34] Stith (2004) used software to create an animation of enzyme-substrate binding for teaching cell biology. The use of visualization technologies such as these in education is becoming more advanced and more sophisticated.

Nowadays, one of the technologies that shows great potential in education especially in visualizing abstract concepts is AR. [23] According to Martin et al. (2011), AR is a new technology that is likely to have an impact on education. [22] This claim is supported by the Horizon Reports from 2004 to 2010 which describe AR as a technology that brings the computer world to the human world (Madden, 2011). AR is different from virtual reality because AR combines the real world with computer graphics, while virtual reality immerses the user in a computer-generated world. AR is a new way to improve the learning of three-dimensional shapes instead of the traditional method in which teachers use wooden



objects. [4] According to Cerqueira and Kirner (2012), there are several advantages of using AR techniques for educational purposes. For example, AR can minimize the misconceptions that arise due to the inability of students to visualize concepts such as chemical bonds, because AR allows detailed visualization and object animation. AR also has the advantage of allowing macro or micro visualization of objects and concepts that cannot be seen with the naked eye. AR displays objects and concepts in different ways and at different viewing angles which helps the students to better understand the subjects (Cerqueira & Kirner, 2012).

In addition, most of the research conducted on AR to date shows that students are excited and interested to learn using this technology. [19] For example, in research conducted by Klopfer and Squire (2008), students gave positive feedback about their experience of the combination of the virtual and real environments. [3] Burton et al. (2011) also reported a similar result, with the participants in their study clearly excited about the potential of this technology for sharing information and learning about new concepts. This feedback is useful in determining the readiness of students to accept and use this new technology. [21] AR also makes students become more active in the learning process due to the interactivity of its applications (Lamounier et al., 2010). Thus, it encourages students to think critically and creatively which, in turn, improves their experiences and understanding.

The advantages of AR in education (highlighted above in Table 1) indicate that there is significant potential to integrate AR in teaching and learning, especially for the subjects that require the students to visualize. [8] However, the meta-analysis conducted in the present study and the research by Dana Korn et al. (2014) indicate that, even though a lot of research has been conducted on AR, relatively few studies have been conducted on AR in the education field.

### 3. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

#### 3.1. 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 & Rutkowski, 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 [Alal wan 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.

#### 3.2. 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.

### 3.3. 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.

### 3.4. 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.

### 3.5. 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.

## 4. Application of AR in Several Fields

This section presents a review of the extant research on the application of AR. This review is organized according to the application of AR technologies in a number of fields of study in education, namely, Medicine, Chemistry, Mathematics, Physics, Biology, Astronomy and History. Research on the application of AR in these fields is reviewed in order to evaluate the potential of AR in education.

### 4.1 Methodology

The goal of this review is to identify the potential use of AR in different fields of education. The keyword used in the search of the literature was the phrase “Augmented Reality”. There were 463 hits from the keyword search, of which nine were selected after taking into account certain criteria. Firstly, only studies conducted from 2007 were selected. This is because the AR technologies began to emerge in 2007. Secondly, the studies must represent different fields in order to give examples of how AR has been used in a range of areas. Lastly, the studies must highlight the purpose and the features of the AR technology that had been used. The search of the literature was conducted using EdITLib which is the digital library for Education and Information Technology.



There are many fields in which AR technology is adapted and applied for teaching and learning. Most of the research studies demonstrated the positive feedback of the participants regarding the AR system under investigation. In conclusion, more research on the integration of AR in teaching and learning should be conducted because of its clear benefits not only to students but also to teachers. With the aid of AR technology, the teaching of subjects that involve visualization will be enhanced, compared to the use of traditional methods alone.

## 5. LIMITATIONS OF AR AND SUGGESTIONS FOR FUTURE RESEARCH

There are many aspects of AR technology that need to be explored and many future research investigations remain to be conducted in this relatively new area. A number of limitations exist in this technology. [17] For example, according to Hsu and Huang (2011), many participants in an AR learning exercise agreed that the AR tools are good but most participants did not consider the tools to be as effective as reading textbooks. They found that AR tools to obtain information was not easy. The reason might be that although the AR tool itself is easy to operate, the procedure of sending the image, recognizing the text and then getting the meaning of the text is time-consuming. This is because the technology used the 3G network to connect to the Internet. Accordingly, the participants may need to wait a short time for the information to be sent back from the server (Hsu & Huang, 2011).

[11] The identification of this limitation is supported by the results of a study by Folkestad and O'Shea (2011) where the participants reported being frustrated when using the technology outdoors and had to resort to asking their teacher for help. The results indicated that although the students encountered technical issues, they found assistance, persisted with the task and engaged effectively in the unique learning process. Despite all the difficulties, the level of engagement in the outdoor AR activities was still very high (Folkestad & O'Shea, 2011).

As mentioned earlier, the replication of studies related to AR is growing rapidly. However, the use of this kind of technology is growing slowly in Malaysia especially in the education field. Thus, more researchers in the education field should investigate the potential of AR to improve the teaching methods in the country's education and to improve the efficiency of the teaching and learning process. [3] For instance, the AR developed by Burton et al. (2011) shows that participants were clearly excited about the potential of this technology for sharing information and learning about new concepts.

Moreover, research should be conducted to investigate the latest technology called the mobile augmented reality (MAR) system which is a smartphone application that is integrated with the AR itself. This new form of AR technology offers a learning experience that is linked to the formal classroom so that students can learn outside of class hours and outside of school limits (Burton, 2011).

The limitations stated above mostly highlight the issues related to the technical aspects of using AR in the learning process. Such technical issues must be improved in the future in order for AR to be widely applied in education [21]. Lamounier et al. (2010) also pointed out that there needs to be improvements in Internet portability in order to facilitate user access to AR systems for learning. Increased Internet access will give students the opportunity to use AR via a smartphone. This has the potential to make AR a powerful learning tool that can help students to gain content knowledge and maintain that knowledge through their interactions with the smartphone activities.

## 6. CONCLUSION

This review of the research conducted in several fields in education shows that AR technology has the potential to be further developed in education. This is because the advantages and beneficial uses of AR features are able to engage students in learning processes and help improve their visualization skills. The features can also help teachers to explain well and make the students easily understand what they are taught. The use of AR technology has also received positive feedback from participants and students who have shown their interest in using AR in their learning processes. These good responses are important because they indicate the willingness of students to actively engage in their studies through AR tools. AR technology is still new in education, thus there are still some limitations. However, the review of the research indicates that most of the limitations are related to technical issues. Such limitations can be overcome over time as research on the integration of AR in education is replicated and improved. When the potential of AR technologies is more fully explored, the beneficial functions of AR can begin to be used widely in all fields of education and the efficiency of the teaching and learning process will be improved.

To sum up, this study contributed to the descriptive exploration of the characteristics of AR studies in education between 2000 and 2022, as well as the qualitative analysis of the most influential studies indexed in the WoS. The findings revealed that AR studies in education have been conducted since 2008, with an increasing number of studies over time. The most influential studies, which were identified in terms of citation numbers, highlighted the potential of



AR to enhance education and training by providing interactive and engaging environments, linking real-world contexts with digital resources, and promoting efficiency and effectiveness in learning. However, the limitations and challenges associated with AR technology were acknowledged as its cost, pedagogical complexity, and the need for proper implementation to achieve desired learning outcomes. Both the benefits and challenges of AR in education should be taken into consideration, and further research and development are required to harness the full potential of AR technology in education.

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