A Literature Review on Mobile Augmented Reality in Education

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Abstract Technology can change the way students learn, become a powerful motivation, and trigger the learning process. This article discusses mobile augmented reality technology in education. Mobile Augmented Reality (MAR) is more effective in providing students with a positive, effective, and powerful learning experience. The researcher looked for Google Scholar and Scopus articles from the year 2015–2020. This advanced technology can help people communicate with each other's senses and experience applications, thereby stimulating consumers' interest through natural interaction. Researchers have been studying ways to incorporate enhanced environments into education so that students can participate in real-world environments. Related topics of the study are also mainly discussed: the past reviewers of systematic reviews, augmented reality education, Mobile Augmented Reality software development kits, Augmented Reality technology, user interfaces in Mobile Augmented Reality, and the future of Augmented Reality in education. Mobile augmented reality has aroused increasing interest in academia and industry. The real world and virtual information work together to create new educational opportunities. The research results indicate that augmented reality has various potentials and advantages and can be added to the field of education.

Keywords Mobile augmented reality · Education · Learning

1 Introduction

This research paper focuses on Mobile Augmented Reality (MAR) in education to help the AR community, especially researchers and students, to learn about Mobile Augmented Reality. Electronic tablets and smartphones are increasingly replacing books. Mobile Augmented Reality is an interactive technology for cross-domain and

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destination apps. It has been expected that the number of users of Mobile Augmented Reality applications will increase to 2.2 billion by 2019 (Zhang 2019). The following sections comprise the remainder of this paper: Sect. 2 presents the previous reviews of systematic reviews of augmented reality education. In Sect. 3, the Augmented Reality in education is discussed. Section 4 explains Augmented Reality Techniques that can be used in Augmented Reality and Sect. 5 discusses Mobile Augmented Reality software development kits. Section 6 addresses user interface design. Finally, Sect. 7 presents the future of Augmented Reality and concludes this research with a conclusion.

This is an example of this new technology. Indeed, augmented reality cannot fully substitute for the real world. Nevertheless, it embraces it by widening the divide between the physical and virtual worlds (Chang 2016). The AR is a technology that enables the users to deliver immersive environments by enriching the physical world with technological components, rather than a fully simulated and artificial environment (Lastname et al. 2019). According to Azuma (1997) the term "augmented reality" refers to the fusion of a direct or indirect view of the physical world with digital objects in real-time to construct a mixed reality.

Face-to-face teaching has become a regular form of school, which is established and communicated by teachers. In addition, the learning content is also focused on static materials, including paper, where static materials cannot dynamically represent any details, like movement or movement. However, teachers and scholars are particularly committed to developing new and useful methods, such as "mobile augmented reality", to improve teaching activities. According to Granado et al. (2016), mobile augmented reality is providing people with a new dimension of perception, viewing, listening, and communication with the real world in an unprecedented way. In addition, mobile AR is defined as the projection of virtual content onto a real-time camera in the actual environment via a smartphone or tablet, allowing users to interact with the content (Laine 2018). The purpose of this study is to lay the groundwork for implementing mobile augmented reality in education. Furthermore, it is anticipated that the development of this article will include some good instances of augmented reality consumer studies that will aid existing augmented reality researchers in their analysis.

2 Past Review

The aim of previous reviewers has been to research, analyze, and identify current work in the Augmented Reality field of education (AR). In the future, augmented reality has a lot of potential to be successful. A great deal of research has been done on augmented reality technology, like cell phone-based augmented reality and augmented reality in education. Related terms, mechanisms, and sample types of analysis are described in this article. There have been a few comprehensive analyses, content research, and meta-analysis articles relevant to AR applications in education in recent years. These studies are relevant to identifying trends in using augmented

reality in the field of education. This current analysis aims to find systemic review papers in education. There were 103 document hits from the keyword search of systematic AND review AND augmented AND reality AND education, of which 4 were selected for different fields in education. Scopus was used to carry out a systematic literature review in education.

Figure 1 shows the publication trend of reviews from 2015 to 2020, which demonstrated an increase in the number of articles published each year. Meanwhile, Fig. 2 shows the documents that have been published by 10 countries. The United Kingdom published 16 documents, which is the highest number of papers. Next, the United States published 15 documents, followed by 10 documents published by Germany. Meanwhile, six articles were written by Italy and Malaysia, whereas Greece published five articles. Figure 3 illustrates the pie chart of documents by

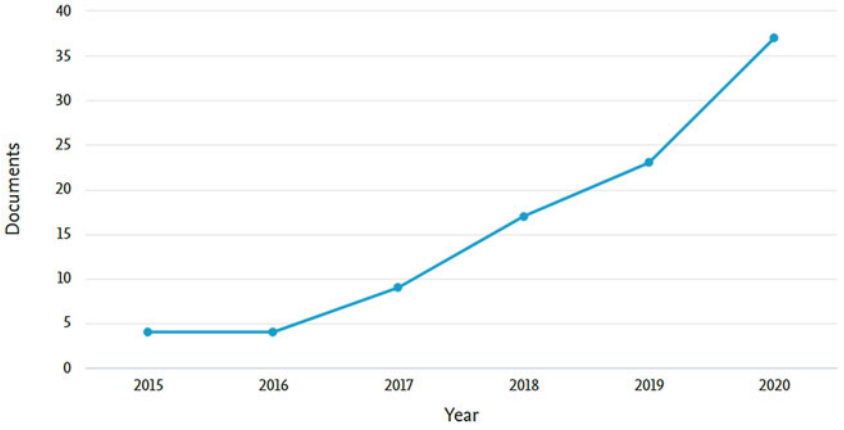

Fig. 1 Shows the publication trend of reviews from 2015 to 2020, which demonstrated an increase in the number of articles published each year

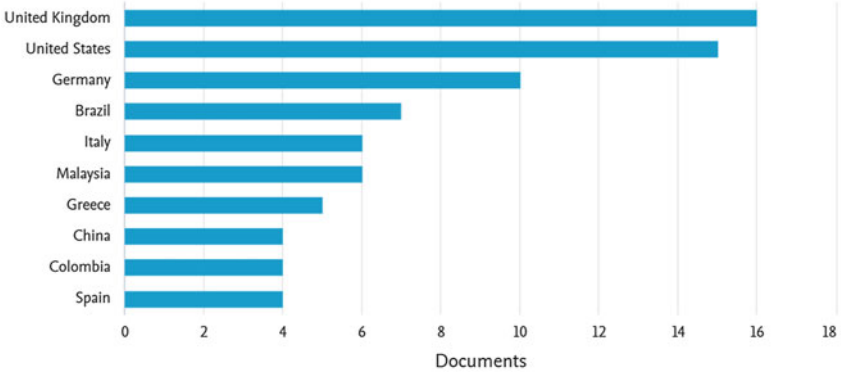

Fig. 2 Documents that have been published by 10 countries

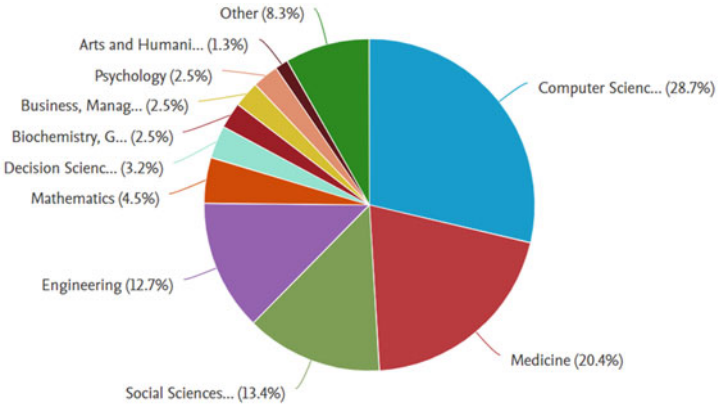

Fig. 3 Illustrates the pie chart of documents by subject

subject. The remaining three countries published four documents each. This pie chart shows that computer science has the highest percentage with 28.7%. The second area was 20.4%, represented by medicine.

Four educators from various fields were chosen to discuss the paper in greater depth. First, the systematic review paper (Laine 2018) discussed mobile augmented reality games in education. The author mentioned that it is necessary to conduct a comprehensive analysis of all research related to educational mobile AR games (EMARG). The researcher used a three-stage filtering and analysis process to conduct a literature review. The researcher looked for Google Scholar and Scopus articles from the year 2015–2020 and provided new information from a multidisciplinary perspective at the end of the article. A systematic review of mathematical trends for the period between 2015–2019 was also explained (Ahmad and Junaini 2020). Using the leading indexed Scopus database, this study found only 19 papers that followed the PRISMA guidelines. A study on these research focuses revealed eight themes to illustrate trends in AR app development tools, research contributions, benefits of AR for math, learning problems, testing methods, and math subtopics. Besides, the study by Sırakaya and Alsancak Sırakaya (2020) systematically investigated studies in which augmented reality (AR) has been used to support science, technology, engineering and mathematics (STEM) education. In general, the research was conducted in classrooms using marker-based AR applications. The study aimed to identify the current situation, benefits, and drawbacks of STEM-related to AR. Meanwhile, the study by Tang et al. (2019) was aimed at helping to direct potential studies. The study built an analytical model for ARAs and carried out a comprehensive analysis to observe the actual condition of ARAs. The theoretical model developed from the study can help standardize AR measurement approaches through analysis and identify the role of AR technology in medical education. Table 1 provides comparisons among the reviews.

Table 1 Comparison with existing article

	(Laine 2018)	(Ahmad and Junaini 2020)	(Sırakaya and Alsancak Sırakaya 2020)	(Tang et al. 2019)
Review Methodology	–	PRISMA	PRISMA	PRISMA
Publication Year	2018	2020	2020	2019
Field	–	Mathematic	STEM	Medical

3 Mobile Augmented Reality in Education

3.1 The Concept of Mobile Augmented Reality in Education

AR has been used for educational purposes in the first training for Boeing Airlines pilots and Air Force pilots (Voronina et al. 2019). Augmented reality offers a great promise, but "the question is whether it is useful to learn about it". "The problem is figuring out how to best utilize its potential" (Kaufmann 2012). Augmented reality (AR) is now used across all educational levels, including classrooms. One of the most widely used multimedia technologies in today's classrooms is augmented reality (AR) (Awang et al. 2019). The term augmented reality refers to a virtual environment technology that enables a device to superimpose virtual images on real-world objects (Shamsuddin et al. 2018).

The effects of mobile technology on classrooms have been extensively studied, while mobile technology combined with augmented reality technology has become ubiquitous across the world with diverse users including students at all levels of education (Awang et al. 2019). Augmented reality is a new experience for learners, that can encourage them to participate in digital content while still interacting with the real environment (Nanthanasit and Wongta 2018). In teaching methods, AR, is applied to several different fields, such as English Learning (Aladin et al. 2020; Pereira et al. 2020; Safar et al. 2017) Medical education (Gouveia et al. 2021; Küçük et al. 2016), Sciences (Midak et al. 2020; Tresnawati et al. 2019), History (Kysela and Štorková 2015; Syahputra et al. 2020) as well as in Mathematics (Kaufmann 2002; Purnama et al. 2014) and Islamic Teaching (Ahmad et al. 2019; Pradibta et al. 2019; Suhaimi et al. 2020).

Another application of AR in educational settings is the provision of 3D materials and the ability for teachers to exhibit content (Wu et al. 2013). AR also provides opportunities in the learning phases for certain issues to be solved. For some learners, bringing stuff into context is challenging (Cai et al. 2014). In this chapter, the analysis of current literature on the implementation of AR is discussed. The goal of this research is to look at existing augmented reality applications in various fields of education. Based on Title-Abstract-Keyword's quest, 1931 document hits were identified from the keyword search: augmented AND reality AND in AND education AND application using Scopus to provide examples and explain ways to use AR in

Table 2 Meta-analysis of research conducted on AR in different fields of education

Author/s	Field	Purpose of Study
(Gouveia et al. 2021)	Medical Education (Breast Cancer)	To accelerate exploratory research in breast cancer imaging
(Syahputra et al. 2020)	History (Historical Buildings in Medan)	To provide information about historical buildings in Medan
(Suhaimi et al. 2020)	Islamic (Jawi Character)	To provide students with early exposure and interest in studying Jawi and self-learning
(Tresnawati et al. 2019)	Science (Solar System)	To help people understand the different types of planets
(Safar et al. 2017)	English (English Alphabet)	Improve the effectiveness of augmented reality technology in teaching English letters for kindergarten children and develop teaching methods
(Kaufmann 2002)	Mathematics and Geometry	Using 3D Geometric principles to teach geometry

various areas of education. Table 2 describes a meta-analysis of research conducted on AR in various fields.

In Table 2, it can be seen that AR technology has been used in teaching and learning in a variety of subjects. The majority of research studies concluded that students who use augmented reality for education have a positive outcome. So, in the end, more research is required on the usefulness of AR in education, as it has great benefits for students and teachers.

3.2 Benefits of Augmented Reality in Education

Augmented reality has emerged as one of the most important educational developments in recent years. AR is a modern technology that, according to experts, has the potential to drastically change education. AR has a lot of benefits, including the unique ability to combine the physical world with a digital aspect, providing users with knowledge of realistic yet managed behaviour (Mahmud et al. 2019). AR is not a conventional methodology applied to traditional education methods but is a new technique for enhancing the learning of three-dimensional shapes. Also, according to Cerqueira and Kirner (2016) there are many benefits to using AR methods for educational purposes. For example, since AR can perform comprehensive simulations and object animations, AR can reduce misunderstandings caused by students failing to envision topics such as chemical bonds. Through different shapes and meanings, AR can display concepts and ideas. For instance, view shots that engage students in learning the subjects better (Cerqueira and Kirner 2016). Table 3 summaries the

Table 3 Benefits of using AR in education

Authors	Benefit of AR
(Pellas and Kazanidis 2019)	Provides interactive learning experience and better performance
(Billinghurst 2016)	Enables students to display and communicate seamlessly through spatial content
(Singhal et al. 2012)	Supports smooth connectivity with physical and simulated experiences and allows the use metaphors for object management with a tangible GUI
(Kiryakova et al. 2018)	Allows students to learn topics better when studying various topic
(Diegmann et al. 2015)	Enables students to learn by themselves, discover and accept new knowledge

benefits of augmented reality in education from the literature.

The educational benefits of augmented reality technology (as shown in Table 3) indicate that it has great potential for integration into teaching, especially in subjects that require student visualization.

4 Mobile AR Technique

AR techniques for learning can be categorized into two major categories: those that use markers and without maker. Image-based (markers) augmented reality and location-based (marker-less) augmented reality are two approaches to realizing augmented reality technology, according to Cheng and Tsai (2013), A marker-based systems needs markers to register 3D objects in the real-world image, while s marker-less system uses location data from mobile devices (Geethanjali and Muralidhara 2021). According to this, the marker-based system allows the positioning of 2D patterns of special patterns and shapes on real objects where the augmentations are superimposed. This involves putting flashcards next to the object of application with predefined pictures or posters. A marker-less picture is gathered from the Internet and displayed in every given place in marker-less augmented reality (can be gathered using GPS). A marker to show the content is not needed for displaying output (Fleck and Hachet 2015). Table 4 shows the comparison between maker-based and marker-less AR.

These are many studies conducted using marker-based (Aladin et al. 2020; Pereira et al. 2020; Gouveia et al. 2021; Küçük et al. 2016; Midak et al. 2020; Tresnawati et al. 2019; Kaufmann 2002; Ahmad et al. 2019; Pradibta et al. 2019; Suhaimi et al. 2020; Arifitama et al. 2019; Romli et al. 2020; Sun and Chen 2020; Tomi 2013) and marker-less systems (Kysela and Štorková 2015; Syahputra et al. 2020; Al-Jabi and Sammaneh 2018; Kolivand et al. 2019; Atzigen et al. 2021). Nonetheless, the majority of researchers used maker-based techniques to develop Mobile Augmented Reality.

Table 4 Comparison of marker-based and marker-less AR technique

AR Techniques		MARKER-BASED	MARKER-LESS
Category			
Hardware Support	Desktop	Support	Not Support
	Mobile Phone	Support	Support
Method	Relative Position	It depends on Markers	It depends on localization
	AR Software Development Tools	Mostly used	Rarely applied
Accuracy of location	High/Low	High	Low

5 Mobile AR Software Development Kits (SDK)

In augmented reality applications, there are various SDKs for making MAR and other important things. A software development kit (SDK) or framework for AR application development includes a coding environment in which users can use the advantages of augmented reality and resources to create functions that will make up the software application. The development of an AR framework for the SDK specification will include certain project functions. Researchers need to choose the right SDK according to the criteria of the project. The Augmented Reality SDK assists with a variety of components in the AR application: AR Recognition, AR tracking and AR rendering and also Abe, which are classified as follows: marker-less, marker-based, and natural feature monitoring (Amin and Govilkar 2015).

Researchers must use a particular SDK (SDK) to integrate AR into a mobile device. All these SDKs have their requirements. ARCore: The ARCore software is used to create augmented reality (AR) experiences for Google. With APIs from the ARCore, a phone can identify its surroundings, learn about the environment, and communicate with digital content. ARCore requires three main capabilities to incorporate interactive information into the physical environment, such as tracking, environmental understanding and light estimation. ARCode only recognizes 2D Markers (ARCode 2020). The first article in the Scopus database that used ARCode that by Sittiyuno and Chaipah (2019), which developed an application that uses augmented reality (AR) to inspire and assist learners with programming.

ARKit ARKit is Apple's augmented reality technology exclusive to iOS and enables the creation of augmented reality apps for iPhones and iPads. All iOS developers with an Ap-P Developer Account are entitled to receive the Apple ARKit SDK for free. ARKit combines object detection on the computer, camera scene capture, advanced stage processing, and display conveniences to simplify the process of creating an augmented reality experience. ARKit can search and recognize 3D static objects and even generate simulated metal reflections of actual objects. Some studies that used ARKits include that by Ismail et al. (2020), which developed mobile-based augmented reality for flexible human height measurement utilizing contact and motion gesture engagement, and also by Kharroubi et al. (2020), which employed

Table 5 Comparison of SDK

AR SDK		VUFORIA	ARKit	ARCode
Type				
Licenses	Open Source	×	×	×
	Free	✓	✓	✓
	Commercial	✓	✓	×
Platform Support	Ios	✓	✓	✓
	Android	✓	×	✓
Image Marker	2D	✓	✓	✓
	3D	✓	✓	×

ARKits to develop mobile applications for massive 3D point clouds and semantics. Besides (Dass et al. 2018) have created a MAR for learning programming.

Vuforia: The Vuforia Engine is the most commonly used AR development platform. To build AR applications that communicate with objects and the real world, developers can quickly apply advanced computer vision functions to Android, iOS, and UWP applications. It has three major components: objects, environment, and platform support. Vuforia provides a web-based environment in which users can build and maintain their mark-up and obtain licenses suitable for checking and publishing their applications. According to the study by Pradibta et al. (2019), this platform has been used to develop mobile applications for pre-school students reading and writing letters to Hijaiyah. Table 5 illustrates the comparison of among these software development kits.

The table concludes that each AR SDK has its attributes that can help AR developers to identify, present and manage their applications.

6 User Interface Design

AR can be used to generate unique collaborative experiences (Dünser and Hornecker 2007; Lukosch et al. 2015; Seichter et al. 2013) but AR technology alone cannot create this unique collaborative experience. It is generated by possible functions in the application design (Spector et al. 2014). According to research done by Seichter et al. (2013), design for children must fit three listed features: touch-screen GUI, FM Radio, and more memory. Colorful colors should be used in interface design for children, and icons should be designed in a cartoon style to display more information. By installing a high-fidelity prototype, the evaluators of the phone managed to sample the degree of interactivity that could be generated by children and adolescents in their age groups.

7 Future of AR in Education

How can Augmented Reality be applied to future education? Augmented Reality technology has the capabilities that can make classes more interactive and easily recognized. Teachers recognize that it is essential to provide students with opportunities to apply learning and their knowledge in ways beyond memorization. Augmented Reality applications require users to use smartphones to run. Cell phones and computers have a negative impact on schoolchildren's health that increases with the length and frequency of their use. Due to the disadvantages of mobile phones for students, AR glasses are the future of augmented reality. By 2023, AR glasses will take the place of smartphones. Many huge companies in IT, such as Microsoft, Facebook and Google, have revealed the use of AR Smart Glasses for the potential movement of mass media technology. Wearable augmented reality is gaining as it offers handy features including AR, like smartphone apps that help to expand people's knowledge while not requiring the use of hands (Matsuhashi et al. 2019).

8 Conclusion

This paper has provided an overview of MAR research that are relevant to education. Mobile Augmented Reality is a fast-growing commercial application industry with development anticipated in other markets. Educational practices are increasingly being implemented. Thus, it can be assumed that AR could prove to be a powerful tool if used correctly, and it is interesting to see how this research area will progress with other academics.

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