

A Quick Survey on the Application of Augmented Reality in Education

SettingsRizdania Dermawi^{*1}, Sapto Hadi Riono², Dimas Rega Hadiatulloh³
¹Brawijaya University, Malang, ^{2,3}Universitas PGRI Wiranegara, Pasuruan
rizdaniadermawi@gmail.com¹, saptoenator@gmail.com², reggadims@gmail.com³
^{*}Corresponding Author

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Abstract. Current conditions, especially the Covid-19 pandemic, force us to conduct online education. However, its implementation must be considered carefully to avoid becoming boring. The use of exciting technologies such as augmented reality can be an option. This scientific paper is a short review of the last ten years of studying AR technology in various fields of education. The evaluation of these previous studies shows that AR is a technology with great potential to be applied in education. However, the survey also demonstrates the limits of AR, which could be tended to in future research.

Keywords: Augmented Reality, Education, Study, Learn, Teach

1 Introduction

During the COVID-19 pandemic that we are currently living in, face-to-face learning cannot be carried out. Instead, online learning is carried out. Implementing online learning certainly involves various technologies to support the performance of the learning process [1].

The result of technology embedded in education positively impacts learning and teaching styles. Individuals and organizations who do not want to learn new educational and digitalization technologies will struggle to become part of the new digital world. Future [2].

Augmented Reality (AR) has become one of the technologies used and applied to support the implementation of education [3]. AR can be applied to early childhood informal education, as in the research conducted by Permana et al. [4]. The technology of Augmented Reality (AR) is a technology that combines virtual information with the real world. The principle is to apply virtual computer-generated knowledge, such as text, images, 3D models, musical instruments [5], videos, etcetera, to the real world after simulation. In this way, the two types of information complement each other, thus achieving real-world enhancement [6].

2 Background of Problem

Currently, the government has taken precautionary measures related to the Covid-19 pandemic, including issuing policies in the form of rules for implementing online learning. All “forced” learning activities are transformed into a digital format so students can access them online [7].

Various methods and technologies are used in providing online learning materials. The use of applied technology can help overcome the problems experienced by educational institutions during this pandemic [8].

Some topics in science require deep understanding and visualization skills. Therefore, presenting various abstract visual images and exploring these objects will improve students' visualization skills [9], just like research conducted by [10] on the effects of Mobile Augmented Reality (MAR) on students' visualization skills.

Delivering material online, of course, will be different from face-to-face learning. Therefore, Augmented Reality is considered a technology that can accommodate several problems that arise in online learning. Some advantages of using Augmented Reality (AR) are that it can increase motivation [11], enhance enjoyment, and increase interest [12]. In addition, AR is a technology that influences education [13]. For example, research by [14] shows that groups of students learning using AR technology have a higher concept understanding than conventional learning.

This paper will conduct a quick survey of the literature of the last ten years regarding the application of Augmented Reality (AR) to education, boundaries, and suggestions for future research.

3 Application of AR in Several Fields

3.1 Methodology

This review aims to assign the application of AR in various fields of education. The following are some of the inclusion criteria used in this study:

- Performed on publications in academic journals (to ensure high-quality refereeing)
- searches are performed on journal databases that are open access (so that everyone can access them)
- Conducted on the Scopus-indexed journal database (for quality of indexing and citation)
- It involves the past ten years [13], from 2011 to 2021 (to study the publication trends).
- The keyword used in collecting literature is “augmented reality.”

The literature search was conducted using Online-Journals.org, provided by the non-profit International Association of Online Engineering. The search results yielded 245 articles. After that, a further filter is carried out by providing additional keywords in the form of “education,” “learning,” “student,” and “teach.” Then, as many as 43 studies will be surveyed in this paper.

3.2 Application of AR in Education

This section reviews research on Augmented Reality (AR) applications in education and the application for helping learning that uses AR. Table 1 is a summary of several studies related to AR in education. Nine studies conducted research generally in education that uses augmented reality technology.

Table 1 Meta-Analysis of Research on the Use of AR in Education

Author	Purpose of AR Use	AR Feature Use
Alkhattabi (2017) [15]	To investigate the teachers' acceptance of using AR applications within an e-learning environment	AR mobile application
Techakosit and Nilsook (2018) [16]	To encourage the students to study and research by themselves	Scientific Imagineering through AR
Zhao (2018) [17]	To summarize the AR-based visual interaction interface design methods	AR-based visual interaction interface design

Chanjaradwichai, Na-songkhla and Chiasiriphan (2019) [18]	To develop the AR technology in the LMS and learning materials	The AR Book as the manuscript of the learning material
Yusuf, Efendi and Yuana (2019) [19]	To develop AR mobile application for learning robotics	AR mobile application
Sun et al. (2019) [20]	To implement the interactive design of the AR system.	The AR -ToolKit converts the two-dimensional picture into a three-dimensional dynamic animation.
Muali et al. (2020) [14]	Examine students' understanding levels after using mobile AR in solar system class.	Animation as AR content and marker
Nurbekova and Baigusheva (2020) [21]	To develop digital education resources with augmented reality (DER_AR)	AR-objects in the DER
Situmorang et al. (2021) [22]	To develop the Mobile Augmented Reality to introduce SMEs to college students	AR technologies to introduce SMEs

Table 2 summarizes the research conducted on some application that uses AR technology to help to learn a specific subject, such as the daily prayer [23] and hajj [24]

Table 2 Meta-Analysis of Learning Application Using AR Research

Author	Purpose of AR Use	AR Feature Use
Markouzis and Fessakis (2016) [25]	Combine with Interactive Storytelling (IS) to enhance the learning and entertainment application.	Combination of low threshold and high ceiling Mobile Augmented Reality (MAR) with the practical methodology of ISMAR learning design
Pradibta (2018) [23]	To teach the daily prayer learning material for the preschool student.	Animation Video as AR content and flashcard as a marker
Madi, Albakry and Ibrahim (2020) [24]	To provide creative information to children in learning about Hajj through AR	Mobile AR Learning Application

3.3 Footnotes Application of AR in Several Fields

This section reviews research related to Augmented Reality (AR) applications. This review is organized according to the application of AR technologies in some fields of study in education. First, research on the application of AR in this field is reviewed to evaluate the potential of AR in education.

Table 3 Meta-Analysis of Research on the Use of AR in Chemistry

Author	Purpose of AR Use	AR Feature Use
Hsiung (2018) [26]	As a technology that is used in the learning resource	AR technologies that were integrated into the classroom instruction
Setiawan, Rostianingsih and Widodo (2019) [28]	To utilize AR for presenting the 3D model of the chemical element and the merging between the elements' animation	Animation as AR content and flashcard as a marker
Saidin, Halim and Yahaya (2019) [3]	To develop a Mobile Augmented Reality (MAR) for learning chemical bonds	Interactive 3D animation of the chemical bond process

Pradani, Munzil and Muchson (2020) [27]	To produce guided inquiry-based teaching material assisted by AR	Pocketbook equipped with AR
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Table 3 shows the research that used AR technology in chemistry. A study was undertaken to determine the students' perceptions of the innovative technologies integrated into the classroom [26]. The research by [25] and [3] focused on the AR application for learning chemical bonds and reactions. The study of [27] aimed to generate teaching material assisted by AR on the electrolysis cells topic.

Table 4 includes the studies of AR technology in the computing area. For instance, [29] investigated the students' performance, retention, and learning outcomes after using Augmented Reality in Computing Education (ARICE). The AR technology also simulates the result of the commands in the program flowchart, which simplifies their understanding of the programming language [6].

Table 4 Meta-Analysis of Research on the Use of AR in Computing

Author	Purpose of AR Use	AR Feature Use
Wang et al. (2013) [29]	To evaluate the use of Augmented Reality in Computing Education	Interaction features of the AR interactive game in computing course
Boonbrahm et al. (2019) [6]	To develop the AR flowchart to simulate the result of the commands in the program flowchart	AR Flowchart
Ozdamli and Hursen (2017) [12]	To implement the AR application assisted with reflective learning skills in a computer hardware course	AR reflective learning skills

Table 5 Meta-Analysis of Research on the Use of AR in Electronics

Author	Purpose of AR Use	AR Feature Use
Odeh et al. (2013) [30]	To provide the students with a virtual object for the engineering experiment	AR-based Remote Engineering Lab
García-zubía et al. (2013) [31]	To improve the user experience and increase the educational potential of the experiment	Mobile AR Learning Application
Daineko et al. (2020) [32]	To conduct a virtual electronic educational laboratory	Mobile AR Learning Application

Table 5 lists the research on the AR technologies used in electronic learning. The studies by [30], [31], and [32] focused on developing a laboratory that utilized AR technology.

Table 6 presents the studies focusing on AR used in the language area. AR technology is applied in the classroom for language learning [33]. The application for helping the students learn Chinese vocabulary [34].

Table 6 Meta-Analysis of Research on the Use of AR in Language

Author	Purpose of AR Use	AR Feature Use
Ashely-Welbeck and Vlachopoulos (2020) [33]	To apply AR in the classroom for language learning	Mobile AR Language Learning Application
Uiphanit et al. (2020) [34]	To develop a Mobile AR application for enhancing Chinese vocabulary learning	Mobile AR Vocabulary Learning Application

Table 7 covers AR technology research in mathematics. The studies on learning mathematics with AR application were used by (Aldalalah et al., 2019; Amir et al., 2020; Guntur & Setyaningrum, 2021; Rohendi & Wihardi, 2020; Saundarajan et al., 2020). Another approach was used by [40] to integrate local wisdom forms in AR applications. Finally, to determine the effectiveness of AR-assisted storybooks on the students' anxiety in mathematics learning was used by [41].

Table 7 Meta-Analysis of Research on the Use of AR in Mathematics

Author	Purpose of AR Use	AR Feature Use
Aldalalah et al. (2019) [35]	To examine the effect of AR and simulation on Students' mathematics achievement and visual thinking	Mobile AR Learning Application
Amir et al. (2020) [36]	To develop a MAR system for Preservice Student Teachers (PSTs) learning	Mobile AR Learning Application
Sudirman et al. (2020) [40]	To integrate the local wisdom forms in the AR application	Local wisdom AR application and markers.
Saundarajan et al. (2020) [37]	To show the problem-solving of math equations in the Photomath application	AR mobile application
Rohendi and Wihardi (2020) [38]	To implement mobile-based augmented reality media in the process of learning mathematics in middle school	Mobile-based augmented reality media
Wangid, Rudyanto and Gunartati (2020) [41]	To specify the effectiveness of AR-assisted storybooks on students' anxiety in mathematics learning	AR-assisted storybook
Guntur and Setyaningrum (2021) [39]	To improve students' spatial and problem-solving skills	Augmented Reality Module in learning vector

Table 8 summarizes the studies in the medical using the technology of AR. The AR technology combined with leap motion was used to study hand anatomy, which was considered complicated. However, it turned out that the application helped the student to understand faster than the conservative ways [42]. Furthermore, the research by [43] showed that using AR tools to teach human heart learning was generally accepted.

Table 8 Meta-Analysis of Research on the Use of AR in Medical

Author	Purpose of AR Use	AR Feature Use
Boonbrahm et al. (2018) [42]	To help the student understand the hand anatomy	Dynamic AR of hand anatomy
Nuanmeesri (2018) [43]	To explore the development of an AR tool for learning the human heart	Augmented Reality Module in understanding the human heart

Table 9 includes the research on the use of AR technology in physics. The multi-viewpoint AR-based learning system was developed to observe the movement of the moon [44] and sun [45]. In addition, Augmented Reality in physics learning was evaluated in the research conducted by [46].

Table 9 Meta-Analysis of Research on the Use of AR in Physics

Author	Purpose of AR Use	AR Feature Use
Tian et al. (2014) [44]	To develop a multi-viewpoint AR-based mobile learning system for moon observation	Multi-viewpoint AR-based mobile learning (M-VARML)
Tian et al. (2014) [45]	To develop a multi-viewpoint AR-based mobile learning system for solar movement observation	Multi-viewpoint Smartphone AR-based learning system (M-VSARLS)
Suprpto, Nandyansah and Mubarak (2020) [46]	To evaluate the students' abstract thinking skills while utilizing AR in the atomic model	Physics Augmented Reality (PicsAR)

Table 10 presents the research on the use of AR in mechanical. [47] introduced the AR-based mobile arc welding learning application (MAWL).

Table 10 Meta-Analysis of Research on the Use of AR in Mechanical

Author	Purpose of AR Use	AR Feature Use
Rusli et al. (2019) [47]	To introduce the Mobile Arc Welding Learning app that enhanced with AR	Mobile Arc Welding Learning (MAWL) app

Table 11 shows the studies on science that involved AR technology. The study by [48] was conducted to determine the student's acceptance of the AR content developed for science education. [49] signified the supplementary classroom technology using AR application. MARPEX was developed by [50] for learning motivation in science experiments.

Table 11 Meta-Analysis of Research on the Use of AR in Science

Author	Purpose of AR Use	AR Feature Use
Karagozlu et al. (2019) [48]	To determine the students' attitudes regarding AR content developed for science education	Mobile AR Science Learning Application
Nasongkhla, Supadaec and Chiasiriphan (2019) [49]	To demonstrate a supplementary classroom technology using an AR application	AR application with multiple AR markers (cards)
Gopalan, Bakar and Zulkifli (2020) [50]	To develop augmented mobile reality for physics application	Mobile Augmented Reality for Physics (MARPEX) application for high school students

Table 12 contains the research in graphic design learning that use AR technology. It aims at the AR application development to learn graphic design skills to face the industrial revolution 4.0 [51].

Table 12 Meta-Analysis of Research on the Use of AR in Graphic Design

Author	Purpose of AR Use	AR Feature Use
Huda et al. (2021) [51]	To develop AR application technology, complementary learning on graphic design	AR media for learning graphic design

Table 13 includes the studies in history that utilized AR. [52] developed a simulation of an object and environment related to its past interpretations. The

research was conducted by [53] to evaluate the effectiveness of AR as media for learning history.

Table 13 Meta-Analysis of Research on the Use of AR in History

Author	Purpose of AR Use	AR Feature Use
Liestøl et al. (2012) [52]	To develop a simulation of an object and environment related to its past interpretations	AR-situation simulations of the objects in the past
Utami et al. (2019) [53]	To evaluate the effectiveness of AR as media for history learning	Mobile AR History Learning Application

4 Results and Discussion Limitations of AR and Suggestions for Future Research

Some limitations remained in some studies. But those boundaries are the green light for more research. For future augmented reality (AR) technology research, many facets must be evaluated, such as studying AR flowchart development for students learning a programming language. Upgrading the code to track the marker and the control structures would focus on its future work [6].

The unfamiliarity with AR technology also was a limitation of the research [33]. So it requires the teachers to own the capability to adjust themselves to the technology used. More local wisdom forms used to represent geometry objects are still available for future research because the study still used limited local wisdom forms [40].

Some schools still had limited AR availability and accessibility [47], which future development might be held to overcome. In addition, future research for the AR empirical review is still open for researchers on the impact of AR application technology [51].

5 Conclusion

This study presents a quick review of the studies conducted in some fields of education. The review shows that the technology of AR has great potential to be applied in education. Many benefits and advantages were obtained from the AR-based application used in various fields of education. It provides creative information, enhances the learning and entertainment application; it improves students' spatial and problem-solving skills and user experience. However, this quick research review shows that the most significant boundary is technical issues. But those issues might be solved by more research that will be held in the future. When the capability of AR advances is completely investigated, the valuable elements of AR can start to be utilized generally in all fields of schooling, and the proficiency of the educating and learning interaction will be improved.

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