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The Promising Roles of Augmented Reality in Educational Setting: A Review of the Literature

Tri Yuliono *
Sebelas Maret University, INDONESIA

Sarwanto
Sebelas Maret University, INDONESIA

Peduk Rintayati
Sebelas Maret University, INDONESIA

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Abstract: This present study imparts a literature review focusing on Augmented Reality (AR) in the field of education. The writers reviewed the published manuscripts by centering on types of manuscripts, research designs, types of participants, and the promising roles of AR in educational setting. A total number of 18 articles were thoroughly analyzed. The results showed a diverse type of manuscripts published in the journal databases including research articles, reviews, technical notes, features, and news. Types of research designs also varied such as Research and Development, Experimental, Content Analysis, Exploratory, Action Research, Descriptive Study, Survey, Mixed Method, and Design-Based Research. Types of participants embraced a diverse range of participants including university students, primary students, secondary students, teachers, and children with special needs. The most prominent role of AR was that it improved students' knowledge and understanding of the materials. Current gaps in AR-related studies in educational setting are recognized, and several recommendations for conducting upcoming studies are proposed.

Keywords: *Augmented reality, educational setting, promising roles, review.*

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Introduction

Technology plays a vital role in transforming education. It allows today's teachers and students to have remarkable teaching and learning activities previously inconceivable. Today's teachers are different from yesterday's teachers in terms of their use of technology in instructional practices. Today's students are inseparable from and addicted to diverse types of technologies in daily lives mainly Information and Communication Technologies (email, the Internet, cell phones, and direct messaging), which can be used to facilitate learning (Prensky, 2001).

Along with the rapid development of technology, types of technologies relevant to education have advanced, from basic technologies such as PowerPoint and word processor, to the advanced technologies such as Learning Management System (LMS), Social Networking Sites (SNS), and Augmented Reality (AR). AR is widely used in educational setting. Virtual objects can be overlaid into the actual world (Akcayir & Akcayir, 2017). AR overlays actual world occurrences with graphic information, images, and spatial sounds (Salmi, Kaasinen, & Kallunki, 2012). According to Martín-Gutiérrez, Fabiani, Benesova, Meneses, & Mora (2015) AR is identified by combining the actual and virtual world; it is real-time; and it is systematized in 3D. AR can be accessed from a user's smartphone, from which the smartphone camera can capture the real images, and the system will add necessary information about the images to the screen (Calle-Busto, Juan, GarcõÂa-GarcõÂa, & Abad, 2017).

Studies provided evidence that AR has promising useful roles in education. Kamarainen, Metcalf, Grotzer, Browne, Mazzuca, Tutwiler, & Dede (2013) suggested that in environmental science education, AR was effective supporting situated learning. It created student-centered learning, useful for peer-teaching, improved teamwork among students, and allowed teachers to mentor. AR allows students to make use of high-tech devices in learning. Martín-Gutiérrez et al. (2015) stated that when using AR applications, teachers do not need to repeat instructions. Students enjoy AR's ability to assist them in learning. Using AR materials also escalated students' motivation and concentration in learning (Yen, Tsai, & Wu, 2013). Akcayir, Akcayir, Pektas¸ & Ocak (2016) disclosed that for physics students, AR was effective enhancing students' laboratory skills and creative positive attitudes to physics laboratories. Evidence suggests that AR has a lot of potential in education, despite several challenges, such as technical problems related to AR operation (Sungkur, Panchoo, & Bhoyroo, 2016), the newly development of AR (Zhu, Hadadgar, Masiello, & Zary, 2014), and students' lack of skills, experiences, and tools required to operate AR (Akcayir et al., 2016).

* **Corresponding Author:**
Tri Yuliono , Sebelas Maret University, Surakarta, Indonesia.
✉ triyuliono@student.uns.ac.id

To date, literature reviews on AR technology in educational setting are still scarce, especially those published in ScienceDirect, Emerald, or ProQuest journal databases. There are only two systematic reviews about AR; one generally highlights the use of AR for education (Akcayir & Akcayir, 2017), and the other specifically concentrates on the use of AR in healthcare (Zhu et al., 2014). AR has just recently become extremely popular in educational setting, indicating the paucity of AR reviews in the published literature (Akcayir & Akcayir, 2017). This study is comparable with a literature review by Akcayir & Akcayir (2017) since this study also explores the potential use of AR in educational setting. A recognized limitation of their study is exploring a single journal database, and reviewing only research articles. This study attempts to address the wider scope by exploring and reviewing manuscripts published in three reputable journal databases – ScienceDirect, Emerald, and ProQuest, which relate to the use of AR in the field of education. The types of manuscript analyzed in this study included research articles, reviews, features, news, and technical notes. Exploring broader databases and diverse types of manuscripts may identify more promising roles of AR in education. In addition to reviewing AR publications related to education, this review also discusses the theory of AR, practical implementation of AR, and examples of AR applications that can be utilized by teachers to make teaching and learning more attractive and effective. This review specifically explores four aspects of educational AR publications:

(1) Types of manuscripts related to AR in educational setting;
(2) Types of research designs used in research studies related to AR in educational setting;
(3) Types of participants selected for research studies related to AR in educational setting;
(4) Promising roles of AR in educational setting.

Methodology

Manuscripts focused on the use of AR in educational setting published in journals indexed in ScienceDirect, Emerald, and ProQuest were chosen due to relatively easy access and download. The exploration of more than one journal database provided more varied information regarding the promising roles of AR in education, in contrast to previous literature reviews that only explored a single journal database such as SSCI (Akcayir & Akcayir, 2017), and Education Resources Information Center (ERIC) (Kucuk, Aydemir, Yildirim, Arpacik, & Goktas, 2013).

To identify relevant publications, the keywords "Augmented Reality," and "Augmented Reality and Education" were searched. The primary focus of the review was to explore the use of AR in education. The search included all types of manuscript that discussed AR in educational setting. The manuscripts were downloaded to be analyzed. Table 1 briefly depicts some inclusion and exclusion for the selection of the manuscripts.

Table 1. The Criteria of Inclusion and Exclusion

Inclusion	Exclusion
AR in education.	AR outside of education.
Clear research design	Unclear research design
Detailed findings and conclusions.	Sketchy findings and conclusions.
Written in English.	Written in languages other than English.
All types of manuscript were acceptable.	

The final search for the manuscripts occurred on January 26, 2018. 18 articles were collected from the three journal databases; 9 from ScienceDirect, 5 from Emerald, and 4 from ProQuest. Not all the manuscripts were free access in spite of being accessed from the university database, notably the very recent publications. A recent relevant manuscript was written in Mandarin and was not utilized (Hsieh & Lin, 2017). Due to those obstacles, this review did not cover all the manuscripts published in the studied databases.

Each manuscript was coded and analyzed with a focus on type of manuscript, research method, participant (learner) type, and promising roles of AR. The type of manuscript identified whether they were research articles, reviews, technical notes, features, or news. Research design identified the kind of study (van Wyk, n.d.). Participant type was split into five categories of participants: primary (elementary) students, secondary students (junior and senior high school students), higher education students, teachers, and children with special needs. The analysis of the promising roles of AR in educational setting identified the findings, discussions, and conclusions of the manuscripts. Each manuscript was coded to discover the promising roles of AR in education using content analysis technique, a research technique used to make inferences by thoroughly and impartially identifying detailed characteristics within text (Stone, Dunphy, Smith & Ogilvie, 1996). It is an organized, replicable technique for condensing numerous words of text into fewer content categories, based on explicit rules of coding (Berelson, 1952, as cited in Akcayir & Akcayir, 2017).

The analysis followed eight steps proposed by Tesch (1990, as cited in Akcayir & Akcayir, 2017): (1) capturing the essence of the entire data; (2) picking one document and considering its essential sense, followed by jotting down concepts; (3) listing all topics, clustering comparable topics, and making columns to differentiate between key,

exceptional, and discarded topics; (4) coding the text; (5) uncovering the most descriptive phrasing for the topics and classifying them into categories; (6) abbreviating each category and alphabetizing the codes; (7) compiling the codes and making initial analysis; and (8) recoding, if needed.

Findings / Results

Types of AR-Related Manuscripts in Educational Setting

This review found out a diverse type of AR-related manuscripts in educational setting, published in ScienceDirect, Emerald, and ProQuest journal databases. Of 18 articles the researchers analyzed, the majority of the manuscripts were research articles (12), while the rest included review (3), technical note (1), feature (1), and news (1). Table 2 shows types of AR-related manuscripts in educational setting.

Table 2. Types of AR-Related Manuscripts in Educational Setting

Type of Manuscript	Number of Manuscript	Percentage	Sample
Research Article	12	66.67%	Calle-Bustos, Juan, GarcõÂa-GarcõÂa, & Abad (2017)
Review	3	16.67%	Akcayir & Akcayir (2017)
Technical Note	1	5.55%	Jeřábek, Rambousek, & Wildová (2014)
Feature	1	5.55%	Craig & McAleer (2011)
News	1	5.55%	Frost, Delaney, & Fitzgerald (2017)

As Table 2 shows, the foremost type of manuscript (66.67%) were research articles. This result indicates that AR is still much being explored in education, either to develop new AR-based teaching media, or to test the usability or the effectiveness of AR in education. The possible explanation for this phenomenon is due to the recent popularity of AR in educational setting (Akcayir & Akcayir, 2017), which attracts teachers and researchers, in collaboration with software developers, to create innovative AR media to support teaching and learning process. This review also discovered that the number of literature review was still scarce. There are only 3 reviews (16.67%) that were published in the databases – one published in ScienceDirect (Akcayir & Akcayir, 2017); another one published in Emerald (Davis & Berland, 2013); and the other published in ProQuest (Zhu et al. (2014). This fact is congruent with Zhu et al. (2014) showing that the majority of the researchers still focused on doing research and development of AR and reporting the newly development of AR. This review also exposed that there was a limited number of technical notes (Jeřábek et al., 2014), features (Craig & McAleer, 2011), and news (Frost et al., 2017). This phenomenon exists since the most preferred type of AR-related manuscript was research articles, with a focus on creating and developing prototypes, as well as conducting considerable testing of AR in educational setting. Due to the paucity of technical notes, the researchers suggest that further technical notes are needed to provide technical details on a specific technology, product, or application (Papalambros, 2009). A considerable number of technical notes help teachers understand more about the nature of AR and its characteristics that harmonize with education.

Types of Research Design Used in AR-Related Research Studies in Educational Setting

This review figured out that there was a wide variety of research designs. They included Research and Development (6), Experimental (3), Content Analysis (3), Exploratory (1), Action Research (1), Descriptive Study (1), Survey (1), Mixed Method (1), and Design-Based Research (1). Table 3 depicts research methods used in AR-related research studies in educational setting.

Table 3. Types of Research Designs

Research Design	Number of Manuscript	Percentage	Sample
Research and Development	6	33.33%	Martín-Gutiérrez et al. (2015)
Experimental	3	16.67%	Shanbari, Blinn, & Issa (2013)
Content Analysis	3	16.67%	Davis and Berland (2013)
Exploratory	1	5.55%	Jeřábek et al. (2014)
Action Research	1	5.55%	Garrett, Jackson, & Wilson (2015)
Descriptive Study	1	5.55%	Craig & McAleer (2011)
Survey	1	5.55%	Salmi et al. (2012)
Mixed Method	1	5.55%	Kamarainen et al. (2013)
Design-Based Research	1	5.55%	Coimbra, Cardoso, & Mateus (2015)

Table 3 shows that the most preferred research design (33.33%) were Research and Development, followed by Experimental (16.67%), and Content Analysis (16.67%). The rest were diverse including Exploratory Design (5.55%), Action Research (5.55%), Descriptive Study (5.55%), Survey (5.55%), Mixed Method (5.55%), and Design-Based Research (5.55%). Based on those reported research designs, all the research studies focused on gaining primary data. This is due to the recent popularity of AR in educational setting (Akcayir & Akcayir, 2017), magnetizing researchers to put a great focus on developing AR applications (Martín-Gutiérrez et al. 2015), investigating the effectiveness of AR in educational setting (Yen et al., 2013), gaining teachers' and students' perception on AR (Kamarainen et al., 2013), and reporting details about AR (Jeřábek et al., 2014). The researchers also found an interesting research design known as Research-Based Design (DBR). The focus of DBR is to design and explore an array of designed innovations (The Design-Based Research Collective, 2002). DBR is a new design in educational-based research (Jeřábek et al., 2014), making this design remained scarce in the published literatures. Content Analysis was also quite scarce in the published literatures since most of the studies put a major interest in reporting newly development of AR (Zhu et al., 2014).

Types of Participant Selected for AR-Related Research Studies in Educational Setting

This review focused on reviewing only research studies that obtained primary data since they included participants. This review figured out that university students were the most preferred type of participant (10), followed by teachers (3), secondary students (1), primary students (1), and children with special needs (1). Table 4 shows types of participants selected for AR-related studies in educational setting.

Table 4. *Types of Participants*

Participant	Number of Manuscript	Percentage	Sample
University students	10	71.43%	Buchau, Rucker, Wossner, & Becker (2009)
Primary students	1	1.74%	Kamarainen et al. (2013)
Secondary students	1	1.74%	Bacca, Baldiris, Fabregata, Kinshuk, & Graf (2015).
Teachers	3	21.43%	Salmi et al. (2012)
Children with special needs	1	1.74%	Calle-Bustos et al. (2017)

Table 4 indicates that university students (71.43%) were selected as the participants of AR-related research studies. This is due to the fact that university students are tech-savvy. University students used technology in daily lives including learning activity (Kennedy, Judd, Churchward, Gray, & Krause, 2008). This result was in contrast to Akcayir & Akcayir (2017), figuring out that elementary, junior high school, and senior high school students were the most preferred types of participants. They argued that according to Piaget's stages of cognitive development, students of those levels of education were at the concrete operational stage, in which they must use their sight, hearing, or senses to know (Martin & Loomis, 2013, as cited in Akcayir & Akcayir, 2017). The strong visualization of AR is vital for students to learn in this stage (Akcayir & Akcayir, 2017).

Researchers also selected teachers (21.34%) as the participants of their study. Teachers' feedback and opinions were explored for further development of AR applications. Kamarainen et al. (2013) figured out that the teachers' opinions about AR were positive. They argued that AR creates student-centered learning, useful for peer-teaching, improves teamwork among students, and allows teachers to mentor. Salmi et al. (2012) also reported that teachers see AR as an innovative tool to shift teaching and learning practices – from instruction to self-instruction, and from teacher-centered to student-centered learning.

Children with special needs were selected as the participants, too. Calle-Bustos et al. (2017) explained the process of developing and experimenting an AR-based game for children suffering from diabetes. AR game allows children with diabetes to acquire important knowledge about carbohydrate. The AR game can be a helpful healing education tool for diabetic children. This finding indicates that there is still a clear void in AR research studies focusing on special education. It is suggested that more research studies on developing AR application for special education can be conducted in the near future.

Promising Roles of AR Identified in AR-Related Research Studies in Educational Setting

This review classified the promising roles of AR in educational setting into three noticeable categories; learners' outcomes, pedagogical contributions, and interaction (Akcayir & Akcayir, 2017). Table 5 depicts the promising roles of AR in educational setting.

Table 5. *The Promising Roles of AR in Educational Setting*

Category	Sub-category	Number of Manuscript	Sample
Learner Outcomes	Achievement	1	Akcayir & Akcayir, (2017)
	Motivation	3	Bacca et al. (2015)
	Positive attitude	2	Akcayir et al. (2016)
	Skills	4	Garret et al. (2015)
	Knowledge and understanding	7	Davis & Berland (2013)
	Learning effectiveness and satisfaction	2	Yen et al. (2013)
Pedagogical Contributions	Enjoyment	2	Zhu et al. (2012)
	Engagement	2	Kamarainen et al. (2013)
	Guidance	1	Martín-Gutiérrez et al. (2015)
	Student-centered learning	2	Salmi et al. (2012)
	Material delivery	2	Buchau et al. (2009)
	Context-related learning	2	Craig & McAleer (2011)
Interactions	Student-student	1	Akcayir & Akcayir, (2017)
	Student-teacher	1	Akcayir & Akcayir, (2017)
	Student-material	2	Frost et al. (2017)

Learner Outcomes

Table 5 shows that the most noticeable role of AR dealing with the learner outcomes was enhancing students' knowledge and understanding in different subjects. In Mathematics, AR facilitated students to comprehend the concepts of Mathematics since it provided more interesting visualization and interface (Coimbra et al., 2015). In computer science, AR application was beneficial to understand complicated concepts of computer (Sungkur et al., 2016). In teaching science for children with special needs, AR allowed children with special needs to acquire new knowledge about carbohydrate of different foods (Calle-Bustos et al, 2017).

AR was also helpful to improve students' skills. Akcayir et al. (2016) stated that AR technology was beneficial to improve the students' laboratory skills. In nursing education, AR developed students' clinical reasoning skills. AR also provided nursing students with the ability to access reliable resources (Garret et al., 2015). Zhu et al. (2012) found that AR helped the healthcare learner to acquire skills related to the treatment to ill people.

AR also enhanced students' motivation, learning effectiveness and satisfaction, and achievement. In astronomy, AR materials escalated students' motivation and concentration in understanding moon phases (Yen et al., 2013). In vocational education, AR increased students' learning satisfaction in repairing paint on a car (Bacca et al., 2015). AR was found advantageous to enhance students' learning achievement in different majors (Akcayir & Akcayir, 2017).

Pedagogical Contributions

In pedagogy, AR was able to enhance learning enjoyment. AR was found beneficial to boost enjoyment (Akcayir & Akcayir, 2017) and offer more conveniences during learning process (Zhu et al., 2012). AR enabled teachers to engage their students in learning process. Akcayir & Akcayir (2017) revealed that AR raised the level of engagement. Kamarainen et al. (2013) also provided evidence that AR was extremely valuable to engage, structure, and enhance the probeware-based activities of the field trip.

AR also facilitated student-centered learning. Salmi et al. (2012) revealed that AR shifted learning process from teacher-centered to student-centered learning. Garret et al. (2015) found out that AR supported self-directed learning by providing students with the ability to access resources independently. AR was beneficial to facilitate material delivery, too. In delivering the materials, AR was a vivid tool to visualize electromagnetic fields (Buchau et al., 2009). In healthcare, AR provided students with authentic simulated experiences, enabling them to increase subjective attractiveness (Zhu et al., 2012).

AR also assisted teachers in conducting context-related learning. According to Salmi et al. (2012) AR facilitated teaching and learning process by focusing on context-related knowledge. Craig & McAleer (2009) found out that AR also had the powerful ability to put data in context to allow students to go into a space and learn more. AR also helped teachers in guiding students during learning process. Martín-Gutiérrez et al. (2012) exposed that AR could allow teachers to provide more assistance at the laboratory training.

Interactions

AR improved interaction in teaching and learning process. In a review by Akcayir & Akcayir (2017), it was found that AR promoted interaction among student-student, student-material, and student-teacher. According to Frost et al. (2017) AR in nursing classroom enabled students to interact with a holographic patient and explore complex scenarios. These findings suggest that AR clearly made teaching and learning process more constructivist.

Discussion and Conclusion

This review explored AR-related manuscripts in educational setting published in ScienceDirect, Emerald, and ProQuest journal databases. It was revealed that research article was the preferred type of manuscript, which reported the result of AR development and testing. The most common research design was Research and Development. This is due to the recent popularity of AR in education. University students were the favorite type of participant due to being tech-savvy and easily accessible to university researchers. This review identified that AR enhances learners' outcomes, pedagogical processes, and interactions either among student-student, teacher-student, or student-material. In addition, AR can support learning on the physical, cognitive, and sociocultural dimensions. Quintero, Salinas, Gonzalez-Mendivil, & Ramirez (2015) say,

> *"In the physical dimension, AR encourages the creation of embodied representations for educational concepts because physical manipulation affords natural interactions. The cognitive dimension scaffolds the progression of learning because spatiotemporal alignment of information through AR experiences can aid students' symbolic understanding of abstract concepts. In the sociocultural dimension, AR facilitates meaningful experiences fostering collaborative learning around virtual content and in non-traditional environments."*

The potentials of AR in education are attributable to its remarkable characteristics. AR is a combination of technologies that enable real-time mixing of computer-generated content with live video display (Mekni & Lemieux, n.d.). The goal of AR is to enhance, in place of replace, reality. An AR system supports the simultaneous perception of the real environment and the virtual overlay (Gamper, 2014). Several types of devices supporting AR including smartphones, tablets, computers, eyeglasses, and head-mounted displays (Perdikakis, Araya, & Kiritsis, 2015) make AR become a new trend in education, thanks to the availability of the devices in modern days as well as teachers' and students' high technology literacy.

AR books is one of the most practical applications of AR in education. These are usual books containing additional digital content that can be seen through mobile phones, tablets, or laptops enhanced with cameras. Through the use of AR in textbook pages, textbooks can become dynamic sources of information (Lytridis, Tsinakos, & Kazanidis, 2018). To assist teachers in creating AR content in textbooks, Lytridis et al. (2018) developed the ARTutor platform to make teachers easily create AR content for existing textbooks. It consisted of two parts: (a) the authoring tool, which is a web-based application used to upload the learning material and the assorted learning objects; and (b) the mobile application, which downloads and displays the learning objects and also allows interaction between the learner and the learning material (Lytridis et al., 2018).

This review has a limitation – it was unable to analyze all the manuscripts published in the studied journal databases since some manuscripts are not written in English. Future researchers who are eager to comprehend manuscripts written in languages other than English may wish to explore those manuscripts to provide more information about AR in educational setting. Since this review revealed that there are only a small number of research studies projected to use AR for teaching students with special needs, future researchers may wish to carry out studies by developing new AR applications for students with special needs as well as conducting considerable number of testing. Future researchers may wish to conduct further reviews on AR-related manuscripts in educational setting by focusing on a specific major, and by exploring different journal databases.

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