Meta-Review of Augmented Reality in Education

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***Abstract*—Augmented reality has been developed decades ago, but its implementation can be enjoyed by the wider community only in the last few years, along with the increasing number of affordable smartphones which are owned by almost everyone. Although previous studies have shown that augmented reality has the potential to improve learning in students, the benefits of education by utilizing augmented reality and the context in which this technology is more effective than other educational media is still not clear. This paper tries to discuss the topic of augmented reality in the world of education by doing a meta-review of some reviews that have been done before. This paper tries to look at the trend of augmented reality research in education and also to help researchers decide which topics to explore.**

Keywords—education; learning; augmented reality

I. INTRODUCTION

Sutherland developed the first Augmented Reality (AR) interface in the 1960's and it was first introduced as a training tool for airline and Air Force pilots in the 1990s. Unlike Virtual Reality (VR) which allows users to be completely immersed in virtual environments, AR enables users to interrelate with virtual objects in a real environment seamlessly. The AR technology provides an object layer generated by the computer to the real physical object in real time. AR technology enables information that once seemed impossible. The virtual objects then show to concur in the same space as objects in the real world [1]. Commonly accepted definition of AR as a technology which has three principal features: the combination of the virtual world and the real world, interaction in real-time, and 3D registration [2]. Learning experiences are increasingly meaningful with the presence of AR technology capable of displaying digital objects or information overlaying physical objects or environments [3], [4].

AR technology has been elaborated in the enhancement and innovation of a lot of domains, especially in education. Some of the most popular fields that use AR in education are Science [5], Library [6], Physics [7], Ecology [8], Astronomy [9], and much more. There are a lot of potentials for implementing AR technologies in different domains, such as entertainment, game, industry, medical, construction, tourism, cultural heritage, and more.

Even though the AR technologies have been around for several years, it is the recent production of mobile devices that has made affordable AR application available to the multitude [10]. The existing generation of smartphones with cameras, high definition display screens, image processing ability, position sensor, orientation sensor, wireless communications, computational abilities and dedicated 3D graphic chips allow mobile devices to perform the AR experiences [9]. Smartphone is a suitable platform for building AR applications and services, with the combination of such technologies incorporated in one device can make the smartphone capable of doing much more than anticipated. The past few years have seen a growing acceptance in the research interest for AR since mobile devices have offered more economical and much easier approach to AR for users than before [11].

Therefore, the paradigm moves away from the lecture-centered style that has been experienced recently, combined with the maturity of AR technologies, have encouraged instructors to exploit the power of AR in educational environments to make interactive and useful learning [5], [12]. AR is a new technology with promising instructional importance and huge proficiencies that enables new methods for education [14]. When applied in educational settings, studies have shown that AR technology offers many advantages [13]. AR provides the facility to users to be able to observe events that cannot be easily seen directly by displaying virtual elements along with real-world elements. [10]. The result from Sumadio and Rambli showed that AR applications for education are well acknowledged, with a positive feedback, even from contributors that had no skill of using the AR application before [15]. AR technology positive effects on learning were recognized in previous studies in the development of skills and knowledge, enhancement of learning experiences, and improvement of collaborative learning [10]. AR implementation in education could be used to improve the learning efficiency and offer a more enjoyable experience for students.

AR applications are starting to appear on mobile platforms lately. Various applications made for smartphones also offer more convenience and innovative ideas [16], [17]. However, most of the existing AR applications are still limited to demonstrate the capabilities of AR technology. There is still enough homework to be considered by researchers to make AR technology more useful and effective. A real environment with images superimposed over the real environment not only allows us to learn about the environment but also helps us with the tools to interpret it.

Some publications have demonstrated the advantages, limitation, challenges of using AR technology in education, but

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as mobile AR is lately developed, it is essential to get a summary of real effect use and progress in learning. How AR is used to create more student-based learning scenarios. The purpose of this meta-review of AR in education is to present the current trend of AR technology from previous studies review. The study findings aim to deliver resources that can be used by the community of AR research, especially mobile AR, to know the potential of AR technology research in education.

II. METHOD

The steps taken in this review are as follows: planning, conduct the review, and reporting the review. The Scopus database was the literature source for this review, one of the highly recognized databases indexing journals. The keywords "augmented reality" and "review" are used to search for the paper's title, since mostly the review paper will use keyword "review" in their title. After removing duplicates, restricting to English language and in the subject area of computer science and engineering, a total of 44 studies were identified, consisting of 22 conferences, 16 journals and 6 books sections. By digesting the abstracts and also their keywords, 8 relevant review studies were chosen to be included, consisting of 3 conferences, 3 journals and 2 books sections. The collected papers were concisely studied and only those that were appropriate to our scope of the study were selected for more thorough reading. The discussion about findings acquired from the literature is described in detail in the subsequent section.

III. RESULT AND DISCUSSION

There is a fairly significant increase of review paper in the field of AR from year to year, it shows that there is also a rise in the amount of AR technology research papers. The AR review paper began to appear in 2006 in the Scopus database and there is only one article of AR review paper every year until 2012, after that there is a significant increase, especially in the year 2017 which have 12 AR review papers. The keyword of mobile AR has begun to appear since the AR paper review was published in 2014 [18], this is because triggered by the presence of smartphones that are capable to implement AR technology and also because smartphones become more affordable. The presence of mobile AR applications can provide benefits for learning by providing information that fits the needs, providing faster information access, increasing motivation in learning, making learning easier and more efficient, and helping students understand the concept better.

Various topics of AR review papers in the field have been done are about education, games, industry, medical, construction, tourism, cultural heritage, and so on. The widest topic of AR review papers is education, including games in educational contexts. There are 8 AR review papers specifically in education which are published in 2014 (2 papers), 2015 (1 paper), and 2017 (5 papers). In this meta-review paper will focus on that 8 AR review papers in education and use some of the data contained in other AR review papers as supporting data. Comparative review paper can be seen in Table I, while detail explanation of each is in the next paragraph.

TABLE I. REVIEW PAPERS COMPARISON

Author (s)	Literature Database	Duration	Topic	Number	Method
[19]	Social Sciences Citation Index	2011 - 2016	Augmented Reality in education	55	Classifying
[20]	Google Scholar	2006 - 2016	Augmented Reality Games for Learning	26	Systematic Literature Review
[11]	Social Sciences Citation Index	- 2016	Advantages and Challenges	68	Systematic Literature Review
[21]	Google Scholar	2003 - 2013	Application or framework	32	Systematic Review
[22]	Google Scholar	2010 - 2016	Acceptance of Augmented Reality in Education	49	Discussions with two AR experts
[23]	IEEE Xplore, Science Direct, Springer, and Elsevier	2013 - 2014	Usability Evaluation	10	Meta-analysis, Qualitative analysis
[24]	Google Scholar	2012 - 2017	Augmented Reality Game-Based Learning	17	Systematic Review
[14]	IEEE Xplore, Google Scholar	2000 - 2013	Collaborative Augmented Reality	10	Classifying

Systematic Literature Review (SLR) is the most common method for the process of reviewing literature since this method is more precise and can be accounted for reviewing. The most common factors used from those 8 paper reviews are interaction, learning outcomes, subject domains, and learner groups. Background, platform, type of AR, effectiveness, advantages, limitation, environment, method, country, and year are the other factors which used in several papers. Interaction and pedagogical contributions are the two most highlighted topics of the AR review papers [11], [20]–[22], [25]. The most applied is Science in the educational field [19], [21], [24]. Marker-based AR is the utmost frequently used type of AR image-based tracking, marker-based tracking process is more stable and effective compared to the marker-less tracking techniques presently available, and followed by location-based AR because of the availability of various sensors on mobile devices such as GPS (Global Positioning System), accelerometers, gyroscopes, and so on [6], [21]. Mixed evaluation methods are the most common evaluation method which is combining the qualitative research method and the quantitative research method [19], [21], [24].

Chen et al. conducted an empirical study published by the Social Sciences Citation Index from 2011 to 2016 on AR in an educational setting. It was found that the number of studies on AR in the field of education has increased quite rapidly since 2013 and is largely written by authors from Taiwan, Spain, and the United States. It was also found that more empirical studies were conducted on science, social sciences and engineering, with quantitative research methods employed more frequently than other methods in AR education research in 2011 until 2016 [19]. From this review paper it is advisable to conduct further reviews taking into account longer research times, larger sample sizes and wider material. Additional interaction aspects, such as games and role playing, can be used to enhance the user's immediate experience and interaction.

Li et al. in the literature review got some interesting findings, such as most of the AR learning games currently played outdoors or in the classroom; the subject and learning content used in previous studies is limited; an important gap is found in the retention effect; the effect of social interaction is found by playing learning games of AR; and discovered many game elements and AR features used in AR game learning design. From this literature review also found are five recommendations for AR game learning design to achieve maximum positive effect, which involves learners in the design process, has clear learning objectives, design to encourage social interaction, identify the effects of AR features, and learn the mechanics of the game to choose the right element in the design. In short, despite the positive effects of the use of AR learning games have been widely known in the last decade, there is still much research to do in the future [20].

Akçayır and Akçayır show that some contradictory conclusions can be seen from several existing literature, for example, despite the fact some studies report that AR reduces cognitive load, others report that it causes cognitive burden. Some things to consider are the usefulness of the AR application, interface design, technical issues of the use of AR applications, training on the use of AR applications in teachers. In addition, it also needs to be considered problems of implementation in the classroom, be it pedagogical problems or technical problems in the classroom [11].

Target group, field of education, type of AR, reported purposes, advantages, limitations, affordances, effectiveness of AR in educational settings, adaptation processes and user modeling in AR, and the addressing of individual special needs with AR applications are factors analyzed by Bacca et al. from selected papers [21]. The research sample, research method, and time dimension of the study were analyzed for evaluation methods. This research contributes to existing knowledge in AR in educational settings by providing the current state of research on this topic. The important technological aspects to improve the learning process have been identified and need further research.

Dalim et al. made a review of several factors that may affect AR acceptance in education, categorized as curriculum, interaction stability, self-study ability, parental involvement, student background, platform, and social factors. This study identifies that most users expect AR technology to be truly implemented in a learning environment, expected to improve understanding of learning content that is difficult to learn without clear visualization, such as learning the concept of spatial relationships. There are six key factors that can impact acceptance between learners and AR educational tools, i.e. curriculum, the stability of the interaction, self-learning capability, parent's participation, student's background, and platform [22].

Satpute et al. studied educational prototypes to see the effects and benefits that can be achieved using AR. This review is using the Intrinsic Motivation Inventory (IMI) survey questionnaires. It is stated that AR technology can increase engagement and immersion, while web 2.0 supports cooperation and social relations, but until now these two technologies are still learned separately for the advantages in the learning domain. The combination of AR and Web 2.0 technologies will allow for better results in educational achievement. Both of these technologies must be examined for experimental assessment of their mutual use in educational settings [23]. In this literature review has not seen literature that actually connects AR and Web 2.0.

Fotaris et al. contribute to the design of instructional education by providing proof of potential AR game-based applications to support teaching and learning in various areas of basic education. This review shows us that effectiveness of AR use in educational setting gives student better learning performance, motivation, engagement and also perceived enjoyment. But there is also some limitation of AR use in the educational setting, especially in the domain of the teacher, most of the AR applications are still not easy for teachers to modify or add the content. This literature results provide perceptions for researchers and offer educators with effective advice and guidance on how to integrate these learning models into their teaching practices [24].

To incorporate collaborative AR into learning there are challenges and benefits. AR can provide the benefits of an effective and engaging learning experience for learners by utilizing the right learning strategies. The integration of AR technology and collaboration in learning demonstrates increased motivation, learning performance, engagement and collaboration among learners. The most frequently reported lack of AR implementation in learning is cognitive overload. In this paper is also questionable AR technology designed in accordance with learners. Challenges to consider are hardware and software failure issues [14].

From 8 AR review papers in education, there are different points of view in reviewing. Currently, no one has done a more thorough review about AR in education with research sample that can represent the real environment of education. Mobile AR has potential to increase the learning experiences and outcomes if integrated effectively into the suitable learning environment. Serious games also become an interesting alternative for learning, especially if it is also implemented with AR. Serious games also have an impact on social aspects and collaborative learning. Personalization on learning is also one of the aspects that need to be considered for effective and efficient learning, personalization is also expected to be able to avoid the occurrence of cognitive overload that occurs in the learner. AR in education mainly focuses on explaining with providing additional information about objects or topics of interest, researchers need to create AR in education that can respond or have alternative info which can give student more challenge to study more.

IV. Conclusion

Analysis of several AR review papers in the field of education has provided positive and negative information, as well as potential underlying factors. This meta review tries to show the trend of AR technology in my education. Although AR shows so much potential, there is still enough homework to be done by researchers to develop AR applications in education. From several review papers it was found that in AR development in education the main thing to consider is the

pedagogical aspect and the interaction aspect between user and AR application. In addition, it is necessary to consider how to develop AR applications that can provide a learning experience that makes learners more comfortable and also easier for teachers to add or update content.

Some future work that may be done is as follows: identify other factors that may be useful in the learning experience with AR, support for teachers in delivering content and learning outcomes, cognitive, motor and spatial skills detection can affect students' ability, determine what content can be used and not used with AR and personalization or recommendation systems also need to be used in the application of technology so that content is presented to the user as expected.

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