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Factors Influencing the Acceptance of Augmented Reality in Education: A Review of the Literature

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Abstract: This paper presents a review of user expectation towards Augmented Reality (AR) and the acceptance of AR for technology-enhanced teaching and learning. Augmented Reality is a technology that superimposes a computer-generated image over a user's view of the real world, thus providing a composite view. This technology has been used in many fields such as marketing, military, entertainment and many other sectors. Studies have found that AR technology can enhance teaching and learning, however more research still needs to be conducted about the acceptance of AR as a learning tool and what users in education expect from the technology. An understanding of the user expectation is one of the key foundations towards establishing better-designed AR systems and applications that will result in more acceptance of this technology. To help with this, this paper reviews previous research on user expectations of AR in education and its acceptance.

Keywords: Augmented Reality, Technology Acceptance, User Expectation, Education

Introduction

Having been studied for over four decades, Augmented Reality technology has been involved in the innovation and enhancement of many sectors. AR involves overlaying virtual objects on the real environment (Kolivand *et al*., 2015a; 2015b) and so is a complement of Virtual Reality (VR), whereas in VR the whole environment is computer generated. Together, AR and VR are part of Paul Milgram's Reality – Virtuality Continuum (Milgram *et al*., 1994) as shown in Fig. 1.

Mixed Reality Continuum is a scale between completely real environments with no computer enhancements, towards virtual environments that are totally generated by the computer. In between these two extremes are Augmented Reality (AR) and Augmented Virtuality (AV), which is a combination of real and virtual worlds. The difference between these two components is that AR uses virtual information to enhance the real world, while AV brings elements of the real world into immersive virtual environments. As a powerful technology that combines virtual content and the real world, AR enables many tasks to be completed that once seemed impossible. For example, a virtual arrow displayed on a live street viewed through a smartphone enables a pedestrian to reach point B from point A, easier. Hunting and shooting virtual game character such as the famous Pokémon GO in real world increases level of satisfaction and engagement in gaming. These are just a few examples from many more AR applications which existed today. AR also improves a lot of empty gaps in certain activities which requires a high level of immersion experience which once could not be achieved. For example, Microsoft Hololens (2017) enables its wearers to feel fully immersed in a virtual environment merged with physical environment, on their own view field.

The benefits of this technology flows across many fields such as marketing, military, entertainment and other sectors. In line with the demand for a more comprehensive ways of delivering teaching and learning activities, the educational sector also has been extensively employing AR technology. Research has found that technology can enrich education practices (Sarkar, 2012; Sheng *et al*., 2010; Talebian *et al*., 2014).

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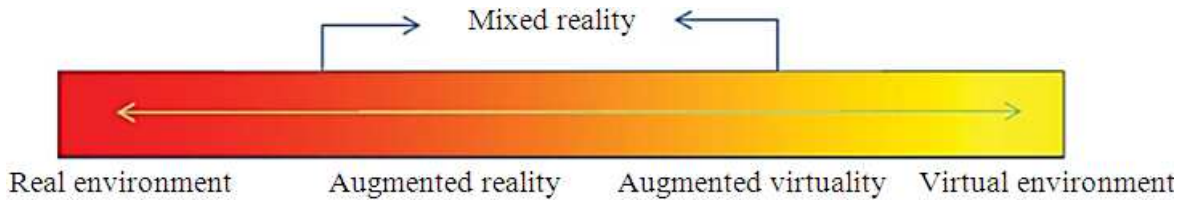

Fig. 1: Reality – virtuality continuum, figure adapted from (Kolivand *et al*., 2015a)

AR is a new technology with huge capabilities and promising instructional significance that enables new approaches for education (Phon *et al*., 2014). The result from (Sumadio and Rambli, 2010) showed that AR applications for education are well accepted, with a very positive feedback, even from participants that had no experience of using the technology before. Recently, there are increasing numbers of publications investigating many aspects of AR implementations in education, ranges from the technical to pedagogical and user experience aspects. However, in contrast to another technology-based approaches, there has been little research on the acceptance of AR as a learning method. For this technology, it is crucial to examine what users expect to ensure total acceptance in education.

Dillon (2001) defines user acceptance as the demonstrable willingness within a user group to employ IT for the tasks it is designed to support. Although AR has demonstrated significant potential, educators still need to understand how to design AR to make the learning experiences affordable and of value (Bronack, 2011). Consequently, in this study we review previous research on user expectations of AR in education and its acceptance. Our work is based on considering the following questions:

- What are the common concerns expected by the user when applying Augmented Reality applications or technology in the learning process?
- What factors that may influence the acceptance between learners and AR educational tools?

The study covers research on AR implementation in preschool to higher education level, as well as its execution with able-bodied and learners with physical disabilities. Hopefully, the review will help researchers in the field to develop better designs of AR systems for education, which will to the technology acceptance level in the future.

Methods

To get a thorough review of the topic for this study, we accumulated articles published between 2010 and 2016 from Google Scholar that were found by searching with the keywords; Augmented Reality, user acceptance and education. A total of 250 articles which are relevant to our topic were selected to be evaluated by inclusion criteria. The inclusion criteria includes the study must report experimental results (those that did user study).

Table 1: The backgrounds of the AR experts

Expert	Expertise	Background
A	Virtual environment, computer graphics, visualization	Computer science
B	Computer graphics, augmented reality	Applied mathematics and computer

We eliminated articles which applied Augmented Reality into fields other than education which brings the final number to 49 articles.

The accumulated articles and conference papers were briefly reviewed and only those that were relevant to our scope of the study were selected for a more detailed reading. A total of 49 articles which meets the criteria of our study were selected for final reading. A series of discussions with two AR experts were carried out to extract significant information that applied to the objective of our study (Table 1 for details of the experts). We first extracted the most frequent topic that was highlighted in each article and explored if there were any common issues or subject raised in other articles. Our assumption is that a topic is significant and should be considered in the design of AR applications if there are more works referencing it. Our discussion about the findings obtained from the literature is described in detail in the following section.

Discussion

Augmented Reality in Education

As teaching and learning is a crucial process, many computer-based technologies have been proposed to provide new experiences in these activities. Over the past two decades, many researchers and educators have worked on ways to bring AR and VR into educational setting. For example, according to Noh *et al*. (2009) students and researchers may use virtual heritage as a medium in their studies historical events. Studies have shown that Augmented Reality can enrich teaching and learning practice in educational sector. For example, Lindgren and Moshell (2011) assess the learning experience gained between a group of children who learnt astronomy through PC-based application and a group of student who learnt the same subject using

projector-based Mixed Reality (MR) application. The analysis of the study shows a significant difference in the understanding of the subject's concept by both groups. While the PC-group focused more on the surface details of the planets, the MR group concern more on direction or movements of the planet. This gives an insight on the cognitive differences of the students, given different learning experiences. Similarly, augmented learning is an on-demand learning technique where the learning environment adapts to the needs and inputs of learners (Klopfer, 2008). Another work implemented AR to teach natural sciences to pre-schoolers (Cascales *et al*., 2013b), where the observation result shows a very positive impact on group of students who used the AR materials over traditional material. By using AR, the students learn more and they achieve more learning goals than the non-AR method. Furthermore, it was also reported that the teachers who participated in the study can easily implemented the AR technology despite having no experience with the technology before.

From an educational perspective, Augmented Reality fits into constructivist learning concepts (Martín-Gutiérrez *et al*., 2010), where learners have the flexibility to control and manipulate virtual objects that existed in the augmented learning environment to obtain understanding and achieve a greater experience for a long-lasting learning experience. Martín-Gutiérrez *et al*. (2010) have shown that AR follows the major beliefs of constructivist learning theory. The only difference is that AR does not trigger consequences for the user actions as would be the case in a behaviourist – learning environment. Johnson *et al*. (2010) in their work stated that "AR has a strong potential to provide both powerful contextual, on-site learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world."

Nowadays, the use of AR is becoming more common in the education sector. Augmented Reality display technologies have evolved from using large expensive head-mounted devices to more widely available smart phones and small handheld devices. This has enabled AR to be used more freely for many purposes, especially in eLearning. For example, by just downloading certain applications, AR-based eLearning can run on standard mobile devices such as - smartphones, PC tablets and other handheld computing devices, therefore transforming the teaching and learning process into a more fun, entertaining and pleasing experience (Wang, 2012).

Advanced research and wide-ranging use of AR technology by researchers and educators have also contributed to it becoming increasingly accessible in the education sector. In higher education, for instance, Liarokapis *et al*. (2004) developed an AR application that allowed students to examine an augmented 3D model of a camshaft arrangement in conjunction with a set of real engine components. Without AR, it is a time-consuming process for the student to grab the concept and the theory. This showed that complex mechanisms and challenging theories can be well understood by students with the help of AR technology. El-Hakim *et al*. (2004; Noh *et al*., 2009) have shown that virtual reconstruction of heritage can serve as an educational resource for history and culture.

There are also many types of research that is carried out to explore different designs for AR educational applications. The aim of this kind of research is to explore the best possible ways of augmenting the teaching and learning process to provide a more intuitive method of learning. Budhiraja *et al*. (2010) presents an AR design that considers the usability of interactive media and their applications in developing a highly interactive and structured classroom presentation system. They combined AR with other interactive media because they believed that AR systems are effective in teaching as they offered a unique learning experience. The system received positive feedback from test users as it provides a good interactivity experience.

The implementation of AR in education has been improving over the previous two decades. The advancement of technologies which makes it possible to develop learning tools, the benefits AR provides for education sector, its potential for the continuous expansion of the learning experience, as well as the extensive research on its area, are all the factors which drives the employment of AR in education. However, there are many other factors that may influence the acceptance of AR in education. In order to make AR technology to be accepted entirely, we need to give attention to every detail of the most discussed aspect of AR implementation. In the remainder of this paper we discuss some of these factors in more detail.

Factors influencing the Acceptance of Augmented Reality in Education: Outcomes from Past Research

Even though the use of AR in education is increasing, especially with the emergence of mobile computing devices, its acceptance level is still at the infancy stage. To apply a new technology into a certain domain, assessing its user acceptance is crucial to improve its quality for future use. In AR technology, a lot of study and research grounded on user needs and user expectations are required to reduce potential usability problems (Nilsson and Johansson, 2007). Numerous studies have been conducted by researchers who interested in the future of AR in education from which we extracted key factors which may influence AR acceptance.

From this research we have identified the following:

1. Curriculum: The technical aspect of the technology must be balanced with the pedagogical aspects of the educational contents

2. Stability of the interaction: The reliability of AR application to provide continuous engagement during interaction
3. Self-learning capability: The interaction in AR can be done by oneself without the needs for teacher or parental guidance
4. Parent's involvement: The participation of the parents at any point or form of the technology usage
5. Student's background: The context or conditions of the students
6. Platform: Tools or device used to deploy the AR application

In the rest of this section we discuss each of these factors in more detail. Table 2 shows the list influential factors.

Curriculum and Pedagogy Design

An important aspect that influences the usage of any technology is the context of use. Lee et al. (2009), believed that one rational for employing AR in education is because of its novel ability to engage students. To create engagement between user and technologies, we have to pay attention to not only the technology but also the context of which it will be applied. For this reason, to employ AR in education, it is necessary to identify the user expectations that will serve as an engagement between the students and this technology to determine its acceptance in the education sector. While AR can provide engagement in teaching and learning process, it also raises many pedagogical issues. Among criticism of AR is that the focus of the learning process is highly determined by the AR tools' strength and weaknesses instead of pedagogy (Denk *et al*., 2007).

A meta-review and cross-media analysis (Radu, 2014) of Augmented Reality in education suggests that to facilitate the adoption of this technology into a school classroom, first the AR experiences need to be designed with curriculum and pedagogy in mind. It is important to identify which subject or concepts that is best taught using AR technology compared to other technologies, for example, learning of abstract concept such English preposition of place for non-native speaker (Hsieh *et al*., 2014). The learning objectives and goals that an educator is trying to achieve should be considered before concerning how best to accomplish them through the AR applications (Denk *et al*., 2007).

Table 2: Factors influencing user acceptance of AR in education-outcome from past research

Author	Research	Influential factor
Radu (2014)	Augmented reality in education: A meta-review and cross-media analysis	**Curriculum**
Hsieh *et al*. (2014)	Learning word using augmented reality	
Laine *et al*. (2016)	Science spots AR: a platform for science learning games with augmented reality	
Wójcik (2016)	Potential use of augmented reality in LIS education	
Brill and Park (2008)	Facilitating engaged learning in the interaction age taking a pedagogically-disciplined approach to innovation with emergent technologies	**Platform**
Nincarean *et al*. (2013)	Mobile Augmented Reality: The Potential for Education	
Sumadio and Rambli (2010)	Preliminary evaluation on user acceptance of the augmented reality use for education	**Stability in interaction**
Cheng and Tsai (2013)	Affordances of augmented reality in science learning: Suggestions for future research	
Dunleavy *et al*. (2009)	Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning	
Hao-Chiang *et al*. (2011)	Establishment and usability evaluation of an interactive AR learning system on the conservation of fish	
Winkler *et al*. (2002a)	Mixed reality environments as collaborative and constructive learning spaces for elementary school children	**Self-learning capability**
Chen *et al*. (2007)	Augmented interface for children Chinese learning	
Squire and Klopfer (2007)	Augmented reality simulations on handheld computers	
Clemens *et al*. (2016)	Implementing augmented reality in K-12 education – analyzing current trends	
Yuen *et al*. (2011)	Study on parent's acceptance of the augmented reality use for preschool education	**Parent's involvement**
Vekiri (2010)	Human factors and qualitative pedagogical evaluation of a mobile augmented reality system for science education used by learners with physical disabilities	**Student's background**
Arvanitis *et al*. (2009)	Recent advances in augmented reality	**Platform**
Cook (2010)	A survey of mobile and wireless technologies for augmented reality systems	

An enduring challenge for educational scholars and experts are to put on new mechanisms as a means toward improved learning rather than having no clear purpose; that is, to take a pedagogically-disciplined approach to teaching and learning innovation (Brill and Park, 2008; Nincarean *et al*., 2013).

Stability in Interaction

Another point to be considered to ensure AR acceptance is that the technology-enhanced education should be able to satisfy the expectation of user regarding to consistency. The consideration is mainly because of negative interaction experience that might deteriorate the student's acceptance in engagement and result in rejection of the technology. Cheng and Tsai (2013) proposed future research of AR in education to draw the attention to stability and interaction of AR system. Earlier, (Dunleavy *et al*., 2009; Hao-Chiang *et al*., 2011) mentioned that the current AR systems are likely to experience operational problems such as system failures, tracking errors, or hardware challenges, which might affect user acceptance.

Yuen *et al*. (2011) reported that an AR video game named Alien Contact was developed to increase students learning and engagement in several K-12 classes. However, due to some problem in hardware and software management, the game had a few shortcomings that caused teachers troubles in managing student groups while trying to solve these problems as well as teach the lesson plan. In Chang's study (Liaw, 2008), the authors used AR technology to develop an AR learning system for learning English vocabulary. The result of this study shows that the system quality is a critical factor affecting perceived satisfaction, perceived usefulness and AR learning effectiveness.

Some studies have shown that school classroom is a noisy environment (Shield and Dockrell, 2003; Södersten *et al*., 2002; Sala *et al*., 2015) so AR developers who plans to develop an AR application with audio or speech input must ensure that their system is adaptable and is not easily interrupted by noise. This can be done by having several modalities to give more interaction choices that are adaptive to the environment. Recently, researchers have discovered the potential of combining multiple inputs into AR system, which termed as multimodal augmented reality, to increase its effectiveness (Billinghurst, 2013; Arroio and de Souza, 2012). In multimodal AR system, the weaker input will be enriched by the strength of another input of the same system. This will ensure a more effective and stable system.

Self-Learning Capability

Many studies (Winkler *et al*., 2002a; Chen *et al*., 2007; Hsieh and Lee, 2008; Squire and Klopfer, 2007) show that AR has been a great companion to the teaching and learning process. This is associated with one of the characteristics of AR, which is the ability to provide an interactive environment between the computer system and its user (Martin-Gutierrez *et al*., 2012). AR offers many ways of interaction between computer system and user and most of the interaction can be used and adapted easily (Cascales *et al*., 2013b). This enjoyable edutainment in friendly interfaces eventually promoted self-learning for students at all ages especially pre-schoolers. Educators may use AR games as an alternative to assist students in grasping class concepts. AR games help to utilize a new highly visual and interactive way of learning (Yuen *et al*., 2011).

To date, many interaction techniques have been proposed to enhance user experience with AR applications. Recently, research focus has been directed to natural interaction methods such as using speech, gestures and gaze to achieve the feeling of 'naturalness' during the interaction. The invention of inexpensive depth sensing and gesture tracking tools such as Microsoft Kinect (2016) or Leap Motion (2016) enable easy to use natural interaction. The use of these tools will provide intuitive interaction that joins both the real and virtual worlds (Billinghurst, 2013). It will be wise to consider natural interaction in the design of AR system for education as it is capable to provide more natural interactivity and encourage self-learning.

To keep children motivated with the learning process, it is good to apply constructionism concepts during their interaction with computers. Activities such as creating and crafting something will highly likely engage children with the learning process. AR technology complement this concept very well. This can be proved by a number of studies (Winkler *et al*., 2002b; Bai *et al*., 2015) which showed the application of this concept in their AR applications and yielded high learning outcomes.

Parent's Involvement

Parents' involvement is a great influence for the acceptance of technology in education (Cascales *et al*., 2013a). The contribution of parents in technology acceptance in education can be delivered by fostering information literacy, providing technology resources, creating learning opportunities and communicating their own values and aspirations about their children's ICT use (Kong, 2008; Vekiri, 2010).

A relevant study (Cascales *et al*., 2013a) indicates that one factor affecting AR acceptance in preschool education is the family background, especially the influence from parents because they have an impact on children's usage of ICT. After assessing parents' perspectives towards the use of AR technology in their children's education, researchers concluded that parents expected AR technology to be convenient, simplifying the learning process and stimulating enthusiasm, understanding, reading and writing, creativeness and satisfaction (Cascales *et al*., 2013a). These are all the

points that should be taken into account when designing AR educational materials.

Student's Background

Besides general education, virtual environments such as AR technology also has high capability as the teaching and learning platform for special education (Brown *et al*., 1997). Arvanitis *et al*. (2009) suggested that any AR experimental scenario to be designed carefully and take into consideration the background of the students (e.g., living conditions, previous experiences, etc.). As most computer-based teaching and learning tools count on natural or coded language, the chances are high for students with severe learning disabilities such as those who suffer from physical disability to experience difficulties in using such systems (Brown *et al*., 1997). Augmented Reality technology, however, has the potential to be a natural teaching and learning platform for learners with physical disabilities. An example of such system is an open-ended pretend play system (Bai *et al*., 2013) for young children with Autism. To ensure the system's acceptance by Autistic children, a thorough study was done before the development phase. This was done to learn the requirements of Autistic children and how to design a proper system for them. Bacca (Brill and Park, 2008) added that multimodal AR provides the ability to assist therapy process for people with sensorial and physics injury.

Radu and MacIntyre (2012) believed that, psychologically, the changes in children's skills and limitations influence how children respond to AR designs. In their work, they investigated children's abilities in the categories of motor abilities, spatial abilities, memory and logic abilities as they believed that these skills have major influence on children's experience with AR. The finding will be beneficial for AR technology designers to design age-appropriate AR applications and to avoid designs which may cause usability issues which will lead to the rejection of this technology.

User's personalities also have great influence on ones behaviour towards something (Rasimah *et al*., 2011). This correlation could be grounded to the Innovation Diffusion Theory (IDT) which stated that user's personality differences can potentially influence how users form their intention to perform behaviours as stated by Rogers (2010). Through his research, Rogers revealed that:

- Users with higher levels of personal innovativeness are more likely to have a more favourable attitudes towards new technologies and
- Highly innovative users are more willing to embrace new technologies into their daily routine by coping with the uncertainty of innovative technologies

Platform

Another influential factor that will determine the acceptance and deployment of AR in education is the suitability of the platform used to deliver the content. Cook (2010) suggested that the integration of physical environment and mobile devices assisted learners to build their own context for development, which can be further understood through AR. Sule (Tekkesinoglu *et al*., 2013) combined virtual environments with web-based applications to support ordinary users in their interactions with AR. The study found out that it was the most appropriative way to produce an educational AR application for pre-school children.

Rapid advances in mobile technology have made it possible for AR technology to be installed in various smartphones and handheld devices for the use in education (Azuma *et al*., 2001; Papagiannakis *et al*., 2008). Many studies have shown that mobile devices play an important role in education and contribute to a great impact in regards to the potential for pedagogical perspectives (Chen *et al*., 2003; FitzGerald *et al*., 2013; Hwang *et al*., 2012).

Conclusion

Integrating AR in education may lead to a brighter future for the educational sector. AR has the potential to engage students in a better learning experience that could create a more comprehensive teaching and learning process. This review has identified a few factors that may influence the acceptance of AR in education. We have categorized the factors as curriculum, stability of the interaction, self-learning capability, parent's involvement, student's background, platform and social factors. Further research, however, is needed to ensure continuous enhancement of the implementation of this technology in the educational sector. It is hoped that these findings will open up a new dimension for the implementation of AR systems and application design to increase the level of acceptance towards its use in the educational sector. Throughout this study, we have identified that most user expected that AR be applied in learning environments where the content to be learned is enhanced by visualization such as learning of spatial relationship concepts and topics that is difficult to be learned through text-based. We also identified six key factors that may influence the acceptance between learners and AR educational tools as listed below:

- Curriculum: The technical aspect of the technology must be balanced with the pedagogical aspects of the educational contents
- Stability of the interaction: The reliability of AR application to provide continuous engagement during interaction

- Self-learning capability: The interaction in AR can be done by oneself without the needs for teacher or parental guidance
- Parent's involvement: The participation of the parents at any point or form of the technology usage
- Student's background: The context or conditions of the students
- Platform: Tools or device used to deploy the AR application

In future, author plans to investigate the acceptance of AR technology in education, particularly for learning of abstract concepts among children. This is motivated by the increasing number of AR applications which targeted children, in particularly young children.

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Author's Contributions

Che Samihah Che Dalim: Investigation, data collection and writing.

Hoshang Kolivand: Writing, edit and supervision.

Huda Kadhim: Edit and revised.

Mohd Shahrizal Sunar: Supervision.

Mark Billinghurst: Edit and supervision.

Ethics

There is no ethical issue for this manuscript.

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