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A Review of Research on Augmented Reality in Education: Advantages and Applications

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Abstract

Technology in education can influence students to learn actively and can motivate them, leading to an effective process of learning. Previous research has identified the problem that technology will create a passive learning process if the technology used does not promote critical thinking, meaning-making or metacognition. Since its introduction, augmented reality (AR) has been shown to have good potential in making the learning process more active, effective and meaningful. This is because its advanced technology enables users to interact with virtual and real-time applications and brings the natural experiences to the user. In addition, the merging of AR with education has recently attracted research attention because of its ability to allow students to be immersed in realistic experiences. Therefore, this concept paper reviews the research that has been conducted on AR. The review describes the application of AR in a number of fields of learning including Medicine, Chemistry, Mathematics, Physics, Geography, Biology, Astronomy and History. This paper also discusses the advantages of AR compared to traditional technology (such as e-learning and courseware) and traditional teaching methods (chalk and talk and traditional books). The review of the results of the research shows that, overall, AR technologies have a positive potential and advantages that can be adapted in education. The review also indicates the limitations of AR which could be addressed in future research.

Keywords: augmented reality, technology, education

1. Introduction

Technology has become embedded in education and the results indicate a positive impact on learning and teaching styles. According to Shapley et al. (2011), lessons that are supported by technology will lead to more innovative forms of teaching and learning. This is because the use of technology involves real-world problems, current informational resources, simulations of concepts, and communication with professionals in the field. In addition, learning using technology is believed to complement the traditional forms of teaching and learning (Yasak et al., 2010).

The integration of technology tools into the curriculum is becoming part of good teaching (Pierson, 2001). Teachers not only have to spend a good deal of personal time working with computers but also should have a high level of innovation and confidence to use the new technologies that are embedded in contemporary education. The integration of technology also provides a means to enhance student learning and engagement in lectures. Therefore, recent studies have aimed to better understand the applications adapted during lectures from the perspective of students, including multimedia, computer-based simulations, animations and statistical software (Neumann et al., 2011). Research by Geer and Sweeney (2012) showed that the use of a variety of media applications to explain concepts increased the understanding and supported greater collaboration between students.

Augmented reality (AR) is a new technology that has emerged with potential for application in education. While a lot of research has been conducted on AR, few studies have been conducted in the education field. The number of studies on AR is growing due to the effectiveness of this technology in recent years. AR has been used in different fields in education. In particular, AR provides an efficient way to represent a model that needs visualization (Singhal et al., 2012). AR also supports the seamless interaction between the real and virtual environments and allows a tangible interface metaphor to be used for object manipulation (Singhal et al., 2012).

2. Background of Problem

In recent years, governments have implemented initiatives with the aim to improve the quality and effectiveness of the teaching and learning process. Thus, there is a philosophy named as *'Falsafah Pendidikan Kebangsaan'* being created for the realization of this initiative. Besides, Malaysia is moving towards the title of a develop country and this needs a community which knowledgeable, progressive, innovative and can contributes in science and technology. These initiatives are motivated by the recognition that the traditional chalk and talk teaching method and the use of static textbooks are failing to engage students and leading to poor learning outcomes. In research conducted by Teoh and Neo (2007), for example, the respondents reported that it was boring to just hear the lecturer talking in front of them. The students believed that the integration of technologies would help them in their learning process. Therefore, educators have begun to seek technologies that have the potential to be integrated in education in order to help students learn actively and to improve their understanding especially in Science subjects. The following sub-sections discuss the issues that have arisen in relation to the teaching and learning of Science and the ways in which technology such as AR can be applied to address these issues.

2.1 Decreasing Number of Students Interested in Science Subjects

The study of Science is a complex process that includes identifying a problem, investigating the problem, making hypotheses, planning the data collection method, testing the hypotheses, collecting the data and making the conclusion and results (Meerah, 1998). Participating in these processes helps the student to think critically in each step in order to gather the best results. Due to the popular perception among students that Science subjects are hard subjects, fewer students are interested in pursuing their education in the Science stream.

According to Phang et al. (2012), the percentage of students pursuing their studies in the Science stream has never reached 60% and there was a worrying trend of decreasing student numbers in this stream. The Government of Malaysia has introduced a range of initiatives in order to address this problem but the target still has not been reached. In the United Kingdom, there has also been a decrease in the number of students taking Mathematics, Physics and Chemistry subjects and a similar trend throughout Europe where young people are not choosing Science, Engineering and Technology subjects beyond compulsory subjects (Bevins, 2005).

Many studies have been conducted with the aim to learn from students about how to make them more interested to study Science. One suggestion made by students that an expert should be present in the classroom to provide them with the relevant context for the subject and make the classroom activities more exciting (Bevins, 2005). Students prefer to learn in interactive ways rather than the traditional teaching methods. Research by Osman et al. (2007) found that students are less interested in studying Science because of their perception that it is a boring subject involving too many abstract concepts.

2.2 Students' Difficulties in Visualizing Abstract Concepts

Students commonly find Science subjects to be abstract, requiring a depth of understanding and visualization skills (Gilbert, 2004). When students have difficulties in understanding the concept well, it leads to misconceptions. According to Palmer (2001), misconception among students has to be taken into account because it can interfere with the students' learning of scientific principles and concepts. Thus, the selection of teaching method plays an important factor in avoiding or minimizing the students' misconception (Palmer, 2001). Visualization technologies have exciting potential for facilitating understanding and preventing misconceptions in the scientific domain (Hay et al., 2000). Kozhevnikov and Thornton (2007) found that is possible to improve students' visualization skills by presenting a variety of abstract visual images and allowing the students to manipulate and explore the images. There is a wide range of available technologies that can be used for the visualization of abstract concepts.

Examples of visualization technologies that have been examined in previous research include animation, virtual environments and simulation. Dede et al. (1996) suggest that students can improve their mastery of abstract concepts through the use of virtual environments that have been designed for learning. Robertson et al. (2008) found that animation together with interesting data and an engaging presenter helps the audience understand the results of an analysis of information. These visualization technologies can be used to address the problem of misconception and help students understand better.

2.3 Potential Technologies for Visualization of Abstract Concepts

Scientific concepts can be categorized as theoretical and descriptive concepts. Examples of descriptive concepts can be found in Biology such as food chains and environmental factors. Theoretical concepts represent the concepts that cannot be seen with the eye such as air pressure (colliding molecules) and photosynthesis (Lawson et al., 2000).

Research has demonstrated the beneficial use of technology as a means of visualizing abstract concepts. Visualization technologies provide a means for making visible phenomena that are too small, large, fast or slow to see with the unaided eye (Cook, 2006). For example, Wu et al. (2001) developed an animation to help students understand the abstract concepts in Chemistry. According to them, this type of technology allows students to visualize the interactions among molecules and to understand the related chemical concepts. Stith (2004) used software to create an animation of enzyme-substrate binding for teaching cell biology. The use of visualization technologies such as these in education is becoming more advanced and more sophisticated.

Nowadays, one of the technologies that shows great potential in education especially in visualizing abstract concepts is AR. According to Martin et al. (2011), AR is a new technology that is likely to have an impact on education. This claim is supported by the Horizon Reports from 2004 to 2010 which describe AR as a technology that brings the computer world to the human world (Madden, 2011). AR is different from virtual reality because AR combines the real world with computer graphics, while virtual reality immerses the user in a computer-generated world.

AR is a new way to improve the learning of three-dimensional shapes instead of the traditional method in which teachers use wooden objects. According to Cerqueira and Kirner (2012), there are several advantages of using AR techniques for educational purposes. For example, AR can minimize the misconceptions that arise due to the inability of students to visualize concepts such as chemical bonds, because AR allows detailed visualization and object animation. AR also has the advantage of allowing macro or micro visualization of objects and concepts that cannot be seen with the naked eye. AR displays objects and concepts in different ways and at different viewing angles which helps the students to better understand the subjects (Cerqueira & Kirner, 2012).

In addition, most of the research conducted on AR to date shows that students are excited and interested to learn using this technology. For example, in research conducted by Klopfer and Squire (2008), students gave positive feedback about their experience of the combination of the virtual and real environments. Burton et al. (2011) also reported a similar result, with the participants in their study clearly excited about the potential of this technology for sharing information and learning about new concepts. This feedback is useful in determining the readiness of students to accept and use this new technology. AR also makes students become more active in the learning process due to the interactivity of its applications (Lamounier et al., 2010). Thus, it encourages students to think critically and creatively which, in turn, improves their experiences and understanding.

Table 1 summarises some of the advantages of AR in education that are highlighted in the literature. There are many advantages when integrating AR technologies into the teaching and learning process; the advantages listed in the table are the most common advantages that are usually emphasised.

Table 1. Advantages of using AR in education

Author	Advantages of AR
Singhal et al. (2012)	Supports seamless interaction between real and virtual environments and allows the use of a tangible interface metaphor for object manipulation
Coffin et al. (2008)	Provide instructors with a way to strengthen students' understanding in the classroom by augmenting physical props with virtual annotations and illustrations
Burton et al. (2011)	Creates a learning experience that is linked to the formal classroom, so that students can learn outside of class hours and outside of school limits
Medina, Chen, and Weghorst (2008)	Enables the visualization of interactions among amino acids and protein building processes as static 2D/3D images and 3D dynamic images (animations)

The advantages of AR in education (highlighted above in Table 1) indicate that there is significant potential to integrate AR in teaching and learning, especially for the subjects that require the students to visualize. However, the meta-analysis conducted in the present study and the research by Danakorn et al. (2014) indicate that, even though a lot of research has been conducted on AR, relatively few studies have been conducted on AR in the education field.

3. Application of AR in Several Fields

This section presents a review of the extant research on the application of AR. This review is organized according to the application of AR technologies in a number of fields of study in education, namely, Medicine, Chemistry, Mathematics, Physics, Biology, Astronomy and History. Research on the application of AR in these fields is reviewed in order to evaluate the potential of AR in education. Table 2 summarizes the meta-analysis of the research conducted on AR in different fields. The analysis includes examples of how the AR technology was implemented in the respective fields.

3.1 Methodology

The goal of this review is to identify the potential use of AR in different fields of education. The keyword used in the search of the literature was the phrase "Augmented Reality". There were 463 hits from the keyword search, of which nine were selected after taking into account certain criteria. Firstly, only studies conducted from 2007 were selected. This is because the AR technologies began to emerge in 2007. Secondly, the studies must represent different fields in order to give examples of how AR has been used in a range of areas. Lastly, the studies must highlight the purpose and the features of the AR technology that had been used. The search of the literature was conducted using EdITLib which is the digital library for Education and Information Technology. The results are presented in Table 2.

Table 2. Meta-analysis of research on the use of AR in different fields of education

Author/s	Field	Purpose of AR Use	AR Features Used
Chang et al. (2011)	Medical education (surgical training)	To provide training and to plan and guide surgical procedures	AR image-guided therapy
Yeom (2011)	Medical education (anatomy)	To teach and test anatomy knowledge (of the abdomen in particular)	Interactive 3D anatomy pictures and haptic feedback
Hedegaard et al. (2007)	Medical education using the electrocardiogram (ECG/EKG) AR system (called the EKGAR system)	To extend medical students' spatial awareness in relation to specific myocardial diseases by enabling users to navigate through and slice open 3D representations of a patient's heart	Vision-based 3D tracking technologies and interactive features
Singal et al. (2012)	Chemistry education	To provide an efficient way to represent and interact with molecules, leading to a better understanding of the spatial relation between molecules	AR technology for exhibiting the models
Cerqueira & Kirner (2012)	Mathematics	To teach geometry through the use of 3D geometrical concepts	Head-mounted display and personal interaction panel
Mathison & Gabriel (2012)	Biology (School in the Park project)	To teach participants that habitats are connected like links in a chain (food chain)	AR experience
Coffin et al. (2008)	Physics	To overlay graphics on top of the physical props to visualize these forces (speed, velocity, acceleration, pressure, friction, energy changes) invisible to the human eye	Augmented video, videoconferencing, tracked physical props (e.g. toy cars)
Fleck & Simon (2013)	Astronomy	To show augmented views of the celestial bodies and support learning using spatial visual guides and views from a terrestrial observer	AR learning environment
Martin et al. (2011)	History	To gather information and enhance the experience of visitors to cultural organisations (museums and archaeological sites)	Mobile AR educational games

As shown in the summary in Table 2 above, there are many fields in which AR technology is adapted and applied for teaching and learning. Most of the research studies demonstrated the positive feedback of the participants regarding the AR system under investigation. In conclusion, more research on the integration of AR in teaching and learning should be conducted because of its clear benefits not only to students but also to teachers. With the aid of AR technology, the teaching of subjects that involve visualization will be enhanced, compared to the use of traditional methods alone.

4. Limitations of AR and Suggestions for Future Research

There are many aspects of AR technology that need to be explored and many future research investigations remain to be conducted in this relatively new area. A number of limitations exist in this technology. For example, according to Hsu and Huang (2011), many participants in an AR learning exercise agreed that the AR tools are good but most participants did not consider the tools to be as effective as reading textbooks. They found that using AR tools to obtain information was not easy. The reason might be that although the AR tool itself is easy to operate, the procedure of sending the image, recognizing the text and then getting the meaning of the text is time-consuming. This is because the technology used the 3G network to connect to the Internet. Accordingly, the participants may need to wait a short time for the information to be sent back from the server (Hsu & Huang, 2011).

The identification of this limitation is supported by the results of a study by Folkestad and O'Shea (2011) where the participants reported being frustrated when using the technology outdoors and had to resort to asking their teacher for help. The results indicated that although the students encountered technical issues, they found assistance, persisted with the task and engaged effectively in the unique learning process. Despite all the difficulties, the level of engagement in the outdoor AR activities was still very high (Folkestad & O'Shea, 2011).

As mentioned earlier, the replication of studies related to AR is growing rapidly. However, the use of this kind of technology is growing slowly in Malaysia especially in the education field. Thus, more researchers in the education field should investigate the potential of AR to improve the teaching methods in the country's education system and to improve the efficiency of the teaching and learning process. For instance, the AR developed by Burton et al. (2011) shows that participants were clearly excited about the potential of this technology for sharing information and learning about new concepts.

Moreover, research should be conducted to investigate the latest technology called the mobile augmented reality (MAR) system which is a smartphone application that is integrated with the AR itself. This new form of AR technology offers a learning experience that is linked to the formal classroom so that students can learn outside of class hours and outside of school limits (Burton, 2011).

The limitations stated above mostly highlight the issues related to the technical aspects of using AR in the learning process. Such technical issues must be improved in the future in order for AR to be widely applied in education. Lamounier et al. (2010) also pointed out that there needs to be improvements in Internet portability in order to facilitate user access to AR systems for learning. Increased Internet access will give students the opportunity to use AR via a smartphone. This has the potential to make AR a powerful learning tool that can help students to gain content knowledge and maintain that knowledge through their interactions with the smartphone activities.

5. Conclusion

This review of the research conducted in several fields in education shows that AR technology has the potential to be further developed in education. This is because the advantages and beneficial uses of AR features are able to engage students in learning processes and help improve their visualization skills. The features can also help teachers to explain well and make the students easily understand what they are taught. The use of AR technology has also received positive feedback from participants and students who have shown their interest in using AR in their learning processes. These good responses are important because they indicate the willingness of students to actively engage in their studies through AR tools. AR technology is still new in education, thus there are still some limitations. However, the review of the research indicates that most of the limitations are related to technical issues. Such limitations can be overcome over time as research on the integration of AR in education is replicated and improved. When the potential of AR technologies is more fully explored, the beneficial functions of AR can begin to be used widely in all fields of education and the efficiency of the teaching and learning process will be improved.

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