USABILITY GUIDELINES FOR DESIGNING A MARKER-BASED AUGMENTED REALITY APPLICATION FOR TEACHING SCIENCE SUBJECT AT PRIMARY SCHOOLS IN MALAYSIA

BY

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ABSTRACT

At primary level, students have difficulty in learning science as it involves understanding and visualizing complex abstract concepts. Meanwhile, the emerging of Augmented Reality (AR) in this era may benefit the effectiveness and efficiency of learning process. However, the usability issues, development and implementation complexities still remain puzzled. Besides, research around how AR should be designed and applied in order to improve the learning process is still lacking. Hence, the purpose of this research was to identify usability problems of using AR application for learning Science subject among primary school students and to propose guidelines for designing the respective AR application. A mixed methodology was used in the research including quasi-experimental design for AR application evaluation, followed by observation and questionnaires for understanding participants' interaction with selected AR applications. Five primary school students in Year 4, 5 and 6 that have learned solar system topic in science subject were involved. The results revealed that there were three areas of usability issues in AR applications which were; 1) difficulty to understand buttons and icons in interface design, 2) tracking loss in interaction design, and 3) no in-app tutorial for first time users in content design. Since only marker-based AR applications were conducted in this study, the guidelines were only for marker-based AR application. Therefore, it is proposed that the design of intuitive buttons and simple icons should be made easy to understand for children, while the usage of markers should be reduced for more convenient experience and avoiding tracking loss. Plus, a user-friendly tutorial with appropriate visual representations should be added. Findings of this research will contribute towards understanding of the challenges in the usage of marker-based Science AR application for primary school students and further propose guidelines to design the respective marker-based AR application more efficiently and effectively.

ملخص البحث

في المرحلة الابتدائية، يواجه الطلاب صعوبة في تعلم العلوم لأنها تنطوي على فهم وتصور المفاهيم المجردة المعقدة. وفي الوقت نفسه، قد تفيد التكنولوجيا الناشئة للواقع المعزز Augmented Reality (AR) في هذا العصر فعالية وكفاءة عملية التعلم. ومع ذلك، فإن قضايا قابلية الاستخدام، وكذلك تعقيدات التطوير والتنفيد، لا تزال لغزا. إلى جانب ذلك، لا يزال البحث حول كيفية تصميم الواقع المعزز وتطبيقه لتحسين عملية التعلم غير موجود. وبالتالي، فإن الغرض من هذا البحث هو تحديد مشاكل قابلية الاستخدام مع استخدام تطبيقات AR لتعلم مواد العلوم بين طلاب المدارس الابتدائية واقتراح مبادئ توجيهية لتصميم تطبيقات AR المعنية. تم استخدام منهجية مختلطة في البحث، بما في ذلك تصميم شبه تجريبي لتقييم تطبيق AR، تليها الملاحظة والاستبيانات لفهم تفاعل المشاركين مع تطبيقات AR المختارة. يشارك خمسة من طلاب المدارس الابتدائية في السنوات 4 و5 و6 الذين تعلموا عن مواضيع النظام الشمسي في المواد العلمية. كشفت النتائج أن هناك ثلاث مجالات لمشكلات قابلية الاستخدام في تطبيقات AR وهي: 1) صعوبة فهم الأزرار والأيقونات في تصميم الواجهة؛ 2) تتبع الخسارة في تصميم التفاعل؛ و3) عدم وجود برنامج تعليمي داخل التطبيق للمستخدمين لأول مرة في تصميم المحتوى. نظرا لأنه تم إجراء تطبيقات AR القائمة على العلامات فقط في هذه الدارسة، فإن الإرشادات مخصصة فقط لتطبيقات AR القائمة على العلامات. لذلك، يقترح أن يكون تصميم الأزرار البديهية والأيقونات البسيطة سهل الفهم للأطفال، في حين يجب تقليل استخدام العلامات للحصول على تجربة أكثر ملاءمة وتجنب فقدان التتبع. بالإضافة إلى ذلك، يجب إضافة برنامج تعليمي سهل الاستخدام مع تمثيلات مرئية مناسبة. ستساعدنا نتائج هذه الدراسة على فهم أفضل لكيفية استخدام طلاب المدارس الابتدائية لتطبيقات Science AR القائمة على العلامات، كما ستعطينا أفكارا حول كيفية جعل التطبيقات أكثر كفاءة وفعالية.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of InformationTechnology.

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DECLARATION

I hereby declare that this dissertation is the result of my own investigation, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degree at IIUM or other institution.

Hamizah Mohd Mohadis

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Signature Date

ACKNOWLEGMENTS

"In The Name of Allah, The Most Gracious, The Most Merciful"

I praised to Allah for His blessing, mercy and guidance that light each of my path of life.

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CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Changes in science and technology have affected the structure of societies and have led to rapid change in human profile. In order to adapt to the changing human profile, reforms in education as well as scientific and technological enhancement in educational environments have become necessary (Sahin and Yilmaz, 2019).

Science is one of the main subjects learnt in primary school. Science subjects require in-depth understanding and visualization skills to grasp a few abstract concepts (Saidin, Halim, and Yahaya, 2015). However, this would not be easy especially for students at primary level. For example, since basic astronomy concepts are abstract in nature, students' attitude towards the course is negatively affected when their comprehension towards the material is interfered (Gündoğdu, 2014; Sahin and Yilmaz, 2019).

According to Weinstein et al. (2018), since abstract concepts are harder to grasp than concrete information (Paivio, Walsh, and Bons, 1994), teachers ought to illustrate abstract ideas with concrete examples. Additionally, the use of visual is necessary to overcome the difficulty in explaining nature and natural phenomena in science subjects, and to make abstract concepts more concrete (Sahin and Yilmaz, 2019).

Besides, it is important to increase students' visual and intellectual engagement through the use of technology in order to enrich students' learning environment. This is really true especially when explaining abstract and difficult concepts. This also allows

students to perceive phenomena in science courses in a multidimensional manner, interpret information better and keep their attention on the course (Akpınar et al., 2005).

The rising power of personal computers and mobile devices enables the concept of Augmented Reality (AR) to prepare effective and interesting technology-based instructional materials, to be applied in traditional educational environments such as schools and universities (Diegmann, 2015). AR is capable to display 3D objects with or without animation, which could help teachers to clarify certain processes. When viewing the animation of processes, students are able to see and learn all the processes in several perspectives or views. Capabilities of Augmented Reality technology may make classes more attractive and information more apprehend able.

AR plays an important role in embodying and visualizing abstract concepts in accordance with students' comprehension levels, and in enabling the observation of phenomena that are impossible to encounter in real life. Findings from previous research shows that the benefit of AR in education includes increased motivation, attention, concentration and satisfaction hence improving the learning process (Radu, 2014; Eh Phon, Ali, and Halim, 2014; da Silva, Teixeira, Cavalcante, and Teichrieb, 2019).

Therefore, to address these issues, this research aimed to identify and propose guidelines in designing AR applications. The target user involved students from Year 4, 5 and 6 that have learnt Science subject in the primary school. Consequently, the outcome of this research could propose guidelines in designing a better AR application for science subjects in primary school with more efficient and effective applications.

1.2 PROBLEM STATEMENT

Saidin, Halim and Yahaya (2015) asserted in their research findings that, due to the popular perception among students that Science subjects are difficult subjects, less students are interested in pursuing their education in the Science stream. This perception has make the students less interested in learning Science because it is a difficult subject and involve too many abstract concepts which requiring in-depth understanding and visualization skills.

Besides, the study of Science is about understanding the whys and wherefore of the world. Abbasi, Waseem, and Ashraf (2017) found that, a scientific study usually involves a series of phases that are used to study the natural existence. These phases involve problem identification, problem analysis, making hypotheses, planning data collection methods, testing hypothesis, collecting data, making conclusions and results. In order to get the best results, students need to think critically in each phase. It is not always easy for students to transfer their knowledge in a particular activity from one learning 'domain' to another (Banks and Barlex, 2014).

Hence, teaching in primary school is a challenging task and teachers are often met with many obstacles. One obstacle to overcome is to schedule the time for science classes. With all of the subjects competing for young minds, it is difficult to create a flexible schedule that can accommodate all the valuable information that students need to master (Munoz, 2017).

Nowadays, one of the technologies that shows great potential in education especially in visualizing abstract concepts is AR. AR has been used in different fields in education. In particular, AR provides an efficient way to represent a model that needs visualization. AR also supports the seamless interaction between the real and virtual environments and allows a tangible interface metaphor to be used for object manipulation (Saidin, Halim, and Yahaya, 2015).

In comparison to other technologies such as multimedia, games and online learning, the implementation of AR in education is still at its developing stage. Although AR has demonstrated such a vast potentials, but it is important to understand how to design AR in order to enhance learning experiences (Eh Phon, Ali, and Halim, 2014). Besides, Sommerauer and Muller (2018) stated that there is still a lack of research on how AR applications need to be designed and applied in order to improve learning process.

In addition according to Akçayır and Akçayır (2017), it is clear that AR can potentially support learning and teaching. However, when the reviewed research studies are compared to each other, some conflicting conclusions can be seen. To give an example, while the top challenge imposed by AR applications is about their usability, in contrast, their ease of use also appears in the list of reported advantages. it is unclear whether there is a real usability issue – and if there is, whether that stems from inadequate technology experience, interface design errors or technical problems. This problem is due to the fact that there are no specific usability guidelines for designing AR applications for children (Radu, 2016).

Thus, this research aims to identify the potential issues in using AR applications among primary school students and to provide the guidelines to design AR applications for primary school students especially on Science subject.

1.3 RESEARCH QUESTIONS

There is a lack of research on how AR applications need to be designed and applied in order to improve learning of Science subject at primary school. Thus, this study has the following research questions:

1. What are the potential issues in using AR applications for learning Science among primary school students?
2. What are the guidelines for developers to design AR applications to support learning of Science subject for primary school students?

1.4 RESEARCH OBJECTIVES

Thus, this study aimed to achieve the following objectives:

1. To identify usability problems of using AR application for learning Science subject among primary school students.
2. To propose guidelines for designing AR application for Science subject in primary school.

1.5 OPERATIONAL DEFINITIONS

This study was conducted based on several theories and concepts that are summarized in the following definitions.

1. Augmented Reality (AR):
   AR is a combination of technologies that capable to display real-time mixing of computer-generated content (text, still images, video clips, sounds, 3D models and animations) with live video display (Mekni and Lemieux, 2014).
2. Interaction Design (ID):
   ID is about creating user experiences that enhance and augment the way people work, communicate and interact in their everyday and working lives (Rogers, Sharp, and Preece, 2011).
3. Usability:

Usability is the ease of use and learnability of a tools or device (Rogers, Sharp, and Preece, 2011).

1.6 SCOPE AND LIMITATIONS

This study involved evaluation of selected educational AR applications, namely SolarAR and AR Solar System. Both applications were selected from Google Play Store specifically for Android devices use only. The selection was made based on consideration of availability and easiness for children to use for learning. This is because both come with free versions, thus easy for them to access and download. Besides, both have similar information about the Solar System as in the syllabus of Science textbook for Year 4 until Year 6 with English version.

In this study, participants among primary school students from Year 4, Year 5 and Year 6 were chosen as the target users. Only students that have learnt about the solar system were selected since this topic demonstrates one of the Science subjects that involve nature and natural phenomena, in which the abstract concepts could hardly be grasped, hence become our interest of study.

Meanwhile, there was also a limited number of students participated since throughout this study, the whole country was placed under the Movement Control Order (MCO) due to the rise of Covid-19 infections. Therefore, individual movement was restricted within a certain distance and all schools were closed for such a prolonged time. Consequently, only five participants that were within the closest area of the researcher's residential area were able to be selected to participate in this study.

1.7 RESEARCH SIGNIFICANCE

This study will help in understanding primary school student interaction with AR application to learn Science subject. Besides, this study would provide guidelines for developers in designing AR application for Science subject to better in formal design decision.

CHAPTER TWO

LITERATURE REVIEW

2.1 AUGMENTED REALITY

Augmented Reality (AR) can be defined as a combination of technologies that capable to display real-time mixing of computer-generated content (text, still images, video clips, sounds, 3D models and animations) with live video display. AR is one of the techniques developed based on Virtual Reality (Azuma, 1997) and interacts not only with a virtual world but also correlation with the real world (Mekni and Lemieux, 2014). For a system to meet Azuma's definition of Augmented Reality system (Azuma, 1997), it must fulfil three main requirements in which there is a combination of real and virtual content, interactive in real time and registered in 3D (Billinghurst, Clark and Lee, 2015).

Usually, user got confused with the virtual reality and augmented reality. The difference concept of virtual reality and augmented reality can be explained with the help of Reality– Virtuality (RV) Continuum by Milgram, Takemura, Utsumit, and Kishino (1995) as in Figure 2.1.

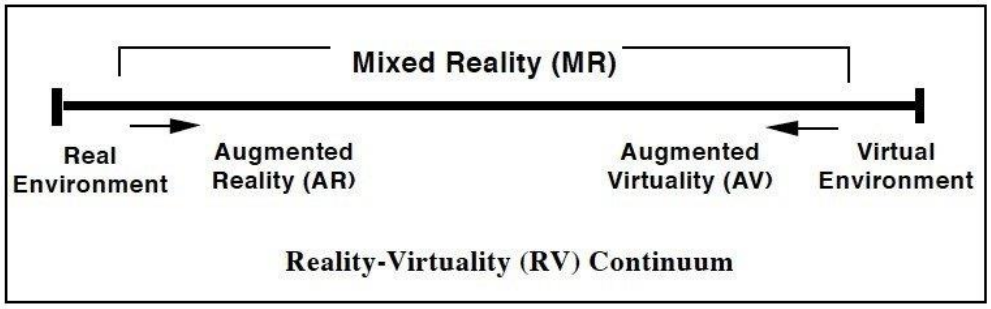

Figure 2.1 Reality– Virtuality (RV) Continuum (Milgram, Takemura, Utsumit, and Kishino, 1995)

Based on Figure 2.1, it can be further elaborated that the real world and a totally virtual environment are at the two ends of this continuum with the middle region called Mixed Reality. The case at the left of the continuum defines any environment consisting solely of real objects, and includes whatever might be observed when viewing a real-world scene either directly in person, or via some sort of a (video) display (Milgram, Takemura, Utsumit, and Kishino, 1995). On the other hand, the case at the right defines any environment consisting solely of virtual objects, such as the one that would include conventional computer graphic simulations, either monitor-based or immersive. Hence, augmented reality is in between a real and virtual environment. It uses computer-aided graphics to add an additional layer of information which, accordingly, can aid understanding and/or interaction with the physical world (Amin and Govilkar, 2015).

In addition, as explained by Milgram, Takemura, Utsumit, and Kishino (1995), virtual reality completely immerses the users in a virtual environment where the real world cannot be seen. This could be visualized when the user wears a glass specifically for virtual reality applications. Once the applications start they feel like they are in a different world and cannot sense what is going around them in reality.

Whereas for augmented reality, even though the user would need a display device such as a computer, smart phone, special glasses or head mounted displays (HMD), they still could see the virtual world being overlaid on the real world and be aware of both the world. This is due to the fact that augmented reality brings virtual information into a user's physical environment and allows the user to use their whole body to interact with the virtual content (Radu, 2014).

All in all, the use of Augmented Reality systems has been investigated in a wide range of industries since the early 1990s, not only medicine, manufacturing, aeronautics, robotics, entertainment, tourism, but also social networking and education recently (Howe et al, 2014).