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The Development of Augmented Reality in The Education of Geometry

R.N. Farah[1], R.L. Zuraida[2], H. Kamaruddin[5]
[1,2,5]Department of Mathematics, Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris, 35900 Tanjong Malim, Perak
K.A. Rahman[3]
[3]SMK Saujana Utama, Persiaran Saujana 3, Saujana Utama, Selangor
A.K. Othman[4]
[4]SK Sungai Limau, Kampung Sungai Limau, 45400 Sungai Besar, Selangor

Abstract **- Education today is evolving in line with the passage of time, there are various technologies that have been used in the education system today. One of the fastest growing technologies that is often included in education is Augmented Reality (AR) to help students understand learning more easily. The purpose of this article is to show the development of AR in the education of geometry. Examples of AR that have been used in Education are Costruct3D, AR iPhone learning game, use of AR application on line and plane titles in 3 dimensions, etc. Researchers argues that AR is very useful in helping education in terms of geometry. Developing this AR also requires consideration in terms of the level of learning activity in terms of pedagogy. Based on the articles, the researchers compared each AR for ease of use and aid in understanding the topic.**

Index Terms – Augmented Reality, geometry, education, teaching aids, 3D thinking skills.

INTRODUCTION

Augmented Reality (AR) refer to the technology that are very attractive to the leaners since they offer new experiences and technologies that students can use to strengthen their understanding in the topic of geometry. Educators have supported the active involvement of students in learning. The articles show that AR is able to provide active involvement from students. Generally, the main goal for AR education is to improve this spatial skill in geometry. Mathematical learning is the process of building concepts and principles, not just teaching that seems passive and static, but learning must be active and dynamic (Bambang, 2019).

AR is a technology can enhance the learning experience in the classroom and has the potential to motivate students in activities and problem solving (Almar,2019). AR also a technology that has potential to be applied in education. The number of research on AR is increasing because the effectiveness of this technology gives the positive impact in the field of education. AR has been used in various fields in education. AR also supports good interaction between the real world and the virtual world (Farhah,2015).

Benefits which can be obtained by AR is a new experience in terms of the use of technology and users can also see the virtual world to the reality world without seeing the real world. Two influences that may affect the use of AR include the use of electronic devices at the school level and the dependence on the use of technology on pedagogy. Rapid development of AR in education usually extensive knowledge from different fields, such as computer programming, graphic design, pedagogy and educational psychology. Many of development approaches and tools are not easily applicable by educators. However, there are tools that enable educators to create simple applications that require no programming by example are CT Reveal, MAKA and more.

The main advantage of using AR is that students actually see three-dimensional objects, but until now AR are not widely uses in school. We assume that by working directly in 3D space, complex spatial problems and spatial relationships can be easily to understand.

MATERIALS AND METHODS

Nowadays the use of AR has shown a very positive development. The development of AR in education has shown in many relevant articles, especially in topics related to geometry. The result for development of AR shows a good impact in education. Technology has helped a lot in education and have a high impact in the learning and teaching styles (Farhah, 2015).

I. Article A: Cyberchase Shape Quest: Pushing Geometry Education Boundaries with Augmented Reality (Iulian, 2015)

(a) Problem Statement

Assessing the level of interaction and the benefits to students in the use of AR as an increase in entertainment through the interaction of the whole body, and promote education through interactive visualization in place. In the domain of learning, AR has been shown to have benefits that can be measured from the traditional approach when faced by students and adults

(b) Proposed/ Methodology

The development of Cyberchase Shape Quest uses an iterative design process that involves high - level user research. Combining formal and external formative assessments into several design cycles has proven to provide significant value during game development as it helps reduce uncertainty over AR. AR is a relatively new technology and unfamiliar to young children, as well as to game designers and educational specialists.

(c) Result

The evaluation confirms that this game can be used and fun for children because they can survive through various levels of the game in the allotted time, this game also helps teachers in attracting students. Researchers also found some usability issues, particularly in the final. In particular, users have major problems in understanding the mechanics of AR and 3D space

II. Article B: A Review of Research on Augmented Reality in Education: Advantages and Applications (Farhah, 2015)

(a) Problem Statement

The problems identified for conducting this study is decreasing the number of students interested in science subjects. Besides that, student difficulties in visualizing abstract concepts and potential technologies for visualization of abstract concepts.

(b) Proposed/ Methodology

A literature review was conducted using the phrase AR, the search showed 463, 9 of which were selected according to certain criteria. The first study selected was in 2007 because AR technology began to emerge in 2007. The second was according to different fields to show examples of differences in each field. Finally, the study must aim at and show the characteristics of the technology used. Article search uses EdITLib which is a digital library for Education and Information Technology.

Result

A review of research conducted on AR shows AR has the potential to further advance in education. This is because the advantages and uses of AR can help students in the learning process and help improve their visualization.

III. Article C: Augmented Reality Applied to Geometry Education (Bambang, 2018)

(a) Problem Statement

The difficulty for schools and teachers to obtain teaching aids for the topic of geometry to build 3D spaces is the main reasons AR is been used to assist in education. From the side of students, they also find it difficult to understand objects that build 3D space, because without teaching aids they are only able to imagine or imagine themselves building 3D space objects.

(b) Proposed/ Methodology

The framework for this exploration is Multimedia Development Life Cycle (MDLC). MDLC have 6 phases of idea, plan, gathering material, get together, testing and circulation

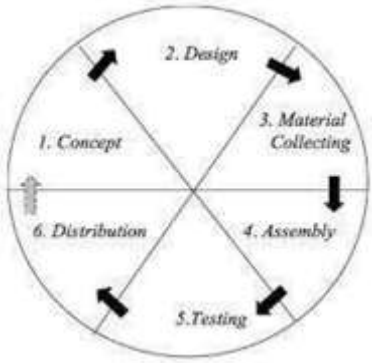

FIGURE 1.
Stages of MDLC method

- Concept - to define the nuts and bolts of a media venture that will be made and created.
- Design – to design the model.
- Material Collecting - to gather the materials that match the necessities.
- Assembly – making all articles or interactive media materials.
- Testing – to get together stage by running for preliminary.
- Distribution – phase for distribution through media or DVD or other media.

(c) Result

Research shows the effect on AR in mathematics subjects. The empirical evidence provides strong support for the suggestion that AR has the potential to be an effective tool for learning formal (mathematical) content

IV. Article D: An Assessment of Geometry Teaching Supported with Augmented Reality Teaching Materials to Enhance Students' 3D Geometry Thinking Skills (Emin İbili,2018)

(a) Problem Statement

Learning using old methods in 2-D drawing is not as successful when teaching three-dimensional geometric objects. Drawings representing 3D views are typically two-dimensional and often cannot help students to understand the rules of representation and component properties. Component properties such as edge length, number of edges; the same kind of inter-component relationships such as equal edges, corner and edge relationships constitute the structure of the object. When the teaching of those geometrical concepts grounded in three dimension is limited by formulas, students may not be able to compare the volume of two cylinders formed by folding one piece of paper along its edge. This example emphasizes the need for spatial configuration and visualization skills, suggesting that geometry should be taught with methods other than memorization.

(b) Proposed/ Methodology

Development of the 3D thinking skills test was about ability to recognize and create 3D shapes: Students have the ability to recognize and construct geometrical objects 3D nets and decide whether to build an object when the net is folded or not. Next, the development of the Augmented Reality Geometry Tutorial System (ARGTS).

(c) Result

At the end of four weeks of experimental study, the students who participated in the AR supported learning environment found that the 3D shape recognition skill increased more than the control group. This shows that AR-supported geometry learning can be effective in increasing student 3D thinking skills

V. Article E: Augmented Reality in Teaching Descriptive Geometry, Engineering and Computer Graphics – Systematic Review and Results of the Russian Teachers' Experience (Marianna, 2019)

(a) Problem Statement

The purpose of this research was to examine the knowledge and practice of existing courses, which use the concept of AR to conduct pedagogical experiments by teaching students how to model information of building structures using the concept of AR. In addition, the study aims to look at the effectiveness of AR technology to students and lecturers on the quality of design work and project presentation produced.

(b) Proposed/ Methodology

The research involved 168 first year students and 26 teachers. The study was conducted in three stages namely the first theoretical analysis of the existing methodological approaches in the scientific literature, the dissertation work on the problem, as well as the theory and methodology of pedagogical research performed. This aims to determine the research methods and experimental research plans are made. Next, experiments are conducted, the results of the experimental work are analysed, tested and clarified thoroughly. Finally, in the third stage, the experimental work is completed making theoretical and practical conclusions are refined, the results obtained are summarized and systematic.

(c) Result

The researcher successfully carried out the task of designing the building using AR and created an information model of this building. Based on the research conducted by the researchers, their teachers gave suggestions on their further research. However, there is a need to teach AR and its applications to design buildings and structures to a new generation of students, this research has shown that there is still no curriculum tested, as well as teaching materials, on the use of AR.

VI. Article F: Impact of Augmented Reality (AR) Technology on Academic Achievement and Motivation of Students Public and Private Mexican School (MariaBlanca,2019)

(a) Problem Statement

Key features of the Mexican education system include: the dominance of half -day schooling; difficult social contexts for schools; less than optimal school infrastructure; many challenges faced by the teaching profession; limited school autonomy; and large financing inequalities (Santiago, McGregor, Nusche, Ravela, & Toledo, 2012).

(b) Proposed/ Methodology

Two different applications were developed to support the learning activity: one application was Web-based; the other application used image-based AR technology. Both applications offered the same educational content and followed the same workflow according to participants' preferences and their answers to assessment items. Two types of schools were considered: public and private. Learning activities are compulsory for students of both schools, pending prior approval from each student. Parents are also notified of the activity, and participation also requires parental consent. Students of both schools followed the same Geometry curriculum. In this study, the specific research questions aim to explore whether type of technology (AR, Web) and type of school (private, public) significantly affect learning outcomes and motivation of students taking a basic Geometry course.

(c) Result

In this research, the investigate the learning effectiveness and motivation appeal of an AR activity targeting the geometry subject. To this end, created the AR Geo learning platform where students of public and private schools practiced basic Geometry concepts. Statistical analysis on pre-test and post-test about the learning effectiveness of AR-based activity compared to the Web-based activity shown that students who used the AR application performed significantly better compared with those who used the web-based application. Previous studies have shown AR contributes to improving learning outcomes in STEM subjects compared to other teaching methods.

VII. Article G: Comparative Evaluation of Virtual and Augmented Reality for Teaching Mathematics in Primary Education (Eleni Demitriadou,2019)

(a) Problem Statement

Many scientists argue that mathematics and geometry are the reasons students often fail to make connections between objects in the three -dimensional of real life, with two -dimensional objects, and as a result, they have difficulty distinguishing solid geometry from flat shapes (González 2015). There is a lack of research on the systematic development of virtual and AR applications for the purpose of practical training and improvement of students' spatial abilities in mathematics and in particular in geometry.

(b) Proposed/ Methodology

As part of the experimental evaluation teaching material related to the delivery of a lesson in geometrical solids was developed using traditional printed material, VR and AR technologies. Experimental process consists of two main parts. First part is about "teaching process" where students need to study the teaching material using books or VR tools or AR tools. The teaching material for this part of the experiment was designed based on views of active educators, and it is consistent with the curriculum. In this part of the experiment the teaching format used is "learning experience" this is because students can learn from experience (Kiili 2005; Kolb 2014). The assessment exercises and questionnaire solution were used as a second method to evaluate the effectiveness of book -based, VR, and AR -based instruction. All the steps of the methodology adopted are presented in the remainder of this section.

(c) Result

With regard to the comparison between AR and VR, results indicate that VR and AR technologies are equally effective for learning mathematics, something that highlights the originality and importance of this work.

VIII. Article H: Augmented Reality-Based Learning Environment to Enhance Teaching-Learning Experience in Geometry Education (Shubham, 2019)

(a) Problem Statement

The concepts of geometry and three-dimensional (3-D) space are still considered difficult subject areas for some students. Therefore, research on learning innovations for the topic of geometry is actively conducted to overcome the problems faced by students. The main objective is to expand AR -based geometry learning for android and iOS platforms from distributing apps among students to teaching 3-D geometry to high school students.

(b) Proposed/ Methodology

Development for ARLE uses the ADDIE concept of analysis, design, development, implementation and evaluate. First, analysis is conducted to identify the problems faced by students. In designing process, it is important to make such a teaching kit that is easy to carry in the regular classes. In the development process is the phase to produce a product.

(c) Result

This ARLE successfully assesses the competence of AR in the field of education for secondary schools, but the scope of this AR is not limited to specific subjects or concepts. If the usability results are positive, this ARLE can be further developed for other topics and subjects.

IX. Article I: Using Augmented Reality Tools in The Teaching of Two-Dimensional Plane Geometry (Natalya, 2020)

(a) Problem Statement

The innovations carried out by the Ministry of Education and Science of Ukraine are focus on making educational institutions have the approval and competence in acquiring knowledge independently to solve problems. This is because there are parties that figure certain conditions for modern approval for secondary or higher education institutions.

(b) Proposed/ Methodology

Build a blended learning model is one of the ways used to solve problems in the face. Interactive learning process, can provide a personal learning ICT-rich mobile and allows you to learn at your own pace. Besides that, AR technology is the one of the technologies that can be used to visualize learning material in a blended learning model. Analysis from previous research found that AR indicates that no program is sufficiently advanced and appropriate for school education, especially in geometry courses. However, AR has been extensively developed to allow teachers to use it easily at the school level.

(c) Result

The AR tools can be used in geometry at school, make teacher can be more strategies to teach the student. AR also can make environment happier and make a good communication tool. Besides that, the learning outcomes are increased, the cognitive activity of the students increases, their creative potential is revealed, the learning process is intensified.

X. Article J: Integrating Ethnomathematics into Augmented Reality Technology: Exploration, Design, and Implementation in Geometry Learning (S. Sudirman, 2020)

(a) Problem Statement

Related studies such as performed an experiment on the use of AR technology on teaching geometry and its impact on students 3D thinking skills studied the integration of AR technology into space geometry teaching and learning activities in junior high school applied a mobile Augmented Reality system (Diedric AR) in field geometry learning studied the effect of AR on space geometry material on student learning performance and attitudes analyze the use of AR on visualization and spatial understanding in higher education.

(b) Proposed/ Methodology

The stages of this study refer to the ADDIE approach (Analysis, Design, Development, Implementation, Evaluation) by limiting it to exploration analysis, design, development and implementation. The second level is ethnomatically integrated with AR At this stage, the steps taken are modelling, texturing, 3D import, Vuforia import, data base upload and import. After the design, the third stage, developing mobile learning that integrates ethnomathematics with AR a number of pre-service mathematics teachers from a mathematics education study program at a university in a province located on the Western Island of Java, Indonesia, participated voluntarily in this research.

(c) Result

The results of the implementation of the use of geometry learning that integrates ethnomathematics into AR indicate that there is an increase in the learning interaction activities of pre- service teachers in the field of geometry and space. The activities of the mathematics teacher candidates observed in this study include activities using the AR application, activities in solving ethnomathematics problem-solving puzzle, activities in discussion, activities in completing evaluation questions, activities in asking technical questions. The results of the observation of the interaction of pre-service teacher activities at the first meeting obtained a percentage of 52.18% and classified as quite active. Meanwhile, in the fourth meeting, the percentage of classical learning activities was 69.40% and classified as active. The classical activities of pre-service mathematics teachers increased by 17.22%.

DISCUSSION

There are many studies on AR that have been done to improve convenience and understanding in terms of learning at the school. There are several main reasons that researchers want to develop AR in education among them to facilitate in terms of student visualization of 3D structures. Most of their reasons are to help in terms of learning.

A deeper analysis of the four motivational factors that underlying user motivational experiences shows that AR fosters higher levels of attention, relevance, and satisfaction. The aim of this articles was to examine the effects of AR-assisted geometry teaching on students' 3D thinking skills. The results of the articles show that AR supported geometry teaching is an effective teaching method for improving the student 3D thinking skills. The effects of AR-assisted geometry learning on the subcomponents of 3D thinking skills are discussed below.

The current research aimed to determine experimentally if VR and AR applications can make the teaching of mathematics more interactive and interesting and can contribute to more efficient learning and understanding of mathematical concept.

CONCLUSION

The development and implementation of AR applications in the field of Mathematics are very importance for teaching and learning. The results of the research indicated that the use of AR applications had a higher impact on student's learning and understanding of mathematical concepts compared to traditional teaching approaches. Furthermore, the results revealed that these technologies are more interactive and interesting for the students than the use of printed material.

This research was to examine the effect of AR supported geometry teaching on students' 3D thinking skills. This research consisted of three steps. Developing a 3D thinking ability scale, design and development of an AR. From the articles listed, it is important in providing student with direct experiences with technologies about AR.

Paper	Purpose of Paper	Augmented Reality	Finding Result	Pro & Cons
A	To exposes elementary school with AR	Cyberchase shape quest is math apps for children 6-8 years old: 3 games Patch the path, Feed the Critters and Hide and seek.	The Cyberchase shape is the game generally usable and fun for the kids. Uncovered several usability issues.	**Pro:** Children can know early the AR technology, can engaging spatial cognition skills, teachers get news experience to teach student. **Cons:** hard to understand the mechanic of AR, make a tutorial that can easily to make teacher to understand.
B	To review the article about development of augmented reality and see the advantages for using the AR in education	Literature review about AR, A new technology in education	The review shown several fields in education that AR technology has the potential in future to make education better. AR helps students in learning process and improve their visualization skills.	**Pro:** technology can support for innovative forms of teaching and learning, potentials technologies for visualization of abstract concepts. **Cons:** AR technology have some limitation in education. Need more improvement about teaching and learning.
C	To study about educational media for student to understand 3D geometry.	AR modelling 3D space objects. The Concept of Building 3-Dimensional Geometry Space	The result of this AR geometry application is that can help teachers to teach student using visual space so that student can improve their skill.	**Pro:** new teaching aids for geometry, student can easily to imagine the 3D space, easier for teacher to present material, able to create a new interactive learning. **Cons:** To hard to understand how to use the AR, students need their own smartphone.
D	The aim of this research was to examine the effect of Augmented Reality (AR) supported geometry teaching on students' 3D thinking skills.	AR Geometry Tutorial System (ARGTS) and AR teaching materials and environments were developed to enhance 3D thinking skills	The results of this research are particularly important for identifying individual differences in 3D thinking skills of secondary school students and creating personalized dynamic intelligent learning environments	**Pro**: Students can improve their skill **Cons**: don't have a good device

E	To examine the current state of knowledge and practice about AR, to help student how to create an information model of building structure using AR.	Descriptive Geometry, Engineering and Computer Graphics (DGECG)	Present result shown AR has a further potential in field of education., this technology help to the educational process.	**Pro:** this application able to use in portable device, easy to create an informational model of building while using AR. **Cons:** not enough evidence to show the impact for AR on teaching and learning, need basic learning in drawing.
F	To explore the Impact of AR on learning outcomes and motivation of students from public and private Mexican school	Augmented reality-based learning	The augmented reality learning environment was more learning effective compared with the web-based learning environment in public schools, but not in private schools, there is not an interactive effect of type of technology, type of school and time of assessment when students' motivation is measured	**Pro**: There is an interactive effect of type of technology, the use of AR-based learning environments can be more effective compared with web-based learning environments for students coming from public schools. **Cons:** AR by students from private schools does not establish a significant advantage in terms of learning effectiveness.
G	To investigate the potential of using virtual and augmented reality technologies for teaching the lesson of geometric solids to primary school children	virtual and augmented reality to visualize 3D objects	The results indicate that the implementation of new technologies in education of virtual and augmented reality improve interactivity and student interest in mathematics education, contributing to more efficient learning and understanding of mathematical concepts when compared to traditional teaching methods.	**Pro:** Education is becoming more diverse, since new technological methods can be used within the classroom as cognitive-exploratory tools **Cons:** Most of the school do not have a good technology.
H	To develop AR based geometry learning for android and iOS platforms, to deploy the applications among the students for teaching 3D geometry in high school students.	Augmented reality base learning in education of geometry, ARLE system	The research gives immersive experience and visualization in learning and teaching process. Give benefit to student and teachers.	**Pro:** students can get personal assistance and better imagination in study of geometry; students get hint to solve problem. **Cons:** need to adapt and execute to make sure the continuous advancement and flexible responses to changes.

I	To analyse mobile tools that can be used to visualize teaching geometry	Two Augmented Arloon geometry and Geometry AR	AR also can make environment happier and make a good communication tool. Besides that, he learning outcomes are increased, the cognitive activity of the students increases,	**Pro:** self-realization for student, construct personal trajectory of learning for teacher, student understand mobile device can be used to organize the learning process. To reduce fear and anxiety attitudes. **Cons:** not free application, only support English and Spanish language
J	This study aims to integrate ethnomatematics into augmented reality technology in learning geometry	Augmented reality technology	The results of implementation analysis can help to increase learning interaction activities improve the understanding of concepts and geometry visualization, provide Kinformation to Mathematics pre-service teachers related to ethnomathematics and local wisdom in Indonesia	Pro: has given its own colour to the interaction of teachers and students in the classroom, increase student motivation and involvement in learning, promote contextual linking, AR-based mobile learning is able to grow the potential of students' spatial abilities, improve learning activities, and foster learning experiences for the users Cons: almost teachers don't know how to use AR and less equipment.

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