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Developing critical thinking competence in algebraic thinking using augmented reality for junior high school

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Abstract

The algebra learning promotes thinking about recognition and analysis of pattern, reasoning and problem solving skills, and generalizing arithmetic operation through representation with symbols. And all of these aspects need critical thinking competence. However, the high level of abstraction in algebra can cause difficulty for some students who have problems learning algebra and tend to show less positive attitudes toward algebra. In order to engage the students to algebraic thinking then teachers should deserve interactive learning such as virtual reality. Based on some papers, the Augmented Reality has positive outcomes on learning activity. Results revealed that students who learned algebra using Augmented Reality showed significantly higher mean scores in algebra thinking and attitudes toward algebra compared to the control group. Therefore, the authors wanted to examine the effects of an Augmented Reality (AR) for junior high school students. Furthermore, the paper also discusses the vision towards the future and opportunities for further research in Augmented Reality for educational systems.

Keywords:

Critical thinking, algebraic thinking, augmented reality

1. Introduction

1.1. Background

Preparing students to be able to think critically is the important key for the teacher. To prepare students for facing the industrial revolution 4.0, the critical thinking ability is the main asset for them to find solutions in order to face the challenges ahead. The critical thinking ability is very important because the ability to think logically, analyse problems, and creativity require critical thinking skills. Ornstein and Levine stated by according to Socrates, Plato's teacher revealed that discussion and critical thinking skills based on knowledge can be more inherent in individual thinking, which is better than a teacher who only transfers knowledge to students. (Changwong *et al.*, 2018)

Reeve (2016) also suggested the importance having critical thinking skills in the 21st century by junior high school students so that they can determine their majors in junior high school which later also determine the direction of their careers.

Algebra as a branch in mathematics plays a role in exploring the ability to think algebra including problem solving, representing, and analyzing skills. Edwards states that the most difficult aspect of increasing algebraic abilities in the early stages of junior high school is mastering important concepts of functions, algebraic notations, variables, and properties of numbers. (Siew *et al.*, 2018) Martinez's study in Trands in International Mathematics and Science Study (TIMSS) also shows that students have difficulties in answering questions that require understanding and application of algebraic expressions to perform complex procedures. (Siew *et al.*, 2018)

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To respond to the difficulties in learning algebra, Ferruci and Sinclair claimed that the modeling approach was a 'powerful tool' to improve critical thinking skills among junior high school students. This modeling approach is a development of pictorial manipulatives to analyze in algebra problems. (Siew *et al.*, 2018)

Based on Sensory Stimulation Theory, sensory stimulation is obtained from color-visual and audio. Virtual reality is an electronic which contains colors, sound, and complex graphics. Virtual reality can stimulate their curiosity, and their challenges. (Siew *et al.*, 2018)

In the last few years, virtual reality technology has been very popular and developed in various fields. First, this is because virtual reality is able to provide a new and interesting experience for its users. In the world of education, especially mathematics, this course will be a solution so that students experience personal experience in building their knowledge. With the simulation in virtual reality that is almost close to the real world, they can still experience conditions that are even difficult to find in the real world without the help of technology. Second, Augmented Reality can be used to illustrate abstract mathematical concepts. Third, students in AR-based learning environments may achieve greater learning self-efficacy.

Thus, the authors undertook this topic to find out how an augmented reality technology can help hone the critical thinking skills of students, especially in learning mathematics, especially algebra topics.

1.2. Statement of the problem

Therefore, the authors undertook the study to know how to develop critical thinking competence in algebraic thinking using Augmented Reality for Junior High School.

1.3. Research objectives

The main purposes of this research were: to evaluate and analyse the effectiveness of Augmented Reality technology in order to develop students' critical thinking in learning algebra.

2. Literature Review

2.1. The critical thinking

Most of difficult algebraic problems involve forming an expression and then solving it. It can develop the students' thinking on learning on algebra which is their critical thinking skill. Critical thinking competency is the ability to question norms, practices, and opinions; to reflect on own one's values, perceptions, and actions; and to take a position in the sustainability discourse. Furthermore, Bellenia, *et al*. (2018), critical thinking involves; asking questions; defining a problem; examining evidence; analysing assumptions and biases; avoiding emotional reasoning; avoiding oversimplification; considering other interpretations; and tolerating ambiguity.

Changwong, *et al*. (2018) stated that UNICEF, UNESCO and WHO list problem solving and critical thinking as two of ten core life skill strategies and techniques. With critical thinking, Bellenia, *et al*. (2018) stated that the students can enhance their creativity to solve the problem and seek new strategies when solving mathematical problems. Mulyanto, *et al*. (2018) stated that problem-solving is important for students to become effective problem solvers in their profession, and for later career success. Furthermore, the problem-based learning is focused on problems in which students can construct their own knowledge, develop inquiry and thinking skills to a higher level (Mulyanto, *et al*., 2018).

Each year the National Council for Excellence in Critical Thinking (NCECT) (2017) meets to discuss critical thinking. NCECT states that critical thinking is defined by an intellectually disciplined process of actively and skilfully *conceptualizing*, *applying*, *analyzing*, *synthesizing*, and/or *evaluating* information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. Students should regularly use the following checklist for reasoning to improve their thinking in any discipline or subject area:

2.1.1. All reasoning has a purpose

- State your purpose clearly.
- Distinguish your purpose from related purposes.
- Check periodically to be sure you are still on target.

- Choose significant and realistic purposes.

2.1.2. All reasoning is an attempt to figure something out, to settle some question, and solve some problem
- State the question at issue clearly and precisely.
- Express the question in several ways to clarify its meaning and scope.
- Break the question into sub-questions.
- Distinguish questions that have definitive answers from those that are a matter of opinion and from those that require consideration of multiple viewpoints.

2.1.3. All reasoning is based on assumptions (beliefs you take for granted)
- Clearly identify your assumptions and determine whether they are justifiable.
- Consider how your assumptions are shaping your point of view.

2.1.4. All reasoning is done from some point of view
- Identify your point of view.
- Seek other points of view and identify their strengths and weaknesses.
- Strive to be fair-minded in evaluating all points of view.

2.1.5. All reasoning is based on data, information, and evidence
- Restrict your claims to those supported by the data you have.
- Search for information that opposes your position, as well as information that supports it.
- Make sure that all information used is clear, accurate, and relevant to the question at issue.
- Make sure you have gathered sufficient information.

2.1.6. All reasoning is expressed through, and shaped by, concepts and ideas
- Identify key concepts and explain them clearly.
- Consider alternative concepts or alternative definitions of concepts
- Make sure you are using concepts with care and precision.

2.1.7. All reasoning contains inferences or interpretations by which we draw conclusions and give meaning to data
- Infer only what the evidence implies.
- Check inferences for their consistency with each other.
- Identify assumptions that lead you to your inferences.

2.1.8. All reasoning leads somewhere or has implications and consequences
- Trace the implications and consequences that follow from your reasoning.
- Search for negative as well as positive implications.
- Consider all possible consequences.

2.2. The algebraic thinking

Algebraic thinking is about reasoning, using notations, and calculation of unknown numbers (Mustofa, *et al.*, 2015). Furthermore, according to Nurhayati, *et al*. (2017), algebraic thinking consists of understandings series which is needed to interpret the world by translating information or events into the language of mathematics in order to explain and predict the phenomena. Siew, *et al*. (2016) stated that algebra is one of the branches of mathematics has the ability to promote algebraic thinking.

In both junior and senior high school, especially in Indonesia, the students have difficulties in learning with algebraic thinking. Most of the students didn't understand about the concept of algebra. They also think that learning algebra is not fun. Based on these facts, the authors were thinking about how to make the learning process of algebra is fun with algebraic thinking.

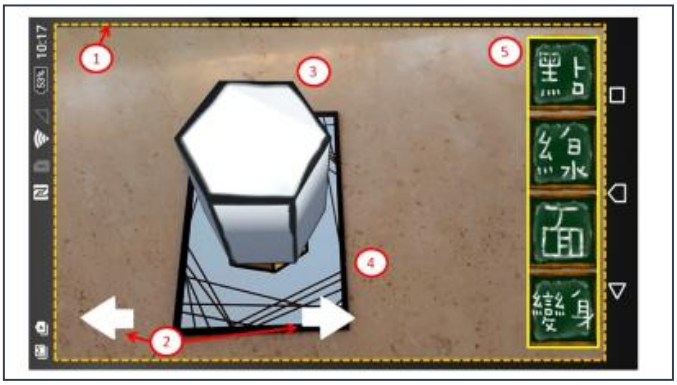
2.3. The augmented reality (AR)

Saltan & Arslan (2016) stated that education can be circled around different forms of media, ranging from non-interactive books to highly interactive ones that might arouse a wide variety of senses. In recent years, technology-enhanced learning (TEL) research has increasingly focused on emergent technologies such as

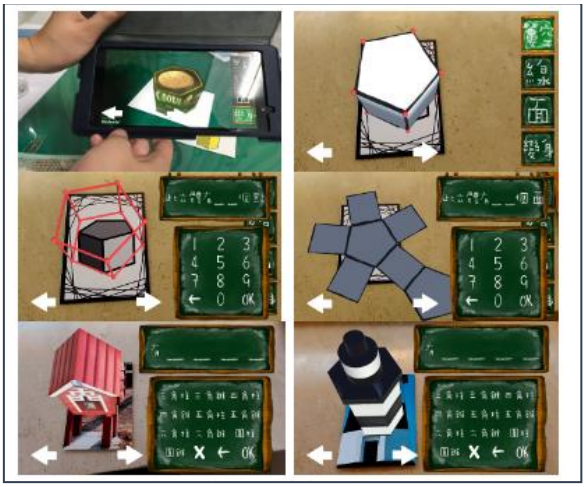
augmented reality (AR), ubiquitous learning (u-learning), mobile learning (m-learning), serious games and learning analytics for improving the satisfaction and experiences of the users in enriched multimodal learning environments (Bacca, *et al*., 2014). According to Saltan & Arslan (2016), AR is defined as having three main characteristics, (1) combination of real and virtual, (2) real-time interactivity, and (3) 3D registration. AR applications supplement the real world by incorporating virtual or computer-generated content.

Increase in the number of mobile devices and easy access to these devices has made it possible for large masses to utilize AR. This prevalence has taken effect in the field of education as well and especially in recent years, the use of AR for educational purposes has become a significant topic of research. In 2018, according to Karl, *et al*. (2018), the costumers of AR & VR chose Education with 26 percent which has the same amount with healthcare and medical devices as top 3 sectors that they expected to see the most investment directed to the development of AR or VR technology in the next 12 months. It means that the customers of AR & VR or in this case were teachers and students were satisfied with the experience of the AR technology during teaching-learning processes.

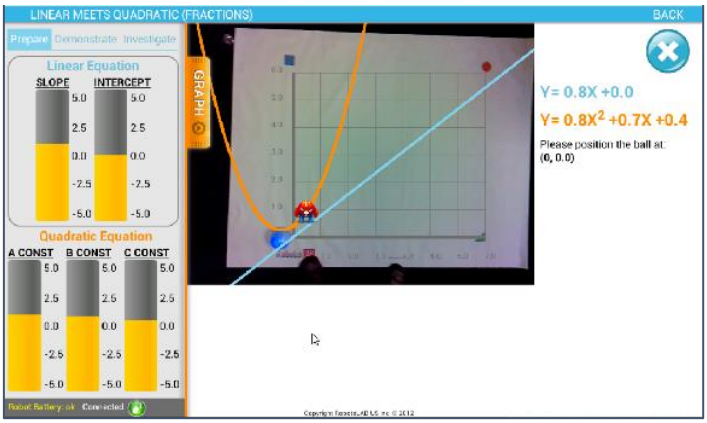
Saltan & Arslan (2016) suggest that to achieve such critical learning outcomes during the teaching-learning processes, the educators must constantly utilize 'contemporary and cutting-edge' technological applications, one of which is AR. Saltan & Arslan (2016) also noted that augmented reality (AR) is recognized as one of the most important developments in educational technology for both higher and K-12 education as emphasized in Horizon report and is expected to achieve wide spread adoption that will take two to three years in higher education and four to five years in K-12 education. To make the algebraic learning and algebraic problem solving fun, the teachers can use the AR during learning process. The teachers can use the AR to explain the real form of an algebra expression and tell the problem solving process to solve them.



Gambar 1. The interactive Math App



Gambar 2. Multimedia effects of the AR Math learning app



Gambar 3. AR-based learning in algebra lesson

3. Methodology

In this study, the authors use the literature method from several researchers, they are:

- From Lin, H. C. K., Chen, M.C., & Chang, C. K. (2015) from Taiwan, they examined 76 students of K-12 with Image-based AR concluded Concept Acquisition, with no pedagogical approach and produced Students' performances from the AR assisted teaching improved, yet there was not a significant difference between the groups. Students with average and low academic achievements benefit the most with the space of AR is not recognized;
- from Chen, C. P., & Wang, C. H. (2015) from Taiwan, they examined 144 students of K-12 with Image-based AR concluded Concept development, with no pedagogical approach and produced a better learning achievement and playing with the AR toolkit was either interesting or valuable with the space of AR is not recognized;
- from Hsiao, *et al.* (2016) from Taiwan, they examined 64 students of K-12 with Image-based AR concluded Academic Achievement, with a learning tool comparison and produced a Greater positive impact on students' academic achievement and motivation. Higher creativity on students' inquiry-based learning. Increase in interest to use the application for learning with the space of AR is not known.

4. Discussion and Conclusion

Many studies have explained that the effects of AR on students' learning gains or motivations, only a few of them paid attention with different self-efficacy. Cai *et al.* (2019) evaluate how an AR application influenced junior high school students' conceptions of and approaches to learning mathematics with different levels of self-efficacy. The students were categorized into two groups (the higher self-efficacy group and lower self-efficacy group) according to the pretest. It was found that the students with HSE attained higher scores than those with LSE. The students with HSE may have more engagement and involvement in the learning activity with the AR application than others, and their confidence may make them learn in deeper way. Meanwhile, for the students with LSE, they pay the same attention, so there is no significant difference between them. However, it does not mean that AR-based learning only beneficial the students with HSE. Due to their self-efficacy level, their gains are not significant as the higher self efficacy group, but they do get enhancement.

Chao & Chang (2018) said that the development of AR applications helps learners to learn meaningfully since provide us with different degrees of interactivity and presentation of information. However, learning through assistance of technology does not necessarily improve students' learning effectiveness. Technology must be accompanied by skillful teachers.

Based on the literature review, AR can improve critical thinking skills and algebraic thinking in junior high school students. Usually, algebra problem solving has two steps to solve it. First, algebra definitely forms algebraic expressions then solves algebraic problems and then gets an answer. It can make students think critically. By using AR application students defined by intellectually disciplined process of actively

and skilfully *conceptualizing* the algebraic concept by constructing their own knowledge, *applying* the algebraic concept by making a graph or else, *analyzing*, *synthesizing*, and/or *evaluating* information generated by observation, experience, reflection, reasoning, or communication, as a guide to belief and action.

The weakness of using AR-based learning cannot be applied in the countryside since there are no sufficient facilities. Therefore, AR can be applied in urban area only. Students in urban areas might perceive the AR in the classroom quickly even if it is their first touch of this technology, for they have more access to new information technologies.

5. Recommendations

This study suggests that the AR-based learning can be used for junior high school students to learn about algebra lesson. This activity will engage students such that pay more attention in algebra lesson. It implies that their critical thinking ability is also enhanced since by using AR application students defined by intellectually disciplined process of actively and skilfully *conceptualizing* the algebraic concept by constructing their own knowledge, *applying* the algebraic concept by making a graph or else, *analysing*, *synthesizing*, and/or *evaluating* information generated by observation, experience, reflection, reasoning, or communication, as a guide to belief and action. The way to apply the AR-based learning to the students with high self-efficacy level, but it will be also possible to apply it to the students with low self-efficacy level.

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