Augmented Reality for Integer Learning: Investigating its potential on students’ critical thinking

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Abstract. Research on critical thinking has been carried out by researchers. Critical thinking is one of the four skills students must have before the 21st century. In recent years Augmented Reality (AR) technology has provided opportunities by making learning more interesting, that able to visualizing mathematical objects in the real world. This research was conducted in a remote area of Bawean Island after the mathematics teachers participated in Augmented Reality-based mathematics learning media development program. The sample of the study was 95 students of 7th grade junior high school from five schools on Bawean Island. Investigation of the potential use of Augmented Reality technology to critical thinking skills, carried out by providing students with pretest and posttest critical thinking skills. Also, student responses were considered in this study. The results of our analysis, the ability of student’s critical thinking skills after the use of AR-based media is better than before the use of AR-based media, and students give a very good response to the use of AR-based media in this integer learning.

1. Introduction
Critical thinking becomes an important issue in education, where critical thinking is one of the four abilities that must be possessed by students before the 21st century [1]. The ability to think critically is very important to have, because as capital in problem-solving. The urgency of critical thinking skills in students has attracted many researchers to conduct research related to how to develop critical thinking skills in students [2-4]. Critical performance abilities are abilities that must be possessed by students [5,6]. Some people give different definitions of this critical thinking ability. Among them is the ability to think critically is thinking aimed and directed at the goal, as well as the types of thinking involved in solving problems, formulating conclusions, calculating possibilities, and making decisions, when thinkers use skills that are wise and effective for the context and types of specific thinking tasks [7]. Because of the importance of this ability possessed by students, it is necessary to do a lot of things to equip students with these skills [3,8].

Various attempts were made to develop students' critical thinking skills. Firstly, improving students’ critical thinking through combines learning science inquiry with mind maps [9], significantly able to improve students' critical thinking skills. Secondly, developed an augmented reality-based learning media to improve students' critical thinking skills 10. Thirdly, developed a guided inquiry-based worksheet that was significantly able to improve students' critical thinking skills in Indonesia
Next, designed Problem Based Learning based student worksheets to improve students' critical thinking skills [12]. Lastly, developed the IRT-Based Physics Critical Thinking Skills Test to answer the challenges of the 21st century [13]. This presentation shows the close relationship between the creativity of teachers in managing to learn towards increasing students' critical thinking skills.

In this research, mathematics teachers in remote areas of Bawean Island followed the development program of mathematics learning media with augmented reality technology. This is one form of teacher creativity in managing to learn. The teacher's creativity in learning and the effectiveness of his teaching are two inseparable things. Because of the urgency of teachers' creativity, much research has also been carried out in the management of learning [14-16]. Some experts provide definitions of teacher creativity in several categories, namely producing new and unique teaching methods, a variety of strategies, and having a strong commitment to increasing the learning success of students through effective means [17-21]. Most of the existing research on teacher creativity is on the teacher's role in increasing student success. For example [21], they investigated the relationship between teacher creativity and teaching effectiveness and explored the differences between the creativity of male and female teachers. The results revealed that teacher creativity positively influenced the effectiveness of their teaching and female teachers were considered more creative than men.

The use of AR in learning by teachers in remote areas of Bawean Island is seen as a form of innovation and creativity in learning. Previous research conducted by researchers related to the effects of teacher creativity on students in 2019, [22] obtained by students tended to be more involved in learning when the teacher was creative. Student's ability to involve themselves in learning is the key to success in learning, including the ability to have critical thinking [23]. In other words, the creativity of mathematics teachers can make students involve themselves in learning so that the effect is an increase in learning outcomes as well as the potential to increase their critical thinking skills [24]. Therefore, this study wants to explore the potential for increasing students' critical thinking skills, after their teachers use augmented reality technology in mathematics learning as a form of their creativity. The results of the analysis show that there is the potential for increasing students' critical thinking skills after the use of Augmented Reality-based media.

2. Literature Review

2.1. Critical Thinking Skill

Critical thinking skills are one of the abilities students must have. Critical thinking skills including the component skills of analyzing arguments, making conclusions using inductive or deductive reasoning, assessing or evaluating, and making decisions or solving problems [25]. So that this ability gets a lot of attention until it produces a critical thinking ability measurement instrument for various categories, namely the California critical thinking skill test (CCTST), California critical thinking disposition inventory (CCTDI), Business critical thinking skill test (BCTST), and Military and defense critical thinking inventory (MDCTI). The instrument was developed and validated by [26].

Research on critical thinking skills has contributed significantly to various aspects of learning, including mathematics learning. For Example, examines the effect of giving three learning models to students on their thinking abilities [9]. They found that there are different values of critical thinking skills with different learning models. The DSI model contributes higher to improve scores on critical thinking skills than conventional models. Meanwhile, DSI combined with the mind map model provides the highest potential to improve critical thinking skills compared to the other two models. Likewise, the inquiry learning model has been proven to contribute significantly to the scores of critical thinking skills. Then, developed an augmented reality-based learning media to improve students' critical thinking skills [10]. In his research, 34 students were given tests of critical thinking skills before and after the use of augmented reality media, the results of students' critical thinking skills after using of media were better than before. Next, designing an inquiry-based worksheet to
improve students' critical thinking skills [11]. In this research, inquiry-based worksheets can be used to improve students' critical thinking skills, with the subject of 7th-grade students of Al-Azhar 26 Yogyakarta. Then, developing the IRT-Based Physics Critical Thinking Skills Test to answer the challenges of the 21st century [13]. In his research, he developed an instrument of critical response skills based on item response theory (IRT) using computers, with research subjects totaling 252 students in Yogyakarta, Indonesia.

2.2. Augmented Reality technology

Augmented reality (AR) allows virtual objects generated by computers to be placed on physical objects in real-time [27]. Combining the real world and the virtual world makes the boundary between the two very thin. AR as a system has the following three characteristics: (1) Real and virtual integration; (2) Interactive in real-time; (3) Registered in 3-D [28]. AR technology can load a video, sound, photos, text, 3D models [29,30]. Users can interact with virtual objects included in real scenes around them and get real human-computer interaction experiences [31]. The use of AR technology in learning allows students to explore the world interactively and collaboratively [32,33].

The use of Augmented Reality in learning, was proven to make students pay more attention to learning, focus more on learning after using augmented reality [34]. Many studies have explored the use of AR technology developed in improving teaching and learning. AR as a technology for education, multimedia that is displayed relative to the actual object [35]. Analysis of research from 2009 to 2017 on how Augmented reality has a positive impact on education, has been carried out[1]. AR technology can improve learning outcomes, improve digital literacy, communication and creative thinking as needed in the 21st century [36].

3. Methods

The research subjects in this study consisted of 95 students drawn randomly from five schools on Bawean Island. Students consist of men and women, and they are all seventh-grade students.

| School participated in this study | Students                  |
|----------------------------------|---------------------------|
| School 1                         | 24 (8 male & 16 female)   |
| School 2                         | 16 (entirely male)        |
| School 3                         | 20 (9 male, 11 female)    |
| School 4                         | 21 (15 male & 6 female)   |
| School 5                         | 14 (5 male & 9 female)    |

In this study, these students access material and practice questions that have been developed with AR technology (Figure 1). Meanwhile, AR content was developed by a team with mathematics teachers on Bawean Island (the results of the development of Figure 2). Before the use of this AR, students are given a critical thinking ability test with a topic on integer material in 7th grade. The questions are 10 items, consisting of 5 short answer items, and 5 applied question items. It should be noted that, in completing these integer operations, critical thinking skills are required, which operations must be performed first.

Furthermore, during four class meetings, students explore integer material using AR media that has been installed on their smartphone. Students discuss in groups (Figure 1). At the end of the fourth meeting, students are again given a critical thinking ability test, which consists of 10 items, with details of 5 short answer items, and 5 question related to the application of integer operations in daily life. Besides, students were also given a questionnaire response to AR-based learning media that they have used.
Both pretest and post-test instruments for the ability to think critically are tested for validity and reliability in advance so it is feasible to use. Next, the pretest and post-test data of critical thinking ability were analyzed using SPSS to see whether there were differences in students' critical thinking skills before and after the use of augmented reality-based learning media. Meanwhile, student questionnaire data were processed using descriptive statistics.

4. The Result
There are two main variables in this study, namely the ability to think critically before the use of AR, and the ability to think critically after the use of AR. First, a descriptive statistical analysis of the two variables was carried out using SPSS.

| Table 2. Descriptive Statistics summary of pretest and posttest critical thinking skill |
|---------------------------------|--------|--------|--------|--------|--------|
| N                                | Minimum | Maximum | Mean    | Std. Deviation |
| Pretest of critical thinking skill | 95     | 40.00   | 76.00   | 62.5271  | 1.88778 |
| Post-test of critical thinking skill | 95     | 50.00   | 95.00   | 83.9147  | 5.51140 |
| Valid N (listwise)               | 95     |         |         |          |         |

The range of critical thinking ability values for pretest is 40 and 76, while the range of critical thinking ability values for the post-test is 50 and 95, then, the normality of the data is tested before paired sample t-test.

| Table 3. The result of the normality test |
|-----------------------------------------|
| Tests of Normality                      |
|                                         |
| Pretest of critical thinking skill      |
| Kolmogorov-Smirnov  \(a\) Statistic     |
| .141                                    |
| df                                      |
| 94                                      |
| Sig.                                    |
| .200*                                  |
| Shapiro-Wilk Statistic                 |
| .959                                   |
| df                                     |
| 20                                     |
| Sig.                                    |
| .529                                   |
| Post-test of critical thinking skill   |
| Kolmogorov-Smirnov  \(a\) Statistic     |
| .174                                    |
| df                                      |
| 94                                      |
| Sig.                                    |
| .113                                   |
| Shapiro-Wilk Statistic                 |
| .896                                   |
| df                                     |
| 20                                     |
| Sig.                                    |
| .035                                   |
| *. This is a lower bound of the true significance. |
| a. Lilliefors Significance Correction |
Table 3 shows that the data to be analyzed is normally distributed. Next is to do a paired sample t-test to determine the significance of differences in students' critical thinking skills before using AR and after using AR.

**Table 4. Paired sample t-test**

| Paired Differences | Mean | Std. Deviation | Std. Error | 95% Confidence Interval of the Difference | t | df | Sig. (2-tailed) |
|--------------------|------|----------------|------------|------------------------------------------|---|----|----------------|
| Pair 1             |      |                |            |                                          |   |     |                |
| Pretest of critical thinking skill - Post-test of critical thinking skill | -10.88235 | 12.93149 | 1.18543 | -13.22982 | -8.53488 | -9.180 | 94 | .000 |

Based on Table 4, we get the Sig. (2-tailed) of 0.00 whose value is smaller than 0.05, so the initial hypothesis of this study that there are differences in students' critical thinking skills after using AR-based teaching materials on integer material compared to before. From Table 3 we can also get the difference in the average test of critical thinking skills when the posttest and pretest are 21.3876. More clearly, the difference between the posttest and pretest scores is presented in the following graph:

**Figure 3. The Field-Testing Data**

The results in Figure 3 show that students' critical thinking skills after learning to use AR-based teaching materials are better than before learning to use AR-based media. This fact confirms that this media can be used on a broader scale, not only students in remote areas of Bawean Island. Meanwhile, the results of students' responses to the use of multimedia based on augmented reality in integer learning in 7th-grade junior high school students can be seen in Table 5.
Table 5. Students responses to product AR-based material

| No | Aspect    | Score | Category |
|----|-----------|-------|----------|
| 1  | Learning  | 4.12  | Good     |
| 2  | Programming | 4.33 | Very good|
| 3  | Display   | 4.35  | Very good|

Based on Table 5, students' responses to AR-based media were generally very good. In the aspect of programming and display got the highest score with a very good category. Students see that AR-based media developed is interesting and easy to use. The input from students at the implementation stage was that the number of practice questions was still lacking because they were very interested in this media, so they were very enthusiastic in working on the questions in the media. Students argue that the using of this media can help them to understand integer material more easily. Besides an easier understanding of various operations in integers. This finding is different from the initial conditions which indicate that students are not yet interested in learning integers. Students are not careful in solving integer problems. Students assess that learning integers with the help of AR-based multimedia makes students involved in learning so that they can better understand the material being studied.

5. Discussion

To our knowledge, there have not been many studies examining the effect of AR-based learning media on students' critical thinking skills. Our results show two significant implications, which we discuss the following:

First, all students are involved in learning activities with AR media, meaning that gender does not influence this learning activity. In contrast to studies that have been done by previous researchers, that female students have a higher involvement than male students [22]. When learning is done with AR-based learning media, both female and male students, are very interested and have high enthusiasm for learning. This finding supports previous research that examines the effect of AR media on student creativity [37] in his research stating that there are no different perceptions of the use of AR in learning activities.

Second, AR-based media as an innovation in mathematics learning especially integer material can improve students' critical thinking skills. This AR-based learning media can help students understand integer material, solve integer problems in daily life, so that this AR-based learning media has a contribution in increasing students' critical thinking skills [38-41]. The results of this study are in line with the results of previous studies. The development of AR-based interactive multimedia on earth and rock structure material can improve students' critical thinking skills [10]. The development of textbooks with augmented reality technology on the material of the digestive system can improve students' ability to analyze problems related to the concept of digestion [42]. Besides, other research also mentioned that the development of interactive learning media based on augmented reality technology can improve secondary school students' problem-solving skills in chemical bonding materials [43]. Then, the use of Augmented Reality media can stimulate students' mindset in thinking critically about something because they can visualize abstract concepts [44]. In this study, the presentation of integer material in 3D objects in real-time through the AR camera can help students understand the material of integers down to solving integer problems. Also, this AR-based learning media can facilitate interactive learning, so there is feedback in the form of ideas, in the form of arguments and providing explanations, as well as the results of problem-solving in integer problems.

6. Conclusion

Integer learning using Augmented Reality-based media, able to create an interactive learning atmosphere, students are involved in learning, students are easier to understand integer material and able to solve problems related to integers in everyday life. So that the use of AR-based learning media in integer material is appropriate for use by junior high school mathematics teachers to improve students' critical thinking skills.
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