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Implementation of mobile augmented reality on physics learning in junior high school students

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Abstract

Technology has an essential role in the educational field. Technology-based mobile has the potential to improve education through Augmented Reality (AR). This study investigates the effect of mobile augmented reality on physics learning achievement and students' opinions on using this technology. The study used a convergent parallel pattern from mixed-method models in which quantitative and qualitative data are collected simultaneously and analyzed independently. The study participants are 64 (7^{th}-grade students) who are learning solar system concepts at one of the junior high schools in West Java Province, Indonesia. This study collects pre- and post-test data as quantitative data to analyze students' learning achievement using the normalized gain score. The result showed that the students using mobile augmented reality have higher criteria for learning achievement than those using textbooks. The qualitative data was collected from interviewed students after using mobile augmented reality and analyzing using descriptive analysis. The results of the student opinion state that augmented reality is a new learning environment that effectively helps them understand physics concepts, enhances students' learning achievement and helps concretize abstract concepts through visual 3D simulations. Moreover, according to the study, students find it easier to understand physics concepts after using mobile augmented reality.

Keywords: Augmented reality, Learning achievement, Physics, Solar system, Students' opinion, Technology.

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Contribution of this paper to the literature:
This study contributes to the existing literature on integrating Augmented Reality (AR) technology in education. This paper explains the implementation of mobile AR in physics learning to improve learning achievement regarding an abstract concept that students have never encountered before. The study found that using mobile AR affected students' learning achievement.

1. Introduction

Physics is difficult for many students. It is important in the 21st century (McFarlane, 2013) because it trains students to think rationally and improves their communication and creative thinking skills (Eristya & Aznam, 2019). Furthermore, science learning enhances lives by using knowledge and becomes a challenge for teachers to ensure that students are interested in learning science.

The teaching of physics as a part of science education must enhance students' understanding of their surroundings using the knowledge they have learned and relating it to the rapid development of technology. Technology can help students understand situations and problems in the real world by visualizing the concepts (Kiryakova, Angelova, & Yordanova, 2018). One of the technologies emerging today is Augmented Reality (AR) (Maulana, Suryani, & Asrowi, 2019) which combines real and virtual environments (Hwang, Wu, Chen, & Tu, 2016). The Horizon report by the New Media Consortium's New Technology Initiative showed that AR is an emerging technology that impacts the learning process (Becker et al., 2017). Augmented reality technology will be more effective when combined with mobile learning so a new term appears: mobile augmented reality (Joan, 2015; Nincarean, Alia, Halim, & Rahman, 2013). In the implementation of mobile augmented reality, objects can be visualized as three-dimensional (3D) (Cai, Wang, Gao, & Yu, 2012) attracting students' attention and interest during the learning process (Saidin, Halim, & Yahaya, 2015) and increasing students' focus which affects their understanding of concepts (Riva, Baños, Botella, Mantovani, & Gaggioli, 2016).

Many students think that physics is difficult because there are many abstract concepts in the concretizing object (Fidan & Tuncel, 2019). It has many formulations and difficult concepts related to everyday life (Schoeller, Perlovsky, & Arseniev, 2018). All problems experienced by students can be overcome by implementing augmented reality in the learning process. Augmented reality allows students to explore concepts that are not visible to the naked eye and make them visible (Yilmaz, 2021) and it displays real objects that have never been seen before (Guntur & Setyaningrum, 2021).

Implementing mobile augmented reality is suitable when the phenomenon cannot be simulated in reality, such as in the solar system (Cai et al., 2012). The introduction of the concept of the solar system is an essential concept in astronomical learning as part of science learning (Martin, Ho, Henesey, & Bestak, 2018). Students are often asked to imagine the planet. However, students' imaginative abilities are still lacking and it is difficult for them to imagine how the solar system uses imagination. This problem requires improvements in the learning methods and tools used in science teaching.

Teachers must create an interactive learning environment where students can learn easily, improving their ability to understand concepts and scoring higher learning achievements. Learning based on experiences can facilitate abstract concepts and increase interest in learning. (Salmi, Thuneberg, & Vainikainen, 2017). Integrating technology into learning can provide new learning experiences for students (Kan & Özmen, 2021). This study will investigate the effect of mobile augmented reality on physics learning achievement in junior high school students. This study attempts to answer the second research question: (1) How does learning physics using mobile augmented reality technology affect students' learning achievement? (2) What are the students' opinions on mobile augmented reality technology in physics learning?

2. Methodology

2.1. Research Design

This research is based on mixed methods with approximate convergent parallel models (Halcomb & Hickman, 2015) which means that quantitative and qualitative data are collected simultaneously and analyzed independently according to the research context. Then, combine two data sets for meaningful results. This study uses qualitative methods to analyze students' opinions after using mobile augmented reality in physics learning. In contrast, a quantitative method was used to collect and analyse student learning achievement scores.

2.2. Participant

The study was conducted on 64 (7th-grade students) at one of the junior high schools in West Bandung, West Java Province, Indonesia, in the 2021-2022 academic year. The participants had never seen or used mobile augmented reality technology before. The study was conducted in a randomly selected class. The demographic characteristics of student distribution regarding gender are given in Table 1.

Table 1. Gender distribution participants.

Group	Female	Male
Class A	18	14
Class B	16	16

2.3. Procedure of Research

The study includes six weeks for the solar system concept in science learning. Class A used mobile augmented reality for learning - solar system supported by smartphones while class B used textbooks. All students who had smartphones in class A were asked to download the mobile apps and use their smartphones during the implementation process. The procedure of implementation research during the investigation and the schematic structure of this study are shown in Figure 1.

The study procedure was completed in 6 weeks as shown in Figure 1. In the first week, students learned about mobile augmented reality technology and how to use these apps. The student also takes a pre-test to test learning achievement and determine initial capabilities. Next, the learning process lasts for three weeks in classes A and B with the same subject. The mobile augmented reality solar system used in Class A is a product of Indonesian government. Students in Class A were asked to download the mobile application and bring their smartphones during the implementation process. The display of the mobile augmented reality solar system is shown in Figure 2.

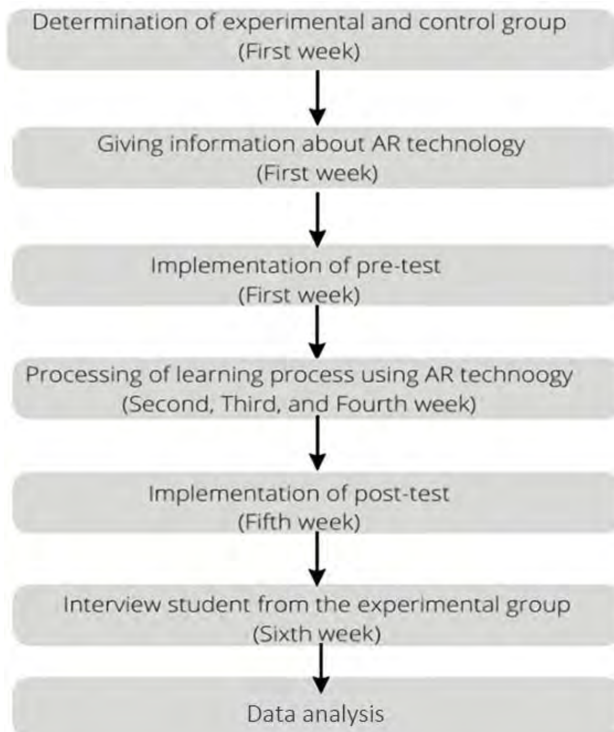

Figure 1. The procedure of the study.

Figure 2. The display of the mobile AR-solar system.

Students learn about the solar system and the sun in the first week. In the second week, students learn the concepts of rotation, revolution, lunar and solar eclipses. Then, in the third week, students learn about the concept of the tide effect. Furthermore, they take a post-test to evaluate students' learning achievement and interview students to investigate their opinions on mobile augmented reality technology in physics learning.

2.4. Research Instrument

The instruments used in this study are pre- and post-tests of learning achievement in physics concepts and student interviews. The learning achievement test consists of 15 multiple-choice questions on the solar system topic with several concepts such as (1) characteristics of the solar system (2) the sun (3) rotation and revolution (4) lunar and solar eclipses (5) the tide effect. Each concept consists of 3 questions and two lecturers have validated the instrument. The question indicator for each item is shown in Table 2. The interviews were conducted after the learning process to determine students' opinions after using mobile augmented reality in physics learning.

Table 2. The question indicators of each item test.

Solar system concept	Item number	Indicator of item test
Solar system	Q1	Students can determine the extent of the planet that is at the closest distance from the sun.
	Q6	When presented a picture of a planet, the students were asked to select the appropriate statement for the planet on the image.
	Q11	Students can group planets based on the trajectory of an asteroid as its limiter.
The sun	Q2	Students were asked to determine the order of the sun's layers from the core to the outermost layer.
	Q7	Students were asked to form a solar structure whose temperature reaches 6000 ^{0}C.
	Q12	Students were asked to determine the layer of the sun that looks like a greyish-colored crown during a total solar eclipse.
Rotation and revolution	Q3	Students were asked to indicate events that were not affected by the revolution of the earth.
	Q8	Students were asked to select events caused by the rotation of the earth.
	Q13	Students can distinguish between the period time revolution of the moon towards the sun and the revolution of the moon towards the earth.
Lunar and solar eclipse	Q4	Presented pictures showing the positions of the sun, moon and earth and students had to determine the events that were happening.
	Q9	Presented a picture when the position of the moon in the penumbra, students was asked to determine the eclipse event that occurred.
	Q14	Students were asked to establish the correct position during a solar eclipse.
Tide effect	Q5	Students were asked to demonstrate activities that take advantage of the effect of the tides.
	Q10	Students were asked to determine the position of the moon resulting in the highest and lowest tides based on the picture presented.
	Q15	Students were asked to determine the date of *Hijriah* based on the highest tides.

The participants in the interview section are six students selected randomly from class A. Students have been informed about the purpose of the interview and how their answers would be used in the study. Before the interview was conducted with students, the interview questions were discussed with a lecturer. Interview questions were distributed after students finished the post-test. All of the conversations during interviews were audio-recorded. The interviews took place in the science laboratory one by one for an average of 10 minutes per student.

2.5. Data Analysis

To describe the comparison between the pre-and post-tests in physics learning achievement, the researcher used "normalized gain $\langle g \rangle$". The formula for calculating the normalized gain is (1) with the scoring criteria presented in Table 3.

$$\langle g \rangle = \frac{\%post - \%pre}{100 - \%pre} \qquad (1)$$

Where %post is the percentage post-test score and %pre is the percentage pre-test score.

Table 3. Criteria of normalized gain scores (Hake, 1998).

Normalized gain $\langle g \rangle$	Criteria
$\langle g \rangle \geq 0.7$	High
$0.7 > \langle g \rangle \geq 0.3$	Medium
$\langle g \rangle < 0.3$	Low

Source: Criteria adopted from Hake (1998).

Therefore, interview data from the audio recording was converted into sentences that matched the actual data, so there was no change. Each participant's interview was given a unique code, for example, P01. P stands for physics and number 01 shows the student order code in the interview. Condensation of facts in the study was carried out by changing the interview transcripts into more straightforward sentences. After converting the audio recording into a sentence, the next step is collecting similar points for categorization and finding keywords for the data narration of the research findings. The categorization presents a collection of facts because the points obtained are so broad and deep, generating sub classification differences (coding) and the most relevant classifications are selected to answer the research question (Basit, 2003).

3. Result

3.1. Effect of Mobile AR on Physics Learning Achievement

The results of this study show that implementing mobile augmented reality in physics learning activities can improve students learning outcomes. Class A and B pre-test scores on learning achievement were calculated, their mean scores were 46.87 and 39.58 respectively. There was an increase in the post-test score in classes A and B, their mean scores were 84.79 and 58.12 respectively. The average pre-and post-test comparison scores between classes A and B are shown in Figure 3.

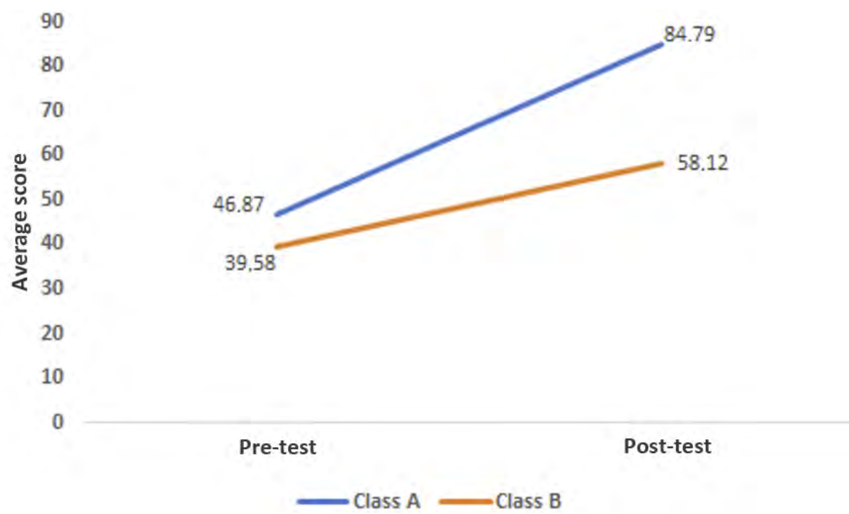

Figure 3. The comparison of pre-and post-test scores in classes A and B.

The normalized gain score is calculated according to Equation 1 and is used to compare the pre-and post-tests in classes A and B as shown in Table 4.

Table 4. Result of the normalized gain score in classes A and B.

Group	Average pre-test score	Average post-test score	Average ⟨g⟩	Criteria
Class A	46.87	84.79	0.71	High
Class B	39.58	58.12	0.30	Low

Table 4 shows that the average normalized gain score in class A is 0.71 which meets the criteria of "high". This contrasts with the average normalized gain score in class B is 0.30 with the "low" criteria. This result can be interpreted as showing that implementing mobile augmented reality in class A can significantly improve students' learning achievement compared with class B without mobile augmented reality technology. In physics learning achievement tests, five sub-concepts were investigated namely: (1) the solar system (2) the sun (3) rotation and revolution (4) lunar and solar eclipses (5) the tide effect.

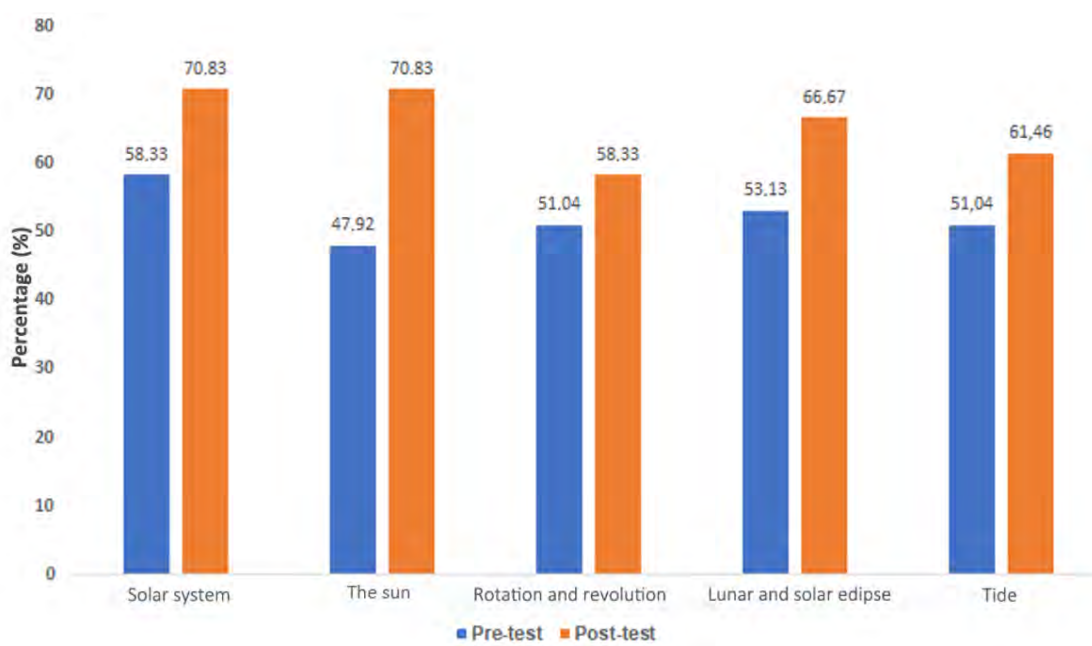

Figure 4. The comparison of each sub-concept in class B.

The score of physics learning achievement on each concept has increased based on the pre- and post-test scores in class B as shown in Figure 4. The normalized gain score was calculated according to Equation 1 and the improvement in each concept is shown in Table 5.

Table 5. The results in the normalized gain scores for each sub- concept in class B.

Sub concept	Average pre-test score	Average post-test score	Average ⟨g⟩	Criteria
Solar system	58.33	70.83	0.30	Medium
The sun	47.92	70.83	0.44	Medium
Rotation and revolution	51.04	58.33	0.15	Low
Lunar and solar eclipses	53.13	66.67	0.29	Low
Tide effect	51.04	61.46	0.21	Low

The highest criteria are in the solar system and sun concepts with normalized gain scores of 0.30 and 0.44 respectively and are included in the "medium" criteria. The other concepts consisting of rotation and revolution, lunar and solar eclipse and tide have a gain score of 0.15, 0.29 and 0.21 respectively and are still included in the "low" criteria. Based on these results in Table 5, learning achievement on each concept increases especially in the solar system and the sun concept.

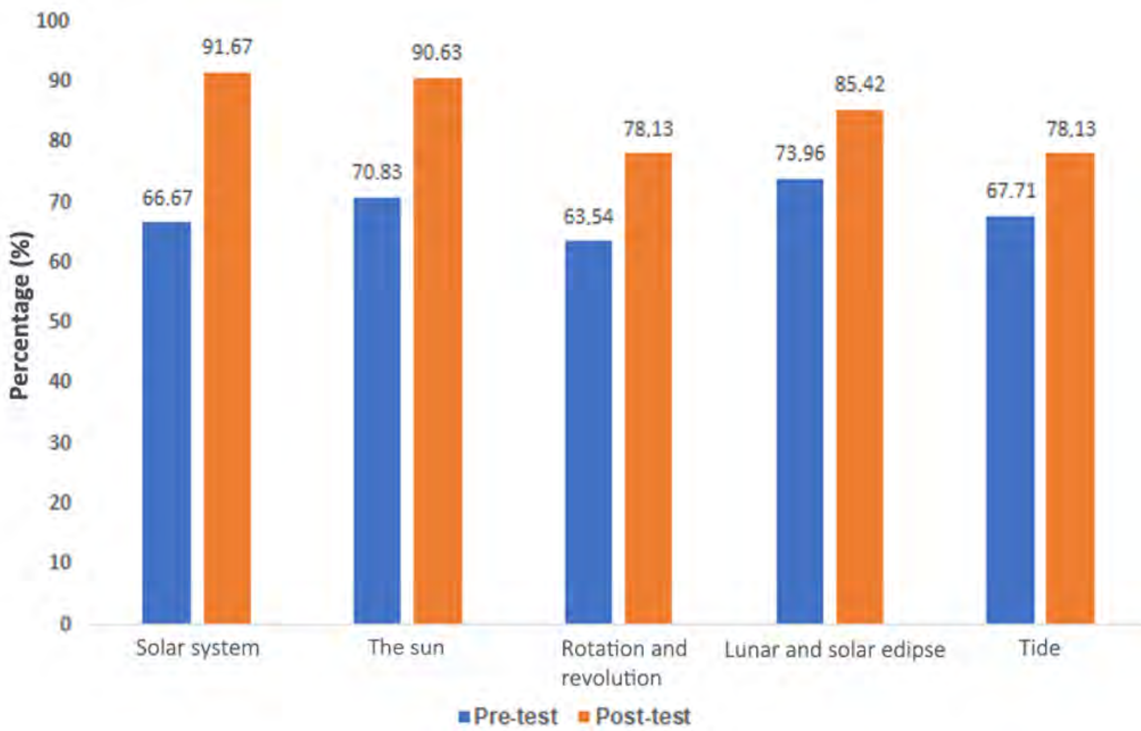

Figure 5. The comparison of each sub-concept in class A.

The score of physics learning achievement on each concept has increased based on the pre and post-test scores in class A as shown in Figure 5. The students' learning achievement of each concept has increased when viewed based on the pre and post-test scores. Then, a normalized gain score was calculated according to Equation 1 to identify the improvement in each concept in Table 6.

Table 6. The result normalized gain scores for each sub- concept in class A.

Sub concept	Average pre-test score	Average post-test score	Average ⟨*g*⟩	Criteria
Solar system	66.67	91.67	0.75	High
The sun	70.83	90.63	0.68	High
Rotation and revolution	63.54	78.13	0.40	Medium
Lunar and solar eclipses	73.96	85.42	0.44	Medium
Tide effect	67.71	78.13	0.32	Medium

Table 6 shows that the highest criteria is in the solar system and the sun concepts with normalized gain scores of 0.75 and 0.68 respectively and are included in the "high" criteria. There are similarities with the results presented in Table 5 where sub-concepts of solar and solar systems are increasingly advanced. The other concepts, rotation and revolution, lunar and solar eclipses and tide are still included in the "medium" criteria. Based on these results, it can be concluded that students in classes A and B understand the concepts of the solar system and the sun clearly affects their learning achievement. As for the other three concepts (rotation and revolution, lunar and solar eclipses and the tide effect) providing a more detailed understanding and enhancing physics learning achievement are still necessary.

3.2. Students' Opinion on Mobile AR in Learning Physics

The results of the interviews are divided into three data categories. The first category is students' experiences of learning with mobile augmented reality technology. Below are some answers from students related to this category:

P02: *Learning with augmented reality makes it easier to imagine objects that have never been seen before, making it easier to understand physical concepts such as the earth's and moon's eclipses. I enjoy learning to use AR.*"

P04: *Learning to use augmented reality makes it easier for me to understand physics concepts and there is no need to memorize texts from books because seeing the object directly provides a new experience. Like the characteristics of a planet, the composition of the solar system and eclipse events are more imaginable and easier to memorize.*

Two statements related to the question indicated that students had new experiences using augmented reality in different learning environments. As usual, students will sit in the class, the teacher will explains with writing on the board and 3D simulated visual objects will be presented in the class like real objects. Augmented reality is a new learning method that facilitates students' easy understanding of the concepts being taught even though the object has never been seen before. Furthermore, students also find that a new experience with augmented reality makes it easier to remember physics concepts without memorizing them from a textbook.

The second category concerns mobile augmented reality's effect on interest and curiosity in learning physics. This study found that students have a higher level of interest during the learning process. Below are some answers from students related to this category:

P05: *Augmented reality increases my interest in learning in class. At first, I thought physics was a difficult subject but augmented reality as a new learning environment made me more interested in learning.*

P02: *AR increases curiosity because presenting objects directly makes me explore more and more. With augmented reality one can imagine in a directed manner and this curiosity can be answered with 3D simulations presented by augmented reality.*

The statements from the student found that implementing augmented reality affected interest and curiosity. Students are more interested in using augmented reality in the science learning process. Students initially thought that physics was difficult because of the many calculations. However, with the passage of time, their thoughts changed and they became more interested in science learning. In addition, students stated that curiosity increases when learning using augmented reality. It concludes that combining real and virtual objects with 3D in mobile augmented reality technology can facilitate students' interest and curiosity.

The third category from the interview with students is the benefit of using mobile augmented reality as a new learning environment in learning physics. Students state that augmented reality is the new technology in their learning process. Below are some opinions from students related to this category:

P03: *Augmented reality is a new learning environment for me that provides many benefits such as being able to display objects that I have never seen before. Previously, learning was only done by looking at pictures in books but augmented reality provides a new experience as we see the object directly. In addition, AR also facilitates students' understanding of concepts.*

P04: *Learning with augmented reality makes the learning environment enjoyable during the learning process. Usually, physics learning in class only pays attention to the teacher explaining and then students are asked to work on questions but the presence of augmented reality makes students to ask more questions and I feel happy during the learning process.*

From the above statement, the students found many benefits of using augmented reality as a new learning environment in physics. The benefits of augmented reality include presenting objects that students have never seen before; augmented reality has 3D simulated objects that can support the student's understanding of concepts, make them more active in asking questions when learning in class, create an enjoyable learning environment and help the student get a higher score in learning achievement.

4. Discussions

4.1. Effect of Mobile AR on Physics Learning Achievement

The study aimed to investigate the effect of mobile augmented reality on physics learning achievement in junior high school students. A significant difference was observed between classes A and B using the normalized gain score as an indicator. The study found that using mobile augmented reality in the learning process can improve student learning achievement in physics. The result of this study is in line with previous research which states that the use of mobile augmented reality affects academic achievement (Erbas & Demirer, 2019), problem-solving (Karagozlu, 2018) and student motivation (Cabero-Almenara & Roig-Vila, 2019). Furthermore, the concept of the solar system mostly contain abstract concepts and students have difficulty understanding these concepts. It causes challenges in creating contextual learning. Augmented reality technology help students see these abstract concepts (Turan & Atila, 2021), achieve more meaningful learning (Saidin et al., 2015) and enhance conceptual understanding which affects learning scores (Prima, Putri, & Rustaman, 2018).

Classes A and B learn the concepts of solar system and the sun. This is in line with previous research that shows the development of a solar system model in mobile augmented reality and 3D that can improve students' understanding of the concept of the solar system, especially the concept of the characteristics of the solar system (Hordiienko, Marchuk, Vakaliuk, & Pikilnyak, 2020). It is still necessary to provide a more detailed understanding of the other three concepts (rotation and revolution, lunar and solar eclipses and tide). The results show that class A has "medium" criteria while those in class B have "low" criteria. The concept of rotation and revolution is challenging for students to understand because it is an abstract concept (Saidin, Abd Halim, & Yahaya, 2019). To solve this, Virtual Reality (VR) technology (Barnett, 2005), computational modeling simulations 3D rotation and revolution (Hansen, Barnett, MaKinster, & Keating, 2004) and using Physics Education Technology (PhET) simulations to understand the concept of solar systems can be used (Prima et al., 2018).

In addition, the concept of lunar and solar eclipses is also a concept that is difficult for students to understand. The best solution to improve students' understanding of lunar and solar eclipses is using holographic projection technology (Fan, Lin, Li, & Chang, 2021) and lunar and solar eclipses by 3D modeling design (Miranda, Kruse, & Hermann, 2016). The effect of tides is a neglected topic (Hartel, 2000). In contrast, the effect of the tides is difficult for students to understand, so effective learning media are needed to increase students' understanding of tide effect concepts such as VR and holographic projection technology.

4.2. Students' Opinion on Mobile AR in Learning Physics

Based on the interviews conducted with six randomly selected from class A who had to learn how to use mobile augmented reality, it was found that most students had never heard of mobile augmented reality technology. It was their first time seeing and hearing about it, they had never used augmented reality before and had not used augmented reality technology in their learning process. The results of the interviews are divided into three data categories: (1) Students' experiences of learning with mobile AR technology (2) The effect of mobile augmented reality on interest and curiosity in learning physics (3) The benefit of using mobile augmented reality as a new learning environment.

The first category explains students' learning experiences with mobile augmented reality technology in physics learning. The student states that augmented reality is a new learning environment that can help them understand abstract concepts and make it easier for them to understand class material and remember a physics concept without memorizing it from a book. This is in line with the results of previous studies which stated that AR is a new learning environment that can facilitate abstract concepts (Karagozlu & Ozdamli, 2017), make it easier to understand concepts clearly (Yoon, Anderson, Park, Elinich, & Lin, 2018) and affect learning achievement (Karagozlu, 2018).

The second category is the effect of implementing mobile augmented reality on the interest and curiosity of students. The study showed increased interest and curiosity when learning to use augmented reality. This is also in line with previous research regarding student insight on the effect of learning environments using mobile augmented reality. Students stated that using augmented reality as a learning environment was enough to arouse student interest during the learning process (Abdusselam & Karal, 2020).

The third category discusses the benefits of using augmented reality as a new learning environment. Students stated that augmented reality has many benefits that can help students understand abstract concepts and create an enjoyable learning environment. The results of this study are in line with the results of previous research related to augmented reality facilitating abstract concepts into concrete concepts (Sahin et al., 2020), creating an enjoyable learning environment (Salmi et al., 2017), increasing motivation (Cabero-Almenara & Roig-Vila, 2019) and creating a positive attitude during the learning process (Wojciechowski & Cellary, 2013). The benefits of using augmented reality are also in line with the results of this study, where students in class A have higher-criteria for understanding concepts than students in class B. Augmented reality technology provides an opportunity to see objects in 3D which is considered more effective than learning to use 2D objects (Rohendi & Wihardi, 2020). Therefore, it can be concluded that augmented reality has a positive effect on improving student learning achievements.

The results of interviews found a positive response from students using mobile augmented reality to improve physics learning achievement. Although there are many benefits of using mobile augmented reality for physics learning, there are still some drawbacks such as the fact that augmented reality can only be used on high-spec smartphones and light affects the camera's sensitivity to capture objects when scanned (Chang et al., 2018). Previous researchers have concluded that the mobile augmented reality technology used in course processing has technical drawbacks (Arth & Schmalstieg, 2011). It is a challenge for researchers to optimize mobile augmented reality so it can be effectively used in the learning process.

Teachers are interested in using mobile augmented reality in the learning process (Tzima, Styliaras, & Bassounas, 2019). These results mean that augmented reality is a solution technology in science learning. The survey also showed that teachers believe that augmented reality improves conceptual understanding, increases motivation and creates an enjoyable learning environment. This is in line with a previous study that found that it improved students' understanding of concepts (Karagozlu, 2018). Students learning using AR exhibit increased motivation (Erbas & Demirer, 2019) and interest because the application provides an enjoyable learning environment (Salmi et al., 2017). Similarly, 3D simulation in AR attracts students, increasing their learning motivation (Cai et al., 2012).

Many science concepts that are difficult for students could be understood using augmented reality technology. Previous studies found that it effectively explained abstract concepts (Karagozlu & Ozdamli, 2017) and material difficult for students to visualize, improving their imagination skills (Yilmaz, 2021). The application of augmented reality in the learning process has many benefits in education. It is a suitable technology to explain abstract science concepts to increase students' understanding. It reduces students' boredom during the learning process through 3D simulation.

5. Conclusion

The study found that students in class A who used mobile augmented reality in the implementation research had higher learning achievement criteria than the students in class B who used textbooks. According to students, mobile augmented reality technology in physics learning makes the learning environment more interesting, facilitates abstract concepts into concrete by adding visual 3D simulation, creates an enjoyable learning environment, helps students understand concepts easier and affects learning achievement.

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