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EXPLORING AUGMENTED REALITY ON ASTRONOMY EDUCATION: CONCEPTUAL KNOWLEDGE, MOTIVATION, AND LEARNING ATTITUDE

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ABSTRACT

Many developing countries, including Indonesia, have large populations but limited resources for conducting high-quality astronomy learning, especially for science club students. The main goal of this study is to create low-cost, augmented reality (AR) astronomy learning and analyze the effects on students' conceptual understanding, motivation, and learning attitude. This study uses quasi-experimental design (non-equivalent control group) with a purposive sampling design for 10-11 grade senior high school students who join the science club. A total of 17 participants were in the control group, while 16 students in the experimental group used AR technology. The test instruments consist of 10 questions about conceptual knowledge, 9 items about motivation, and 7 items about learning attitude. The result showed there was no significant difference in students' conceptual knowledge and motivation in both the control and experimental groups ($F(1,30)=0.069$, P-value > 0.05). However, students' conceptual knowledge and motivation in the experimental group increased significantly before and after the learning process using AR technology (P-value (0.0089) < 0.05, which did not happen in the control group ((P-value (0.20) > 0.05). The result also indicated positive attitudes from students whose astronomy lessons were taught via AR technology. AR-aided astronomy teaching positively contributes to students' achievement, motivation, and attitudes toward the course. Thus, positive outcomes can also be achieved via AR technology in different courses.

Keywords: *augmented reality, solar system, conceptual knowledge, motivation, learning attitude*

1. INTRODUCTION

Following the continuous evolution of simulation-based instructional models, education researchers can now provide adequate e-learning systems to enhance certain learning activities for which subject attribute and traditional models are ineffectual (Yeh, 2004; Guo, 2007). Past research has proven that instruction that incorporates the use of interactive 2D or 3D models can considerably improve learners' grasping of spatial ideas. (Shelton & Hedley, 2002). Integrating the benefits of authentic technologies to provide solutions unrestricted by the real environment can solve problems caused by the following circumstances: some subjects' concepts may be excessively abstract, require dangerous experiments and operations, require long periods of recording and observation, or the surroundings for observation cannot be easily constructed or meet the requirements due to the cost and technological limits or remote locations (Yen et al., 2013). Specifically, Chen et al. (2006) have demonstrated that using augmented reality (AR) technologies to build instructional materials can significantly boost learners' academic motivation and help them achieve higher learning outcomes. As a result, a simulation-based e-learning system may assist students in gaining more diverse and extensive knowledge to develop a comprehensive and accurate conceptual framework (Hsu, 2008).

Li (2010) used "Interactive Software of Lunar Phase" to conduct e-learning and proved that multimedia courseware improved the learning effects of concepts such as the phenomena, causes, and periods of moon phases and the earth, sun, and moon motions. The learners' misconceptions about the moon phases can also be clarified through the multimedia presentation. Furthermore, Ma (2008) discovered that 3D animation instruction improved learners' immediate learning effects on moon phase concepts but had no significant influence on delayed post-test learning outcomes. All of the preceding studies concluded that a simulation-based e-learning model that provides teaching resources such as 2D and 3D animation is extremely useful for boosting the learning efficacy of moon phase concepts. However, further research is needed to determine whether other more authentic presenting formats, such as augmented reality (AR) materials, might improve the learning effectiveness of abstract conceptual knowledge (Yen et al., 2013), such as planetary motion and space telescopes. This research aims to examine the effects of applying AR technology on planetary motion and space telescopes topics students' conceptual knowledge, motivation, and learning attitude in astronomy learning. It hopes to lay a foundation for further research into the application of AR to the concepts of learning in the natural science field. Based on the abovementioned explanations, this research is done to answer the following research questions:

1. To what extent does AR technology affect students' conceptual knowledge in astronomy learning?
2. To what extent does AR technology affect students' motivation in astronomy learning?
3. To what extent does AR technology affect students' attitudes toward astronomy learning?

2. LITERATURE REVIEW

2.1 AR in Astronomy Learning

Over the last few years, the market for camera-equipped smartphones and tablets has exploded (Vogt & Shingles, 2013). Although not being advertised specifically, these common gadgets' features support Augmented Reality (AR) applications (Papagiannakis et al. 2008). The merging of live visuals with virtual

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overlays of supplementary content is referred to as augmented reality (Azuma, 1997). There exist two distinct types of AR, which differ in the way that the virtual layer associated with a given environment is identified: location-based AR and image-based AR (Cheng and Tsai 2012). In the case of location-based AR, applications rely on the spatial position and orientation of the device to select and display location-relevant information. For image-based AR, applications use image recognition algorithms to trigger the display of relevant content over a recognized physical pattern (Vogt & Shingles, 2013). In this article, we focus on image-based AR applications.

Although a virtual learning environment based on AR technology is new in terms of theoretical research, several of its properties align with notions in educational theories. Behaviourism, for example, claims that learning occurs as a result of associations made between stimuli and responses. Users engage with the environment and receive rapid feedback in an AR-based learning environment, allowing them to determine what to do next and building a link between their reactions and knowledge (Cai et al., 2013). Furthermore, Cai et al.(2013) stated that an AR-based learning environment provides users with a variety of model-building tools and situations, all of which are meant to be user-friendly. In this autonomous learning environment, learners can construct the objective world and gradually improve their recognition structures, which satisfies both Piaget's assumption and practice of "bringing laboratories into classes," as well as constructivism's argument that "learning is embedded in authentic social experiences".

To demonstrate the benefits of AR teaching, Wood et al. (2004) used five examples of AR teaching in their study. These benefits include: (1) learners prefer this type of instructional material; (2) in courses about spatial concept relations, AR materials can assist learners in clarifying relative conceptions; (3) AR materials can better demonstrate knowledge of time concepts than traditional teaching materials; (4) virtual objects created by the AR learning system are presented as 3D objects, allowing learners to interact directly with them; and (5)learners may be able to change their native knowledge on their own using this strategy. Specifically, Lin and Huang (2017) conducted research for fifth-grade students and found that students who use mobile devices with AR technology in astronomy learning performed better in term of flow experience and learning achievement compared to those who use an astrolabe and compass only. Similar research by Shelton and Hedley (2002) who used AR to illustrate the Sun-Earth interaction found a significant overall improvement in student understanding after the AR exercise, as well as a reduction in student misunderstandings. Furthermore, Say & Pan (2017) used AR instruction using astronomy cards for 7th-grade students and noticed that their progress in fun, easy learning, interactively participating in lessons, and individual learning has improved their positive attitudes, which has reduced their anxiety levels and increased their success in learning. On the other hand, Yen et al. (2013) examined the effect of 2D animation, 3D simulation, and AR on students' moon phases concept learning and their academic achievement and found no significant difference, which means that the developed AR materials can help learning process, but its advantages require further exploration.

2.2 Zappar Application as AR Creator

Zappar is a web-based augmented reality program aimed primarily at the advertising divisions of enterprises and publishing houses, as well as the development of 3D augmented reality educational packages (Salcedo-Viteri & Espinoza-Celi, 2020). It is possible to assign specific learning and revision materials to a Zapcode and show them on mobile devices that have the Zappar app installed. The AR project can also be shared using links that can be opened without installing the Zappar app. Zappar has a lot of features that connect the digital world to everyday life with videos, games, and even 3D characters to play with. After scanning the code or clicking the shared project link, students had to scan a code with their mobile devices because the Zappar software uses image tracking.

We plan to develop augmented reality using Zappar on the topic of the solar system as provided in the table below:

Table 1. AR for Solar System Topic

No	Sub-topic	AR interfaces
1.	Overall solar system	3D model of the sun and all planets, video, sound, poster, website article link
2.	Sun	3D model of the sun, video, sound, poster, website article
3.	Mercury	3D model of the mercury, video, sound, poster, website article
4.	Venus	3D model of Venus, video, sound, poster, website article
5.	Earth	3D model of earth, video, sound, poster, website article
6.	Mars	3D model of Mars, video, sound, poster, website article
7.	Jupiter	3D model of Jupiter, video, sound, poster, website article
8.	Saturn	3D model of the Saturn, video, sound, poster, website article
9.	Uranus	3D model of Uranus, video, sound, poster, website article
10.	Neptune	3D model of Neptune, video, sound, poster, website article

Figure 1: AR interface examples of all solar system objects, the sun, and the screenshots from students' android smartphones using developed AR.

3. METHODS

3.1 Experimental process

The research uses a quasi-experimental design with a non-equivalent control group and purposive sampling with the evaluation using a digital test and survey. In total, the participants are 35 students from a science club in grades 10 and 11 at a private high school in Sidoarjo, East Java, Indonesia. The learning will be a fully online model for three meetings in one week using Google Meet software. After taking the pre-test, the teacher introduces the topic of astronomy and the sub-topic of the solar system by lecture method. The only difference is the students in the experimental group will use AR to learn deeply about the planets of the solar system with their specific characteristics. Slides will be used to do lectures and AR markers will be placed on the slides for experimental group students to scan to use AR.

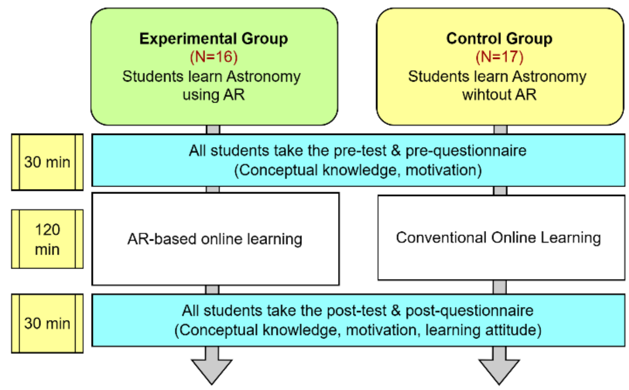

Figure 2: The overall experimental procedure.

3.2 Instruments

3.2.1 Conceptual knowledge

Conceptual knowledge is an understanding of the principles and relationships that underlie a domain (Hiebert & Lefevre, 1986). To evaluate students' conceptual knowledge, the test instrument indicator in astronomy developed by Ervana et al. (2022) is modified based on Anderson and Krathwohl (2001) based on the teaching-learning topic which is the solar system and planetary characteristics.

Table 2: The conceptual knowledge sub-type and sub-topic for the assessment

No	Conceptual Knowledge Sub-Type	Learned Conceptual Knowledge	Number of Question
1	Knowledge of classifications and categories	• Knowledge of the characteristics of the planets in the solar system.	2
		• Knowledge of the characteristics of the components that make up the solar system.	2

		• Knowledge of the inner and outer planets in the solar system.	1
2	Knowledge of principles and generalizations	Knowledge of the daily and annual apparent motion of the sun.	4
3	Knowledge of theory, model, and structure	Knowledge of planetary models.	1
		Total	10

3.2.2 Motivation

Motivation to learn is the drive and strength within a person to achieve specific goals (Cook & Artino, 2016). The students' motivational beliefs are measured using self-efficacy and the intrinsic value scale of the Motivated Strategies for Learning Questionnaire (MSLQ) that was developed by Pintrich and de Groot (1990), which consists of 18 items in total. The example of items is like "I am certain I can understand the ideas taught in this course" and "I am sure I can do an excellent job on the problems and tasks assigned for this class". And the example of intrinsic value items is like "I prefer classwork that is challenging so I can learn new things" and "I think that what I am learning in this class is useful for me to know". Students are instructed to respond to the items on a 5-point Likert scale (1 = not at all true of me to 5 = very true of me).

3.2.3 Learning attitude

It refers to a student's positive or negative feelings and predispositions toward learning (Lovelace & Brickman, 2013). This study analyzes the students' learning attitude questionnaire questions by dividing them into two main sections adopted from Cai et al. (2013): (1) in-class physics learning experiences and (2) AR tool instructional applications. The examples of in-class physics learning experience items are "I am interested in some physical phenomena in our daily lives, and I hope to make inquiries" and "It's easy to summarize the results of physics experiments". AR tool-related items are used to examine whether the AR instructional applications attract students' attention and stimulate their curiosity so they want to explore physics more deeply or not. The example items are "I concentrate on doing experiments when I use the AR instructional tools' and "I am very impressed with AR instructional displays and experiments". Students are instructed to respond to the items on a 5-point Likert scale (1 = not at all true of me to 5 = very true of me).

3.3 Data Analysis Process

One-way ANOVA and paired sample t-tests are used to compare means and identify any significant differences between groups or variables. The analysis is performed using Excel and SPSS 25. One-way ANOVA is used to test for differences in means across multiple groups of pre and post-test, while paired sample t-tests are used to compare if there are any changes between their pre and post-test within a group. Learning attitude data from experimental group is analyzed using descriptive statistics such as mean and standard deviation. The results of the analysis are then interpreted and used to conclude the effectiveness of the intervention or treatment in improving conceptual knowledge, motivation, and learning attitude among students.

4. RESULTS & DISCUSSION

4.1 Research question 1

To assess the effect of AR on the students' conceptual knowledge in astronomy learning, the one-way ANOVA and paired sample t-test are provided in the table below.

Table 3: One-way ANOVA of the mean between groups of conceptual knowledge

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.0028125	1	0.0028125	0.0686324	0.7951289	4.1708768
Within Groups	1.229375	30	0.0409792			
Total	1.2321875	31				

The result of one-way ANOVA in table 3 shows that there is no significant difference between groups (F(1,30)=0.069, P-value > 0.05).

Table 4: Paired sample t-test of the mean pre-posttest scores on conceptual knowledge

Pair	*Group*	*Mean difr.*	*N*	*t*	*df*	*sig. (1-tailed)*
Pair 1 (pre-post)	Experimental	0.075	16	-2.666	15	0.009
Pair 2 (pre-post)	Control	0.053	17	-0.855	16	0.203

The result of paired sample t-test in table 4 shows that pair 1 of the experimental group (AR group) has significantly lower than 0.05 which means that there is a difference between the conceptual knowledge value of pre and post-significantly after learning using AR. Although there was no significant difference between the groups in the ANOVA test, there was a significant difference in the increase in conceptual knowledge value of post-test scores for the experimental group after learning using augmented reality in paired sample t-test.

4.2 Research question 2

To assess the effect of AR on the students' learning motivation in astronomy learning, the one-way ANOVA and paired sample t-test are provided in the table below.

Table 5: One-way ANOVA of the mean between groups of learning motivation

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Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.125	1	0.125	0.9886086	0.3280352	4.1708768
Within Groups	3.793209877	30	0.1264403			
Total	3.918209877	31				

The result of one-way ANOVA in table 5 shows that there is no significant difference between groups (F(1,30)=0.989, P-value > 0.05).

Table 6: Paired sample t-test of the mean pre-posttest scores on learning motivation

Pair	*Group*	*Mean difr.*	*N*	*t*	*df*	*sig. (1-tailed)*
Pair 1 (pre-post)	Experimental	0.208	16	-1.874	15	0.040
Pair 2 (pre-post)	Control	0.098	17	-1.718	16	0.053

The result of paired sample t-test in table 6 shows that pair 1 of the experimental group (AR group) has significantly less than 0.05 which means that there is a difference between the learning motivation value of pre and post-significantly after learning using AR. Although there was no significant difference between the groups in the ANOVA test, there was a significant difference in the increase in learning motivation value of post-test scores for the experimental group after learning using augmented reality in paired sample t-test.

4.3 Research question 4

To assess the effect of AR on the students' attitudes toward astronomy learning, descriptive statistical results are provided in the table below.

Table 7: Descriptive statistics of the experimental group (AR group) of attitudes

Factor	Question No	Question Item	Mean	SD	Average	Total Averate
Physics learning experience	Q1	When I'm in a physics course, I always look forward to the end of the course.	2.4	1.2	2.8	3.5
	Q2	I am interested in some physical phenomena in our daily life, and I hope to make inquiries	3.5	0.6		
	Q3	AR instructional applications are very difficult to understand and are not easy to operate.	2.6	1.1		
AR exploration and attention	Q4	AR instructional methods facilitate my understanding of physical phenomena and concepts	3.9	0.6	4.1	
	Q5	The AR instructional method could increase my motivation to learn in the physics course.	3.9	0.8		
	Q6	I strongly prefer learning physics by AR instructional tools	4.0	0.8		
	Q7	I am very impressed with AR instructional display	4.4	0.6		

Based on table 9, the average was 3.5 in this part, showing that the students actively participate in the learning process with the AR. Furthermore, the average score for the factor of AR is higher than the physics learning experience (4.1 > 2.8) showing that students were strongly interested and motivated to learn with AR in the topic of Astronomy.

5. CONCLUSION

The current study aimed to identify the effect of AR technology on high school students' conceptual knowledge, motivation and learning attitude in astronomy learning. It was observed that the students in the experimental group had the same levels of conceptual knowledge as those in the control group. However, students' conceptual knowledge in the experimental group increased significantly before and after the learning process using AR technology which did not happen in the control group. This result can be taken as evidence of the positive effect of AR technology. AR applications in astronomy were developed and implemented in the experimental group because students find this topic very interesting. However, as it contains mostly abstract concepts, students generally have difficulty learning the relevant concepts and fail to achieve meaningful learning (Gundogdu, 2014). With the help of AR applications, however, students were able to see these abstract concepts physically through 3D virtual objects, achieve more meaningful learning, and consequently, make greater improvements in their conceptual knowledge after the learning process.

The same condition was there for students' motivation where there was no significant difference in both groups after the learning process, but students' motivation in the experimental group increased significantly after the learning process using the AR technology which did not happen in the control group. The AR model seems to enhance social context and environment, which are important parts of student motivation and self-regulation.

Results also indicated positive attitudes from students whose astronomy lessons were taught via AR technology. There are other studies with similar results in the literature. For instance, a study carried out by Mejías Borrero and Andújar Marquez (2012) revealed that AR applications enhance students' motivations and students have positive attitudes toward their AR-based course and find AR applications enjoyable and interesting. These results can be explained by the characteristics of AR. Specifically, AR is a new and interesting technology, sometimes considered to be magical, which some students will encounter for the first time in the lesson (Sahin & Yilmas, 2020). All these factors may render the course more interesting for students and change their perceptions for the better. Also, learning with 3D objects attracts students' attention. In the literature, it is stated that since AR uses 3D objects, students can observe these objects more concretely and can experience learning by doing, which leads to more effective and permanent learning (Chen et al., 2011; Wojciechowski & Cellary, 2013). Based on the findings of the current work, the following suggestions are given:

1. The study was carried out for high school science club students from 10-11 grades. Similar studies can be conducted for class students in different grades.
2. Zappar software can only be accessed after students update the Google Chrome application. Thus, students need enough storage to update their Google Chrome.
3. Within the scope of this study, the effect of AR technology on students' conceptual knowledge, motivation, and attitudes toward the course was analyzed. However, its effect on the permanence of the knowledge acquired was not examined. This may be a fruitful area for future studies to explore.
4. This study is limited by the fact that only a single treatment was applied and the focus was on a specific topic. To concretize and visualize abstract concepts and enable the observation of phenomena that are impossible to meet in real

life, AR can be used for different course topics. Other technologies using 3D models would also be useful as teaching or learning materials.

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