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Comparison of Student Achievement in Electricity Using Augmented Reality between Offline and Online Classes

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ABSTRACT

The COVID-19 pandemic has affected education in Indonesia. The government has suggested alternatives to solve the learning problems during the pandemic. Offline and online classes were used to fulfil the various learning needs of students. This study investigated the effect of using augmented reality-assisted media in offline and online classes on student achievement amid the COVID-19 pandemic. This study used a quasi-experimental design by utilising augmented reality (AR) in each class for eight weeks. Validated test questions were used following the use of AR. According to the results of the independent t-test in the current study, student achievement from offline ($n = 63$, $M = 74.71$) and online ($n = 64$, $M= 71.46$) classes increased drastically with $t = 1.994$, $p = 0.048$. However, in terms of differences in achievement improvement between the two classes, students in offline classes had higher achievement compared to those in online classes. Thus, it can be concluded that student achievement in Physics has improved with the help of augmented reality-assisted media amidst the COVID-19 pandemic, particularly through offline learning mode. This study contributes to the development of AR for future education, particularly how to enhance student achievement in Physics. Future AR studies can be carried out in more classes from various regions or countries, considering that the 3D models in AR are useful to aid the learning of other subjects with abstract concepts.

Keywords: augmented reality; offline learning; online learning; physics; teacher presence

INTRODUCTION

The Indonesian Ministry of Education aims to reform the country's education curriculum through three educational concepts, namely, century skills, scientific approach, and authentic assessment (Mayasari et al., 2016). The concepts are achieved when teachers can encourage students' active participation in the process of learning, particularly the learning of science subjects (McKellar et al., 2020). This is because students' active involvement in the science learning process determines the extent to which they can improve their achievements and skills (Harmer et al., 2011). However, the repercussion of the Coronavirus disease (COVID-19) continues to impact the learning process. For instance, during the pandemic, science learning was mostly conducted online (Setiawan 2020).

In 2022, the Indonesian government, through four ministries Ministers (Ministry of Health, Ministry of Education Culture, Research and Technology, Ministry of Religion, and Ministry of Home Affairs), customised a regulation for offline and online (face-to-face) teaching and learning processes for each region. The regulation, which has changed the education pattern in Indonesia, is divided into four levels. Level one and level two are with 80 per cent or above educators and education staff at the district/city level receiving two doses of vaccination. At these levels, 100 per cent face-to-face teaching and learning hours with activities that are in accordance with the curriculum are conducted. On the other

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hand, level three and level four consisted of below 80 per cent of educators and education staff receiving two vaccination doses at the district/city level. At these levels, face-to-face and online learning are conducted on every alternating day, with face-to-face learning conducted for a maximum of six hours per day at 50 per cent of the room's capacity (Regulation of Indonesian Government No.516, 2020; Joint Decree (SKB four ministers) No. 01/ KB /2022, No. 408 of 2022, No. HK.01.08/MENKES/1140/2022, No. 420-1026 of 2022 on guidelines for implementing learning during the COVID-19 pandemic, 2022).

Among the learning media that influence teaching and learning processes is augmented reality (AR) technology. AR is a direct or indirect display of a real-world environment whose elements are usually added through computer-generated sensory feedback such as audio, video, and visuals (Abbas, 2015). AR also merges the real environment and virtual environment by adding virtual objects (Amelia et al., 2020) and its 3D technology enhances the real-world environment generated by a computer through a device typically using an image layer (Yung & Khoo-Lattimore, 2019). Despite that AR complements, strengthens, and augments the real world with virtual content, it does not completely replace it (Cao & Cerfolio, 2019).

In addition, AR is used for visualising scientific phenomena (Adami et al., 2016). The effect of this visualisation enables AR to replace assisted learning media which uses multimedia limited to pointers (Jian-Hua, 2012). AR is a low-cost device with innovative features to make learning more effective and get better results (Ibanez & Delgado-Kloos, 2018). It is a low-cost device as AR can be developed for smartphone software. Accordingly, access to AR through smartphones can improve students' academic success compared to traditional learning methods (Ozdemir et al., 2018).

AR is useful in science, technology, engineering, and mathematics (STEM) as it promotes spatial abilities, practical skills, conceptual understanding, and scientific inquiry learning (Ibanez & Delgado-Kloos, 2018). According to Maeir et al. (2009), AR assists students' understanding by enabling them to visualise the actual spatial framework of even difficult learning concepts. The positive emotional effects of using AR not only lead to achievement but also affect the students' interest, attention, and motivation (Shirazi & Behzadan, 2015; Singh et al., 2019; Salar et al., 2020).

Several studies mention the various effects of AR on learning at school, significantly to facilitate learning that has abstract concepts (Wu et al., 2013) as it increases students' conceptual understanding (Ismail et al., 2019) and improves student learning outcomes (Cai et al., 2013; Lin et al., 2013; Chang et al., 2016). This finding from Cao and Cerfolio's study (2019) confirms that the AR interface is considered successful if it is designed properly, satisfies users, and considers other influencing factors (Pujiastuti & Haryadi, 2020). This basis also shows that there is another role to support the use of AR in the classroom and provides a new perspective on the development and use of AR in teaching that can be done for subjects that require a more in-depth explanation of student difficulties.

Accordingly, Hsiao et al. (2012) and Bressler & Bodzin (2013) provide evidence that the use of AR is important for learning difficult subjects, such as Physics. Physics requires the development of scientific attitudes and processes by improving skills in carrying out investigative science, developing scientific skills, and student achievement (Rokhmah et al., 2017). It is not limited to listening, taking notes, and remembering but also observing, experimenting, discussing, paying attention, answering questions, applying concepts, and communicating (Craciun & Bunoiu, 2017). Students are required to actively study and have high achievements. With these demands, the learning conditions, techniques, or methods must lead to understanding, developing literacy, and better achievement despite the learning being conducted offline and online (Littenberg-Tobias & Reich, 2020). AR is believed to play a role in increasing learning success in understanding electricity in Physics subject, in which abstract topics on electricity can be better explained or visualised with AR offline and online. In short, AR can affect student achievements in both offline and online teaching and learning processes of learning Physics.

Studies by McFarland and Hamilton (2005), Rivera & Rice (2002), and Olson (2002) suggest that learning modes, namely offline or online, do not result in significant differences in student achievement, but other factors, such as the use of learning media in the classroom. This is because of the difficulty in evaluating the effectiveness of offline and online teaching and learning processes, thereby failing to reach consistent conclusions (Bartley & Golek, 2004; Cook et al., 2008). On the other hand, some studies have provided evidence to demonstrate the extent to which media can support or influence student achievement under challenging conditions or in any learning mode.

The unpredictable mutations of COVID-19 allow for rapid changes in teaching instructions. To ensure students receive better learning even though teaching and learning processes are carried out in a hybrid manner, evaluating the differences between offline and online learning modes is important. Besides that, understanding the influence of learning modes on student achievement at schools is also vital.

AR as a learning media is expected to maintain or increase student achievement, despite the use of two different learning modes. Following the latest Ministerial regulations, some schools in levels three and four (red zones) still use online mode because the schools are not allowed to open. The offline mode is carried out for students who do not have an Internet network and access as they are far from the city. Accordingly, AR can be accessed both offline and online so no student is left behind. With AR platforms accessible on smartphones, abstract concepts can be used to visualise concepts in detail. Thus, AR is versatile, easy to use, and can facilitate both offline and online learning.

Syakili (2019) notes that the real potential of innovative technologies such as AR to enrich the learning environment and provide deep and meaningful learning has recently been recognised in distance learning. In terms of offline learning, Urbano et al. (2020) reveal that students who are exposed to AR acquire more profound conceptual knowledge than non-AR students. Furthermore, AR also allows students to engage with suitable strategies, increase the knowledge acquisition, and react to learning actions (Ribeiro, 2016). Therefore, it can be concluded that AR can bridge the gap between theory and practice and provide a practical means for the achievement of learning outcomes of various disciplines based on the development of current practical knowledge.

Eminently, the role of learning media greatly influences student learning both offline and online. AR is a learning media that can bridge achievement through offline and online modes of teaching and learning processes. However, there is no empirical evidence to prove which one has a more significant effect on student achievement. Additionally, in the offline and online learning of Physics, it is difficult to address which supports students to learn more effectively; therefore, it creates gaps.

AR can improve student achievement regardless of whether the teaching and learning process is performed offline or online. Previous research has discovered various findings on the comparison between offline and online learning performance. This study focused on the influence of AR on student achievement in Physics. This study examined the differences in Form 4 high school students' achievement as a result of using AR in offline and online classes for the Physics subject, specifically on the electricity subchapter. One offline class and one online class from two schools in an area participated in the current study. Thus, the hypothesis form was:

H: There is no significant difference in the student achievement of Physics between offline and online classes using AR.

METHODS

This study used a quantitative research methodology with a quasi-experimental design (see Figure 1). The study used two classes from two schools without disturbing the classroom learning system. The sampling was selected via purposive sampling with a total sample of 130 (see Table 1) Form 4 Science high school students. It was to get authentic data from the actual class and not be affected by external conditions (McMillan & Schumacher, 2010). The two classes used AR as the medium influencing classroom learning with one class experiencing online and another offline learning. The students were selected by the researchers with permission granted by the Jambi provincial education office based on the school's desire to participate in the research. Besides that the students studied Physics, other accounts in selecting students were that they had never used or known the use of AR in Physics. A pre-test was carried out to see the initial achievements of students from the two classes and the post-test was used to determine student achievement after the implementation of the AR in the classroom.

Table 1. Map of the Distribution of Study Samples before Post-Test

Groups	Female	Male	Total
Offline Class + AR	33	32	65
Online Class + AR	33	32	65
Total	65	65	130

According to Table 2, a total of 127 students sat for the post-tests. A total of three people, one from offline class and another from online classes, did not take the post-tests. As a result, the three students were excluded from the study sample because it would disturb the study data.

Table 2. Map of the Distribution of Study Samples after Post-Test

Groups	Female	Male	Total
Offline Class + AR	32	32	64
Online Class + AR	32	31	63
Total	64	63	127

This study provided two classes with AR-assisted Physics learning intervention. The classes used the AR developed by researchers. The AR has been approved by experts for use by students to access learning materials, assignments, exercises, and simulations during learning sessions. The content was new to the participants.

Both classes had to complete the same set of tasks during the intervention phase. However, before conducting the study, all students were introduced to AR-assisted devices in the previous academic course to familiarise students with using AR in the classroom. Therefore, the subjects studied were taught using AR devices in physics subjects, especially electricity material, so there are no instrumental factors that could interfere with this research because of the possibility of using AR devices.

The intervention took eight weeks with each meeting taking 60 minutes (See Table 3). The intervention was deliberately designed to be of a short duration of eight weeks and consisted of eight sessions to be realistic and following the period that was usually devoted to AR (Ropawandi et al., 2022). Based on technological activities in offline and online classroom situations. Regarding the two different learning models, both groups could still use and learn with AR-assisted applications in Physics learning. The schematic flow of the experimental design of the study is provided in Figure 1.

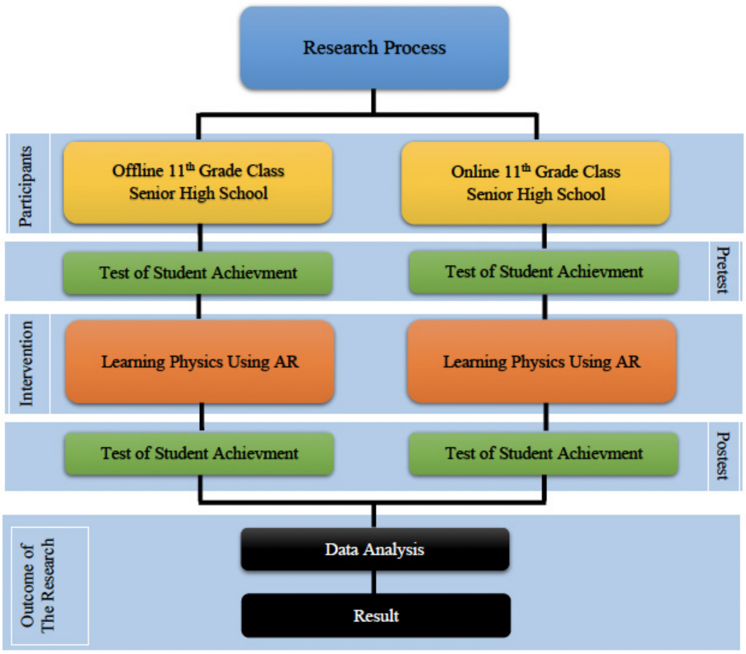


Figure 1. Research Process

The lesson plans and content are explained in the table below.

Table 3. The Implementation of Learning and Teaching (Weeks 1–8)

Materials/Content	Offline and Online classes
Weeks and Learning Materials	Week I : Pre-test Week II: Electric Charge Week II: Electric Field Week III: Electrical Potential Energy Week IV: Coulomb's Law Week V: Strength of Electric Current Week V: Voltage Week VI: Electrical Potential Difference Week VII: Resistance (Ohm's Law) Week VIII: Post-test
Procedure	Engagement Phase: In this phase, the teacher helps the learners to recall their prior knowledge. This was achieved by stimulating learners' interest in the AR application provided to them. Exploration Phase: During this phase, the teacher allows students to engage in activities using AR applications, such as testing predictions and hypotheses through alternative approaches, recording observations, and discussing with other students. Explanation Phase: Students are expected to solve, refine, and further develop the topics studied. Based on the discoveries in the AR applications, students must explain in their own words the concepts they have learned. Elaboration Phase: The teacher then instructs the students and let them investigate and collect data themselves according to the application flow. The tasks designed in the AR applications promote more profound understanding of the concepts being studied. These activities lead students to apply what they have learned, linking concepts, and apply them to new scenarios. Next, the teacher empowers the learner to analyse facts and generate preliminary arguments based on the simulations and resources provided by the AR application. Evaluation Phase: The teacher allows the students to review the data themselves, and makes a preliminary argument based on the simulation and the data obtained from the application. In addition, the teacher guides the students through an in-depth discussion of the findings. The teacher assesses the progress of the students' understanding based on the completed excercises.
Learning Method	The use of AR in Physics learning for both classes involved in the study

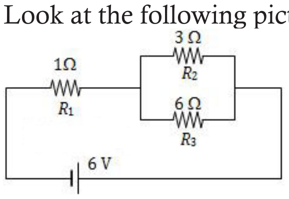
Student achievement tests were administered by adapting questions from high school textbooks, adhering to the standards of the Ministry of Education and Culture of the Republic of Indonesia. Changes in the numbers and texts were made to make them easier to understand and more applicable. Students must complete 20 multiple-choice questions before and after the teaching and learning process. The distribution of the number of questions for each indicator was based on the level of difficulty commonly experienced by students in the subchapter on electricity, with the first indicator being the most straightforward by experts and teachers (See Table 3). In preparing for the questions, the questions were validated by expert teachers and textbook education officers. The questions were also tested for reliability to determine the coefficient and consistency of the measuring instrument. Problematic questions were modified and discarded if found invalid several times. Then the questions were also tested in terms of scientific suitability and consistency as parameters for reliability estimation. To determine reliability, nonconforming issues were revised. In the study, Cronbach's alpha value of teaching and learning Physics was 0.742, indicating high reliability. This is in line with Arikunto's (2002) statement that a reliability value above 0.7 has high reliability to be used in a study. The indicators and the number of questions built are presented in Table 4.

Table 4. Indicator and the Number of Questions

Indicators	The Number of Questions
Know the electrical properties caused by a material	2
Know the concept of electrical properties, current and electric potential difference	3
Know the concept of electrical properties of current and electric potential difference	3
Know the properties and make electric circuits for both series and parallel	3
Know and be able to investigate the relationship between the current and potential difference in an electrical circuit described	3
Know and make a correlation between the potential difference through the E source and the potential difference of two resistors arranged in series or parallel	3
Analyze the relationship between electric current and potential difference using tables and graphs	3
Total	20

The questions were related to the basic electricity concepts. The examples of questions (refer to Table 5) were based on the indicators in Table 4.

Table 5. Example of Test

Question	Choices
It is known that the electric charge of Q1 is positive and Q2 is negative (1) the charge Q1 attracts the charge Q2 (2) the Coulomb force is proportional to Q1 and Q2 (3) the Coulomb force is inversely proportional to the square of the distance between Q1 and Q2 (4) the electric field strength in the middle between Q1 and Q2 is zero the truth is ...	a. 1, 2, 3, and 4 b. 1, 2 and 3 c. 1 and 3 d. 2 and 4 e. 4
Two point charges of the same type and magnitude qA = qB =10 -2 C are 10 cm apart. The repulsive force between the two charges (in Newtons) is	a. 9.10-14 b. 9.10-9 c. 9.10-5 d. 9.103 e. 9.107
Look at the following picture!  The electric current flowing through resistor R2 is.	a. 0.7 A b. 1.3 A c. 2.0 A d. 3.0 A e. 3.3 A

In this study, the data analyses used were descriptive analysis, independent T-test, and qualitative data analysis. All data assessed as outliers and extremes were deleted. Then the skewness and kurtosis statistics were controlled for each variable. The data value was normally distributed because it was between -2 and +2 (Lyon, 2013). For AR in online classes, the skewness line was -0.069 (*SE* = 0.302) and the kurtosis line was -0.176 (*SE* = 0.595), whereas, for AR in offline classes, the skewness line was 0.346 (*SE* = 0.299) and the kurtosis line was -0.159 (*SE* = 0.590). The independent T-test was used to identify the difference in student achievement before and after AR was used in both offline and online classes. Meanwhile, qualitative data analysis was only used to determine the factors that enabled AR to enhance student achievement and to strengthen the quantitative analysis from the interview.

RESULTS AND DISCUSSION

This study focused on student achievement in the teaching and learning process of the electricity subchapter of the Physics subject. The comparison was made between offline and online classes. A total of 127 students completed the post-tests, while 3 students failed to take the post-tests and were hence excluded from the study sample to avoid data disruption. Table 6 shows the percentage of student achievement levels before the learning session for offline and online classes. Based on the results obtained from the pre-test, the students from online classes had a higher percentage of achievements ($\bar{x}$ = 55.06, σ = 8.83) than students in offline classes ($\bar{x}$ = 51.82, σ = 8.80). This demonstrated that online learning sessions had a greater impact than offline classes, even though the disparity was not significant. Table 6 presents the difference in the pre-test results of student achievement between the offline and online classes.

Table 6. Pre-Test Data Regarding Student Achievement Using AR in Offline and Online Classes

	Groups	n	$\bar{x}$	σ	t	p
Pre-Student Achievements	Offline *	127	51.82	8.80	-2.067	0.041
	Online		55.06	8.83		

Table 7 presents the subject achievement of the groups studied during the teaching and learning sessions. Students in offline classes showed achievement in learning the electricity subchapter ($\bar{x}$ = 74,71, σ = 8.4936) compared to students from online classes ($\bar{x}$ = 71,46, σ = 9.8763). An independent t-test was used to determine student achievement in understanding the subjects for students from offline and online classes. From the tests carried out, AR had a more significant effect on students in offline classes compared to students in online classes with t = 1,994, p < 0.048. Table 7 shows the results of the independent t-test test data analysis using SPSS 26.

Table 7. Data Regarding the Effect of AR on Offline and Online Classes after Intervention

	Groups	n	$\bar{x}$	σ	t	p
Post-test Student Achievements	Offline *	127	74.71	8.49	1.994	0.048
	Online		71.46	9.87		

This study followed the latest study trend which is the role of AR as an auxiliary learning medium. This study identified the impact of AR on student achievement in two learning modes, offline and online. From the results, students in both modes had an improved knowledge of electricity. This indicates that AR has a positive impact on student learning in both learning modes. However, students from offline classes were considered better than those from online classes even though they both used AR in their learning. This indicates that the developed AR was successfully adapted to the chosen subchapter, namely electricity. The content was then introduced to the two target groups, who assumed that the subchapter was a difficult topic to understand due to its abstract concept (Kollofel et al., 2013), misconceptions (Turgut et al., 2011), and difficult relationships between electrical concepts (Stetzer et al., 2013).

According to the results of this study, there are differences in the learning achievement between the two classes. In the subchapter on electricity, students from offline classes performed better than those in online classes. This is because, in offline classes, the teachers aligned teaching and learning processes to suit the different levels of students in the class. This is following the relevant past studies (e.g., Yao et al., 2020; Rasmitadila et al., 2020) that teacher roles cannot be ignored despite reforms in learning because they remain the facilitator needed by students. Another factor that enhanced offline learning was the ability to physically control students to utilise AR and pedagogically modified learning that suits their interests and cognitive abilities for group discussion, peer assistance, and peer assessment (Khairuddin et al., 2019; Soltero & Lopez, 2020). Therefore, AR cannot independently be used alone without guidance from teachers. This also provides evidence that there are influencing factors that affect the effectiveness of AR use such as the role of the teacher to properly guide and explain raised issues and the teacher's freedom of movement. This study supports Mystakidis et al. (2022) who state that AR does not allow direct communication between users, but provides an alternative to solve problems, work safety, and save time. Researchers who have conducted detailed research, such as Thees et al. (2020), report a positive impact on students as AR also serves as a medium for solving visualisation problems, which is not easily demonstrated in the real world, through its graphic and real-world nature through animations, 3D models, and text pop-ups (Mystakidis et al., 2022). Therefore, the cognitive load that occurs in AR-based systems is much lower than with traditional methods (Chu et al., 2019). This is consistent with the study of Vassigh et al. (2020) who conclude that students can work individually or collaboratively to understand problems and solve tasks, thereby showing a greater interest in a subject. In addition, AR can simulate complex theoretical concepts such as interactive experiments from research-based microparticles (Cai et al., 2014; Barraza et al., 2015).

On the other hand, Nengrum et al. (2021) also found that the learning process conducted online faces several obstacles, such as limited learning time. A limited learning time results in the content not being optimally conveyed. Also, the obstacles include technical problems such as poor network and internet quota (Ekantini, 2020). These obstacles hugely impact learning conducted online (Zhang et al., 2020). Suresh et al. (2018) also found that the ability of teachers to provide online courses is also an issue besides issues with access to technology in online learning. First, teachers cannot adequately control the class because of the limited space online and the distance between teachers and students. Second, online learning is relatively new in Indonesia. Third, according to Xia (2020), online learning can only be guided by protocols and digital devices to support classroom learning. This is in accordance with Guo & Li (2020), who state that live videos, equipped with recording and micro lessons can help students learn but with limited teacher movement. Hence, learning online limits teachers' explorations of students' learning desires which later hampers the student learning process.

To support the data gathered in this study, interviews with several students from both classes were also carried out to identify several points of differences in student achievement between the two classes. The results show that students from offline classes received more assistance from their teacher when they had difficulty using AR. They received quicker feedback and had a better understanding of what to do. Whereas in online classes, students had trouble asking questions due to problems such as poor network access. As a result, they had fewer opportunities to ask questions compared to offline classes. This proves that AR-assisted independent learning is not effective as it is without the significant role of teachers. This additional evidence reveals that the use of AR for learning still requires guidance and support from teachers. For this reason, students from offline classes had better achievement than those from online classes as they were physically assisted by their teacher in the process of using AR.

Nevertheless. AR can influence learning by improving student achievement. The use of AR allows for the formation of plans that can improve education such as by allowing users to interact with virtual objects in the real-time environment where the user is located so that it will affect student curiosity (Bujak et al., 2013; Liou et al., 2017; Chang et al., 2018). Accordingly, Billinghurst & Duenser (2012), Sanii (2020), and Cheng & Tsai (2013) state that students consider AR as a new and unique medium and an extraordinary miracle in learning as it provides many benefits to users. These reasons further emphasise the belief that AR is a medium that can help students improve their learning achievement. In addition, higher interaction with AR allows students to engage in more physical activities compared to other learning activities (Hsiao et al., 2012; Giasiranis & Sofos, 2017). Knowledge earned through AR may deeply pique student interest and attention (Bujak et al., 2013; Wojciechowski & Cellary, 2013; Chiang et al., 2014) as AR permits the formation of a new environment, in which physical and virtual objects are integrated into different levels (Flavián et al., 2019). Moro et al. (2017) add that the most important part of improving student achievement using AR is increasing class participation.

The results of this study show that AR is a learning medium capable of improving student achievement in both offline and online learning modes. AR provides better explanations of abstract material, making it easier for students to study Physics, especially the subchapter on electricity. Moreover, the presence of AR provides students with a new alternative to learning and facilitates classroom learning, especially in the era of technology. This is in line with Ropawandi et al. (2022), who believe that AR solves Physics problems, particularly related to misconceptions, by presenting better abstractions of content to develop a better understanding of concepts among students. AR enables the visualisation of abstract concepts according to student's level of understanding, enabling students to observe phenomena that they may not encounter in real life. Ropawandi et al. (2022) further added AR affords to visualise abstract concepts in the form of 3D patterns. Thus, AR allows students to understand the phenomena from various points of view (Laine et al., 2016; Gun & Atasoy, 2017). Also, AR provides an indirect gamification effect in learning to make a subject more attractive and enjoyable for students (Klopfer & Square, 2007). This creates student-centred learning in which students feel free to learn everything related to the things they encounter (Kamarainen et al., 2013). It is evident that AR supports more flexible learning both inside and outside the classroom (Sirakaya & Alsancak Sirakaya (2020). This is in line with the findings that new technology or learning media will not only increase student interest and motivation but deepen their understanding because AR aids students in actively finding solutions to problems (Kreijns et al., 2013). It can be concluded that AR is one of the media that can overcome the problems in the teaching and learning processes because it provides information about abstract or non-visual concepts, especially in the teaching and learning of Physics.

AR fills the gap between reality and virtuality using hybrid forms of learning, including graphic design, visualisation, and simulation. The forms aid understanding of the real world and existing phenomena by deepening the learning content, collaborating, combining, and imagining phenomena.

The analysis carried out within the framework of this study shows that the use of AR in Physics on the subchapter of electricity has increased the achievement of Form 4 high school students in Jambi besides improving spatial abilities, developing cognitive abilities, and providing permanent learning. However, there are still some learning challenges when students have are given the freedom to find information using AR in Physics. Therefore, the learning must be scaffolded to assist students in the process of finding answers to the teaching and learning process. In addition, this study has indirectly shown that AR is a technology-assisted learning platform that afford to support the explanation of abstract knowledge (Barrow, 2019). AR provides a meaningful experience for students that can enhance their knowledge and improve their academic achievement (Nuanmeesri et al., 2019).

AR will have an important role in education in the future as AR can increase student achievement. However, the role of the teacher in the classroom is still one of the reinforcing factors to improve student achievement. Teachers are still needed by students to facilitate learning and solve difficulties when utilising AR. This means that teachers continue to have a significant effect on student achievement even with the use of learning media and other applications.

CONCLUSION

This study examined the effects of the use of AR in offline and online classes on student achievement in Physics, specifically in the electricity subchapter. Even though this study is with certain limitations, especially in the research process that can affect data collection, the findings can still be used as a basis for a sustainable study of AR in the field of Physics education. This study also contributes to the studies on AR as having a significant influence on student achievement both in offline and online classes and encourages future studies to study other variables because AR continues to evolve from time to time and becomes more accessible. In addition, this study was limited to one offline class and one online class from two schools in an area. In the future, AR studies can be carried out in more classes from various regions or countries, considering that 3D models in AR may be useful for other subject materials with abstract concepts. In terms of learning, AR can hinder a learning process due to issues with the quality of lighting, images, cameras, and the resulting output. Therefore, future researchers need to take appropriate actions when conducting related research. In addition, the difference in the learning time between offline and online classes is a significant influence because online classes were conducted in 10 minutes less time than offline classes.

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