Mobile Augmented Reality Learning Media with Metaverse to Improve Student Learning Outcomes in Science Class

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Abstract—Information and communication technology development affects the learning methods and media used. Augmented Reality technology allows students to experience learning with objects seen in person. This study aimed to decide the efficaciousness of mobile augmented reality learning media with metaverse on improving student learning outcomes in Science classes. The population consists of 92 students from elementary schools in Cluster I, Depok Subdistrict. Then the sample was taken using the slovin formula until it obtained 75 samples of fifth-grade students. This study employed experimental research techniques and a single group pretest and post-test. In this study, the data analysis performed was an inferential analysis with a t-test. According to the findings, using that metaverse application positively impacts students' learning outcomes. Students can use the Metaverse app to see better learning outcomes. Students are also more interested in learning and can easily understand and discover new knowledge. In addition, students find it more fun to learn using the Metaverse app, which is a mobile augmented reality.

Keywords—mobile augmented reality, learning outcome, metaverse

1 Introduction

In a new global era, technological advances in education are a central issue aligned with learning materials assuming that incorporating technology into learning can usher in a new age in education [1]. The new period in question is the technological progress that supports the learning process. One of the most prominent characteristics in this era is the broader and easier access to science. The development of diverse applications that can be utilized as a learning medium offset the rapid development of technology.

In today's world, digital media is used for learning as they allow students to learn through educational games and interactive simulations. This digital learning experience can be accessed through a smartphone or tablet, making learning easy, especially with Augmented Reality (AR), where students can interact with virtual content through mobile devices. AR systems are used to integrate virtual information into an actual environment so that students can see the information as it is in their state [2]. This technology is an update in education that will give rise to different learning styles and is expected to promote the teaching and learning process [3]. Students feel the object is accurate and get a new picture. Studies outline teachers' way of thinking towards teaching modernization and using these current teaching techniques in education to gain capability of the action [4]. Strong ICT-based coaching vitalizes college students to bring their attitudes close to the subject. The excellent point of behaving toward ICT to brace learning delivery is improving the superiority of learning, increasing entry to education and learning, visualizing abstract ideas, and facilitating mastery of the material under study. It can make the learning material more exciting and allow it to interact. Schools must always make great efforts to achieve the demand of these ICT provisions.

Educators have to adjust to online coaching programs at all levels of education and adapt and disseminate these materials and resources to help scholars preserve their knowledge during the pandemic [5]. Additionally, all faculty and college students had to find a way to use the various online distance learning programs. One of the frightening consequences of the pandemic is that many students are forced to continue their online learning at homeschooling after schools' physical closures and face-to-face classes [6]. Due to the pandemic, the shift from face-to-face learning to online learning has highlighted the hypothetical imbalance of economically disadvantaged students. Adopting innovative teaching methods with mobile learning environments will affect student learning outcomes [7–9]. Smart mobile devices with mobile apps can help students recognize numbers. Technology can provide easy-to-find information in a variety of formats, and this will undoubtedly make it easier for students to get various information.

A new foundation is needed to build consensus and trust in technology [10]. For this reason, educators must now be able to use technology in all training courses. Hopefully, the participation of this technology in the learning process can be more exciting, which can strengthen students' inspiration to participate in the learning process in the future. The new generation of learners is closely connected with the digital age and always uses information and communication technology (ICT) in their daily lives [11]. The advantages of applying ICT to back up the execution of learning can revamp the mastery of learning, fatten admittance to education and learning, aid to predict conjectural ideas, simplify recognizing the material being studied, unveil learning materials to be more entrancing, and permit interaction between the learning process and material being studied. Schools must always aspire to fulfil the necessity of these ICT facilities as a learning medium.

As the application of Augmented Reality in learning can describe something abstract into something, 3-dimensional objects projected through technology, it can also make it easier for students to receive, manage, and understand learning materials. Jean Piaget said that elementary school students are at a concrete operational thinking stage where all learning materials must be described clearly and clearly to be easier to understand. One of the mobile AR used is the metaverse projected to make learning materials easier for students and improve student learning outcomes, particularly in science, through mobile learning media. A learning result is a person's capacity gained from learning activities. Studying science is a skill gained by someone who has completed learning activities such as explaining the type of digestive tract tools, functions, and processes of food digestion.

Previous research explains that Augmented Reality is an effective tool if used in learning [12]. Students become motivated and help improve learning outcomes and increase information knowledge [13]. This medium's cognitive abilities can provide a different experience and explain a suitable concept. Many studies have integrated Augmented Reality in education, but few have noticed the generalization of concepts and the accuracy of information. Therefore, this study developed a mobile-based AR learning media through a metaverse application for students to study the human digestive system.

This study further examined the students' knowledge value focused on real-life experiences using Mobile Augmented Reality in science learning to increase student learning outcomes. This study aimed to construct a metaverse-based augmented reality medium and investigate how it influenced grade 5 fundamental science learning results. "Does the use of metaverse-based augmented reality mobile media have a beneficial impact on student's academic performance?" was the core question in the study. The following questions will be addressed in this research:

a) How to design metaverse-based augmented reality mobile learning media for fifth-grade students?
b) What if the effect of mobile augmented reality in the metaverse app on student learning outcomes in science class?

1.1 Educational technology

Computer hardware, software, and educational theories are used in educational technology [14]. Educational technology imposes high-quality information contributions for students, teachers, parents, and the community. For the production of instructional technology, theoretical knowledge from various fields is coupled with classroom experience. These domains include communication, education, psychology, sociology, artificial intelligence, and computer science. These include learning theory, computer-based training, online learning, and mobile learning, all of which use mobile technology.

The instruments and theoretical foundations used to support learning in teaching are referred to as educational technology. Educational technology does not just refer to high-tech devices; it encompasses anything that helps students learn better in the classroom [15]. Teachers leverage technology in the classroom to help students learn more effectively. As a result, instructional technology has become a significant part of modern society. Learning via the internet and mobile devices can be done from any location. Therefore, the learning situation can change to be more flexible and anytime.

Existing technology now brings many positive impacts to education [16], including facilitating reasoning, abstract thinking, problem-solving, and experimentation, and improving children's engagement and learning curve. Education is one of the principal objectives of developing human resources to meet a better direction.

The existence of mobile learning can ensure the availability and accessibility of learning materials and tools for acquiring knowledge [17]. Advances in self-education require technical and educational attestation as several challenges exist. It is necessary to determine whether such a transition will improve the quality of instruction without significant prior training, education, and preparation of teachers and students [18]. Teachers need to build communication entices that suit digital needs and understand the importance of technology in current learning to improve the quality of education through this activity.

Students must also improve their technological skills [19] to compete in future global economic competitions. Students must gain technology skills to help them compete in the worldwide economy. Critical thinking abilities, creative problem-solving skills, communication skills, cooperation skills, and technology-savvy citizen skills are just a few of the skills students must develop.

1.2 Augmented reality

The technological advancements of this century have led to the belief that technology's integrity in education can usher in a new age in education [20] as the existing technology has been designed to adapt to the learning materials. Technology can be used in several aspects of education; one example is Augmented Reality (AR). Modern technological means improve and develop the educational process, taking part in a critical part on students' motivation to learn.

AR is believed to improve education with interactive and enjoyable experiences in various disciplines ranging from science to language and other social sciences [21]. This interactive experience happens as AR technology combines the natural world and the virtual world, projected on the object, making the boundary between the two even thinner, making the information provided interactive and authentic.

AR apps are created using digital images or text to recreate the real world [22], helping visualize an abstract concept to look actual and blend into the real world. Students get an idea of something they may never experience, improving user perception and allowing us to hear, see and hear natural environments differently. AR can be applied with senses such as touch and hearing, as AR applications can take the actual object from the environment and add a virtual object.

While working in stimulating environments, AR technology can help students improve and facilitate learning, memory capacity, and decision-making [23]. By using AR in the learning process, students can learn through experiences both individual and group experiences that can be easily understood, helping them overcome the difficulty of complex abstract learning. One of the most popular mobile AR apps is the metaverse offering many educational benefits. For students, these benefits can be summarized as follows: enjoyment of classes, reduced cognitive load, increased motivation and interest in the class, more significant opportunity to ask questions, increased interaction between students, new opportunities for individuals to learn, the concretization of abstract concepts, increase in success. For teachers, these benefits consist of contributing to the development of students' creativity, ensuring effective student participation in the course, and the ability of students to carry out the course at their own pace.

Metaverse is a platform that allows anyone to create interactive content in Augmented Reality, including studio tools to support AR experiences integrating learning into online learning resources [24]. The use of moving icons or avatars is likely to facilitate students in understanding learning materials and improve student learning outcomes, especially in science learning.

AR could be used as an alternative technology that will improve the learning process, motivate students and revolutionize future learning paradigms [25], especially in math education, to enhance students' spatial skills development. This may positively reduce a phenomenon known as mathematical anxiety, which may affect STEM (science, technology, engineering, and mathematics) education. In general, AR is becoming a modern way to support and empower self-study according to the abilities of each student.

1.3 Learning outcomes

Learning outcomes result from a two-part learning process, namely affective and cognitive [26]. Non-cognitive outcomes are concerned with individual attitudes and personality values, while cognitive outcomes involve acquiring knowledge and abilities. Some examples of learning outcomes include computer and communication skills, the ability to perform analysis, synthesis, problem-solving and evaluation, and critical thinking. This research is limited to the cognitive realm.

Cognitive learning outcomes lead to human changes after the learning process in terms of thinking, such as increased knowledge, increased understanding, and achievements [27]. Cognitive strategies that can be adopted include memorizing, understanding, applying, analyzing, evaluating, creating, and deviating from the subject. Bloom's revised taxonomy can also be used to assess students' cognitive strategies.

For quality and outstanding learning, schools need to pay attention to these students' satisfaction and academic achievement. Student satisfaction plays a significant role in adding knowledge and skills to improve learning outcomes [28]. Highly autonomous and supportive learning environments have significantly increased the satisfaction of students' basic psychological needs, student motivation, course evaluations, and academic success. These results suggest that what is most important to students is not the specific techniques used by the instructors but the quality of the student and interactions with instructors.

Students who direct more effort into cognitive matters such as focusing on learning and doing assignments will have strong learning outcomes [29]. They can focus more on learning if they feel happy and interested in learning. Therefore, technology is indispensable to improving students' learning outcomes in school. Technology enhances teaching outcomes, which impacts students' learning outcomes. The quality of learning can be measured from the student's learning outcomes, whether the student understands and has mastered the learning material. In this situation, technology usage is expected to change learning outcomes, including technology that can improve teaching in schools, enhance the student experience, and improve the quality of learning [30–33]. Through the mastery of technology, the learning model in schools becomes more interactive, engaging, and keeps up with developments. The learning model is no longer monotonous and boring as technology strongly supports the visualization of abstract ideas, can facilitate the learning system or understanding of the material taught by the teacher and allows positive interactions between teachers and students in the learning classroom. Mastering technology is a priority that all teachers must understand as a competency standard in the digital era. The role of technology can help the administrative management of educational institutions in managing organizational problems. With technology features, schools or educational institutions can provide more accurate information so that school policy-making can be more targeted. Technology does offer enormous advantages and benefits in supporting a higher-quality learning system. Students can access all knowledge or material insights provided through the latest technological devices.

This study aims to understand whether the use of metaverse apps in the study of digestive system materials in humans affects the learning results of fifth-grade elementary school students.

2 Method

This research was conducted in 2020 at elementary schools at the sub-district of Depok in West Java in Indonesia.

2.1 Design of research

The experimental research approach evaluated the link between causation and variables. Through experimental examinations, researchers were able to see how one independent variable affected one or more dependent variables. This study included a single group pretest and post-test; pretests (O_1), treatments (X), and post-tests (O_2). The initial phase in the study was selecting a sample and dividing it into single-class research. A pretest was given first, and the next step was using augmented reality apps in the sample. After the teaching intervention, a post-test was conducted, and the results were eventually measured.

Table 1. Metaverse application usage research design

Pre-Test	Treatment	Post-Test
O_1	X	O_2

Notes: O_1 = pretest before given treatment; O_2 = post-test after a given treatment; X = treatment in the form using metaverse applications.

2.2 Population and sample

Participants in this study were 92 Grade 5 elementary school students from the Cluster I Depok subdistrict. The sample was taken using a simple formula until it reached the number of 75 students. The study took place during the school year 2020/2021.

2.3 Data collection tools

Pre- and post-tests were provided to determine the intervention results utilizing the AR application. The data was analyzed using descriptive statistical methods, and the t-test was used to test whether the average values before and after the intervention differed significantly.

2.4 Data analysis

Normality tests were performed using Kolmogorov Smirnov formulas in compliance with Asymp regulations against pre- and post-test scores at a 5% alpha significance rate. The homogeneity tests were performed after normality tests, and homogeneity tests were conducted against pretests and post-test scores. To examine the average difference between the two groups, a paired sample t-test was used. SPSS version 26.1.0 was used for data analysis.

3 Results

3.1 Mobile augmented reality design for human digestive system materials

Based on information collected about the digestive tracts, functions, and food digestion processes in the human body, augmented reality models were built and paired in the system through the Metaverse application. This metaverse application can be accessed using smartphones or tablets by scanning images via QR Code, and some activities can be followed to study the material of the digestive system in the human body.

3.2 Development in human digestive system materials using mobile augmented reality

Making augmented reality media can be done through the website https://studio.gometa.io/discover/me. This website can be accessed for free and can b used to create augmented reality models in QR codes.

We created a medium based on information collected about digestive tracts, functions, and food digestion processes in the human body. Many models and scenes can be used in the storyboard can be created, and the choice of characters contained in the metaverse is varied.

Each scene had a different usage function. However, some scenes required additional tools in VR to use them. The characters provided by the metaverse are very numerous and varied, and they start from 2D to 3D.

The storyboard can be filled with several scenes that are mutually continuous. Each scene contains information about the digestive tracts, functions, and food digestion processes in the human body.

Before publishing, a user can fill in a description for the title and description of augmented reality media created. Once published, a QR Code will appear, which can be scanned through the metaverse application. This metaverse application can be installed through the play store or app store.

Students can directly scan the QR Code resulting from augmented reality media created and instantly begin the experience of learning digestive system materials.

3.3 System interface

Figure 1 is a view of products that have been scanned through a QR Code in the metaverse application on smartphones.

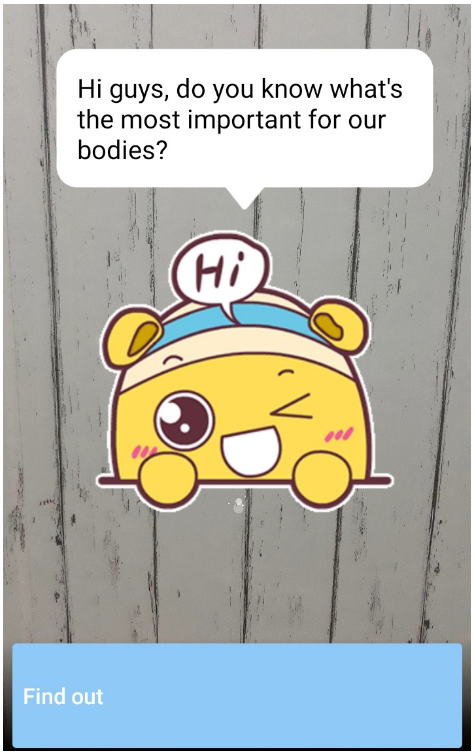

Fig. 1. Early look at the learning model of the human digestive

The smartphone has to be moved to the right or left to bring up the character. The response icon can be clicked to proceed to the next scene.

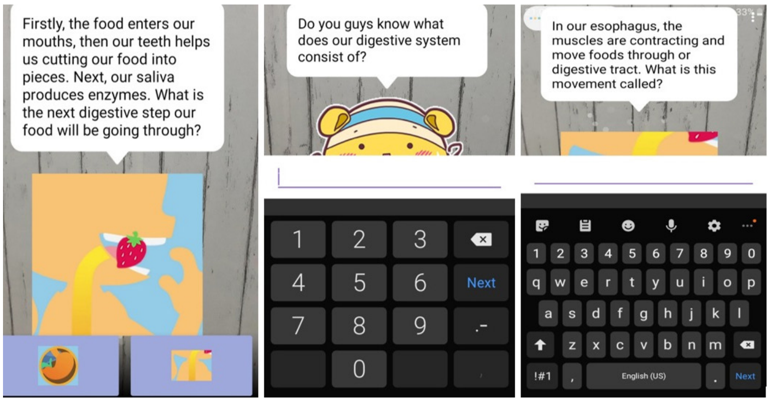

Fig. 2. Display multiple models of the response icon selection

In addition to writing, the selected response icon can also be an image. The use of images is considered to facilitate and strengthen students' memory of the shape of the human gastrointestinal tract. Students can also write a response directly according to the question asked. Responses can be text and numbers. Students must fill out this question with the appropriate response to move on to the next experience.

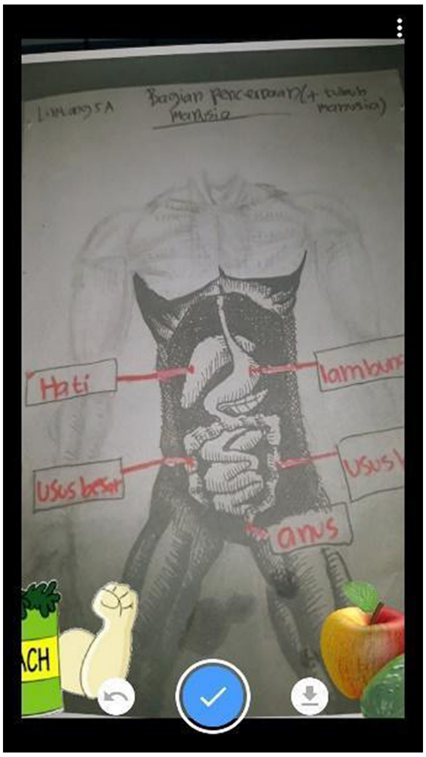

Fig. 3. Display for photographing objects directly

Students can also draw the digestive tract in humans equipped with its name and function. After that, the image can be photographed directly.

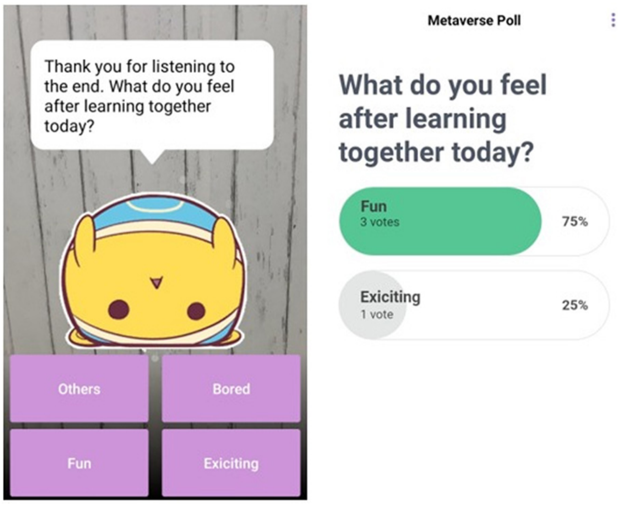

Fig. 4. Poll view

At the end of the learning, students asked about their feelings when studying the material of the digestive system in humans using this augmented reality mobile media. Students can immediately see the poll results of the question.

3.4 Effect of metaverse application on learning outcomes

The table and description below show changes in student learning outcomes related to metaverse applications. The normality and homogeneity of study data and pre- and post-test scores received by students before and after using the Metaverse application were evaluated using test data analysis procedures. In the Kolmogorov-Smirnov normalcy test, the Asymp criteria are applied, with Sig 5 per cent. The data is normal if $p > 0.05$. As indicated in the Table 2 below, the normality calculation was done with SPSS 26.1.0.

Table 2. One-sample Kolmogorov-Smirnov test

		Unstandardized Residual
N		75
Normal Parameters	Mean	.000
	Std. Deviation	8.209
Most Extreme Differences	Absolute	.078
	Positive	.078
	Negative	–.069
Test Statistic		.078
Asymp. Sig. (2-tailed)		.200

Based on the findings of Kolmogorov-Smirnov normality tests, we achieved a p-value significance of 0.200 > 0.05. Both the pre- and post-test data have a significance of greater than 0.05, indicating that H1 is acceptable. As a result, it is possible to deduce that the pre- and post-test data are normally distributed, and the study data is parametric.

Table 3. Test of homogeneity of variances

Levene Statistic	df1	df2	Sig.
2.000	1	128	.160

Homogeneity tests are performed utilizing significance value criteria computed above the threshold of 0.05 on pretest and post-test scores. Table 3 shows the results of homogeneity calculations using SPSS 26.1.0. This variance similarity test's hypotheses are as follows:

H0: All variants are equal or homogeneous
H1: All variants are not equal or not homogeneous

Conditions:

If the value of p > 0.05 (5%) then H0 is accepted; H1 rejected
If the value p < 0.05 (5%) then H0 is rejected; H1 received

Because the difference in significance value of 0.160 indicates larger than 0.05 and the data analyzed indicated the same variant, it may be assumed that H0 was received (homogeneous). According to the normality and homogeneity test results, this data is normal and homogeneous. The Paired Samples T-Test method then evaluates product efficiency using rheumatic statistics.

Table 4. Paired sample t-test

<table>
<tr><th colspan="2"></th><th colspan="7">Paired Sample t-Test</th></tr>
<tr><th rowspan="3">Pair 1</th><th rowspan="3">Pretest-Posttest</th><th rowspan="2">t</th><th rowspan="2">df</th><th rowspan="2">Sig. (2-tailed)</th><th rowspan="2">Mean Difference</th><th rowspan="2">Std. Error Difference</th><th colspan="2">95% Confidence Interval of the Difference</th></tr>
<tr><th>Lower</th><th>Upper</th></tr>
<tr><td>–17.949</td><td>74</td><td>.000</td><td>–24.360</td><td>1.357</td><td>–27.064</td><td>–21.656</td></tr>
</table>

The Sig value is known based on SPSS results. The known Sig value (2-tailed) is 0.000 < 0.05. If the (2-tailed) value is less than 0.05, it can be concluded that combining mobile augmented reality learning media with metaverse applications in learning has a beneficial impact. These results show that using metaverse applications can improve learning outcomes in human digestive system material science subjects.

4 Discussions

This study aimed to see whether mobile augmented reality influence learning outcomes of grade 5 elementary students in science subjects in cluster I Depok subdistrict, Indonesia.

These results show that the intervention successfully improved students' learning outcomes. The present study outcomes complement and expand knowledge of existing research outcomes [34]. This research supports previous findings that learning through augmented reality improves conceptual understanding during the learning process [35]. According to this study, augmented reality should be incorporated into specific learning methodologies in line with previous research integrating augmented reality in mathematical learning using digital technology strategies through photo math applications [36]. The study suggests that augmented reality changes will affect the new curriculum. In the meantime, past research has found that using augmented reality can aid in grasping the relationship between information and their comprehension of something presented with real-time visual assistance [37]. Accurate visualization helps make it easier for them to understand new information. This study backs up prior research, which shows that augmented reality can help students improve their spatial visualization skills and increase their interest in complex subjects [38]. Spatial visualization capabilities can be enhanced due to the realization of 3D forms and other complex learning when using augmented reality. Existing research also states that augmented reality can improve visual perception and overcome distance and time limitations in historical learning [39].

Augmented reality is also considered influential and beneficial for language learning, in line with previous research suggesting that augmented reality can increase motivation and result in positive student engagement in language learning [40]. Augmented reality allows students to engage in language learning actively [41]. Augmented reality places a premium on vocabulary in language learning, in line with previous research stating that students have increased arousal and attention in learning with 3D models equipped with live sound [42]. The study also showed that the use of vocabulary significantly contributed to language proficiency, and the results of learning vocabulary using augmented reality were positive.

According to another empirical finding of this study, students can increase their imagination skills and thus their learning results. This is also consistent with earlier studies, showing that augmented reality can overcome space and time constraints and free up teachers' time to focus on their students [43]. Creative visual experiences can also be used to solve abstract problems in keeping with an earlier study, which claims that by employing augmented reality, students may modify material by completing cognitive activities such as observing, manipulating, and analyzing into a rule in a step-by-step manner [44]. It is advantageous for students to deepen their understanding, connect with their daily lives and see how it affects learning. Students can explore independently and present complex and varied experiences [45]. Students can actively develop their cognitive talents in problem-solving and determine the best approach to a problem according to their immersion, interaction, and imagination.

Augmented reality-based learning outcomes positively impact student motivation, critical thinking skills, concept understanding, spatial visualization skills, language skills, and problem-solving, showing that augmented reality-based learning can be applied in schools [46–48]. Even students with lower achievement skills showed positive results when using this augmented reality mobile app. Augmented reality learning models can help students explain abstract concepts that are difficult to understand. Students will understand a subject matter more quickly if there is a direct or concrete form.

In today's world of education, technology is highly beneficial to students in terms of developing cognitive skills and accumulating information. Using technology related to the surrounding life and connecting it with learning methods can increase students' interest and motivation.

Based on the direct experience of the researchers studied, some of the limitations that occur may be more noticed for future researchers to improve and perfect it. Some of these limitations include: the number of samples is only 75 people, which is still very lacking in describing the actual situation. The research was conducted online due to the covid-19 pandemic situation that has not ended. In other words, researchers take data through the help of the google form application. The data of learning results provided by respondents through google form sometimes does not show actual results because we do not know how honest each respondent was when answering the pretest and post-test questions.

Students may now view images in the real world, but they cannot interact. Therefore, further research can be reviewed on interactive features involving students in this media. For example, it can help the child move their teeth when chewing with hand gestures or provide vivid animations that can later lead to new experiences that can be saved and unforgettable in the long run. Finally, the present augmented reality mobile media method has a positive application since it can develop cognitive skills and generate novel experiences in material acquisition. The primary goal is to improve students' learning results, and this will further reinforce the fact that mobile augmented reality learning media can be very effective when incorporated into school learning activities.

5 Conclusion

Overall, this study shows that augmented reality mobile media positively affects student learning outcomes in science subjects of digestive system material in humans. Students can quickly gain new experience in learning digestive system materials and independently understand them and access them under whatever conditions they wish. Learning in this way is considered more exciting and fun. Increased knowledge of various technology-based learning media must be utilized to make teaching materials easier to understand for students, as well as to offer learning materials more interestingly and efficiently, and to promote learning models in the globalization period.

This mobile augmented reality learning media with metaverse can be recommended for future investigation to enhance student learning outcomes in science classes at elementary schools providing direction to primary school instructors on improving student achievement. More research should be conducted worldwide to understand the impact of mobile further augmented reality learning media with metaverse on student learning outcomes.

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