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Effects of Augmented Reality Learning Media on Students' Cognitive Learning Outcomes in Virus Topics

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Abstract
This study examines the effect of Augmented Reality (AR) media on students' cognitive learning outcomes on virus material in class X of SMA Negeri 51 Jakarta. The method used is a quasi-experimental method with a non-equivalent control group design, involving an experimental class with AR media and a control class with conventional media. Data were collected through pretests, posttests, and observation sheets to measure the implementation of learning and learning outcomes. The results of the analysis showed that AR media was implemented very well, with an average implementation of 97% during four meetings. The use of AR significantly improved students' cognitive learning outcomes in the domains of C1 (remembering), C2 (understanding), and C3 (applying) compared to conventional media. The results of the t-test showed a p value = 0.018 ($p < 0.05$), with an average posttest of the experimental class of 73.08, higher than the control class of 65.63. AR media is effective in visualizing the abstract concept of viruses in improving students' understanding more deeply. The cognitive learning outcomes of students showed C1 = 82.14%, C2 = 81%, and C3 = 60%, higher than the control class. These results indicate that there is an influence of the use of Augmented reality media on students' cognitive learning outcomes on virus material at SMA Negeri 51 Jakarta.

Keywords: Augmented Reality, Cognitive Learning Outcomes, Viruses, Learning Media

1. Introduction

Biology learning is one of the means to understand and get to know the surrounding environment more deeply. This approach to learning, especially in the 21st century, emphasizes the use of technology to explore global issues, support the visualization of abstract concepts, and improve students' competencies (Banila et al., 2021). One of the technologies that is in the spotlight in modern learning is Augmented Reality (AR). This technology is able to integrate the real world with digital elements to provide a more interactive and effective learning experience (Stuart et al., 2017).

AR media in education, especially biology learning, offers various advantages, such as realistic visualization, interactivity, and ease of access through common devices such as Smartphone or Tablets (Pradana, 2020). AR technology allows students to understand abstract concepts that are difficult to visualize with conventional media. For example, viral material involving microscopic and complex structures is often a challenge for students. Media Augmented reality (AR) helps to recognize, abstract concepts to be transformed into easy-to-understand three-dimensional representations, thereby improving students' motivation and learning outcomes (Kamaruddin & Thahir, 2021).

Media Augmented reality (AR) is in line with the challenges of 21st century learning that demand not only material understanding, but also skills such as critical thinking, creativity, communication, and collaboration (Aripin et al., 2020). AR provides a solution to the limitations of traditional learning media in conveying relevant and interactive information. The results of observations in class X of SMA Negeri 51 Jakarta and interviews with biology teachers, show the difficulty of students in understanding abstract concepts, including viral material.

Teachers have not utilized technology-based learning media such as AR, so the teaching and learning process still depends on conventional media which has an impact on low student learning outcomes. The use of AR in learning virus material is believed to improve students' understanding and learning outcomes through 3D models, virus replication simulations, and visualization of abstract concepts in a more interesting and interactive way. Students are able to improve their understanding of viral material, which has been difficult to visualize using conventional learning methods (Ummah, 2021).

Augmented reality (AR) is a technology that integrates digital elements into the real world, playing a major role in various fields including education. According to Dhar et al (2021), AR allows for more immersive interactions between physical and virtual environments. AR works through stages such as capture, identification, processing, and visualization to produce interactive content (Saputri, 2017). The development of AR starting from the concept of sensorama by Morton Heilig to its application in modern technology has changed the learning paradigm (Kamaruddin & Thahir, 2021). The application of AR in learning, such as discovery-based learning, AR Books, and Object Modeling, providing an immersive learning experience, helping students understand complex material visually and interactively (Yuen et al., 2011); (Indahsari & Sumirat, 2023). This is especially relevant for improving cognitive learning outcomes, which include aspects of remembering, understanding, and creating (Krisnaningrum, 2022).

Cognitive learning outcomes are intellectual changes that are evaluated through specific learning objectives, influenced by internal factors such as intelligence and motivation, as well as external factors such as family support and school environment (Umami, 2021; Agustiandini, 2023).

Bloom's taxonomy shows six cognitive levels ranging from C1 (remembering) to C6 (creating), which are used as a reference in designing gradual learning. The scientific approach in education involves steps: observing, questioning, collecting data, reasoning, and communicating. This approach encourages students to learn through logical exploration and reasoning, resulting in knowledge that is not just memorization but meaningful findings (Rhosalia, 2017); Aisyiyah & Amrizal, 2020).

Some studies have shown that the use of Augmented Reality (AR) can improve students' cognitive learning outcomes, but unfortunately most studies still focus on improvement in general without examining in depth the distribution of improvements at each cognitive level in Bloom's taxonomy, especially in highly abstract materials such as viruses. In addition, many studies have only emphasized the effectiveness of AR media compared to conventional media, but have not specifically linked how the three-dimensional visualization characteristics of AR contribute to the improvement of thinking skills at the C1, C2, and C3 levels separately. This shows that there is a research gap related to a more structured and detailed analysis of the impact of AR on each cognitive domain.

The implementation of AR in biology learning in schools is still relatively limited and has not been optimally integrated with the scientific approach that is the demand of the curriculum. Previous research has tended to focus on media development or effectiveness testing in general, without examining how AR can support each stage of scientific learning such as observing, questioning, collecting data, reasoning, and communicating. Therefore, this study has novelty by examining not only the influence of AR on cognitive learning outcomes, but also how the media is systematically implemented within the framework of a scientific approach to viral material, so as to make a more comprehensive contribution to the development of technology-based biology learning.

This study aims to examine the effect of the use of AR on students' cognitive learning outcomes in viral materials. The focus of the research is to improve students' understanding of abstract concepts, by utilizing technology as an interactive learning tool. The results of this research are expected to provide new insights related to the application of digital media in the world of education and become an effective solution in biology learning.

2. Methods

The research was carried out at SMA Negeri 51 Jakarta, from November to December 2024, with a quantitative approach using a *quasi-experiment method* based on *non-equivalent control-group design*.

Table 1. *Non-equivalent control-group design*.

Classes	*Pretest*	Treatment	*Posttest*
E	O1	X	O2
K	O1	Y	O2

The sample selection was carried out by *cluster random sampling,* so that class X1 was selected as an experimental class using *Augmented Reality* (AR) learning media with a total of 35 students, while the control group used conventional learning methods with a total of 36 students. The conventional learning model is a teacher-centered learning approach, where teachers are the main source of information and students act as passive recipients of knowledge. In practice, this model is usually carried out through lecture methods, direct explanations of material, and assignments or practice questions. The interaction that occurs tends to be one-way, namely from teacher to student, so that students' opportunities to discuss, explore, or construct their own knowledge are relatively limited. The main characteristics of conventional learning include the delivery of structured material from textbooks, the use of simple or minimal technology media, and the emphasis on basic memorization and understanding.

The collection of research data, including cognitive learning outcomes, and the implementation of learning using AR. Students' cognitive data were obtained through *pretest* and *posttest* which had been validated through *expert judgment* by lecturers in the field of biology using the Likert scale with the category "Feasible" to be used after minor revision. *The pretest* is carried out at the beginning of learning while the *posttest* is at the end of learning. Data on the implementation of learning using AR media was collected through observation by observers. The research instrument is a teaching module based on scientific approaches and *Augmented reality media.*

The research procedure includes three main stages. First, validation of instruments with experts to ensure the validity and reliability of measuring tools, including *pretest* and *posttest questions* consisting of 20 multiple-choice questions and 5 essays, as well as teaching modules. Second, the implementation of research begins with *a pretest*, followed by learning according to the modules that are prepared. The experimental class used AR as a learning medium, while the control class did not use AR. Third, *posttests* are carried out to measure students' cognitive learning outcomes. The data obtained were analyzed using a prerequisite test (normality and homogeneity) with SPSS version 26. The normality test was performed using *Shapiro-Wilk*, while the homogeneity test used *the Homogeneity of Variance*. If the data met the assumptions of normality and homogeneity, a t-test was performed to compare student learning outcomes between the experimental and control classes. The results of this study are expected to provide empirical evidence regarding the influence of AR learning media on students' cognitive learning outcomes on viral materials.

3. Result and Discussion

Quasi-experimental research has been carried out at SMA Negeri 51 Jakarta in the even semester of the 2024/2025 academic year with a research population, namely all students of class X. Quasi-experimental research was carried out to find out whether there is an influence of learning media *Augmented reality* on student learning outcomes on virus material at SMA Negeri 51 Jakarta. Samples in the research class X1 as experimental class and X3 as control class. Researchers provide treatment *(Treatment*) to the experimental class using AR learning media in the experimental class while the control class used media with Biology textbooks at school.

Posttest It is a test given to students to obtain data on research results both in the experimental class and the control class with the aim of finding out the ability of students after being given different treatments. The learning outcome data was obtained from multiple-choice questions as many as 20 questions and 5 essays with viral material, which were adjusted to the cognitive levels of C1 (remembering), C2 (understanding), and C3 (applying). Cognitive learning outcome data was analyzed using descriptive statistics. The following is presented the results of a descriptive analysis of student learning outcomes in *Posttest* experimental class and control class in Table 2.

Table 2. Results of Descriptive Analysis *of Posttest* Experimental Class and Control Class

Classes	N	Min	Max	Red	Std. Deviation
TO	33	42.20	93.30	73.08	12.14
CD	34	31.10	82.20	65.63	12.95

Table 1 shows that the *maximum posttest* score obtained was 93.30, the minimum score was 42.20, and the average score was 73.08 with an average difference of 7.44. The results indicate that learning with AR media has a positive influence on improving students' cognitive learning outcomes.

Statistical analysis in the study was carried out with a prerequisite test which included a normality test and a homogeneity test in the experimental class. The test was carried out using the SPSS application program ver.26. The results of the test can be seen in table 3.

Table 3. Prerequisite Test Results

Prerequisite Test	Testing Techniques	Significance
Normality Test	*Shapiro-Wilk*	*Experimental class posttest* = 0.29 *Control class posttest* = 0.12
Homogeneity Test	*Homogeneity of Variance*	0.88

Table 3 shows the results of the normality test of the posttest learning outcomes *of* the experimental class and the normally distributed control class with a significance value of 0.29 > 0.05. In accordance with the provisions of the normality test, if the significant value is greater than 0.05, then the data is distributed normally. The results of the homogeneity test using *Homogeneity of variance* showed homogeneous data with significant values of 0.88 > 0.05, so that the data was declared homogeneous. Furthermore, a parametric statistical test was carried out with t-test analysis using *an independent sample t-test.* The results of the t-test in table 4.

Table 4. T-Test Results

	F	t	Free Degree (db)	Sig (2-tailed)
Posttest	0.25	-2425	65	0.018

T

he results of the t-test show a value of sig. (2-tailed) of 0.01 (p < 0.05), which means that there is a statistically significant difference between the two classes. This is in line with previous research by Kamaruddin and Thahir (2021), and Brandon et al. (2023), which found that learning using AR media was able to improve student learning outcomes compared to learning with conventional media. The use of AR media not only facilitates the understanding of abstract concepts through interactive visualization but also supports the active involvement of students in the learning process, as observed in each stage of learning involving observing, questioning, analyzing, and presenting the results of discussions collaboratively.

Understanding concepts in cognitive learning outcomes reflects students' ability to do more than just remember theories, but also apply knowledge in real situations (Wahyuningtyas, 2019). The implementation of learning using *Augmentd reality* media on viral materials showed high success in all four meetings. At the first meeting, the learning was carried out very well, marked by a *100% implementation* percentage.

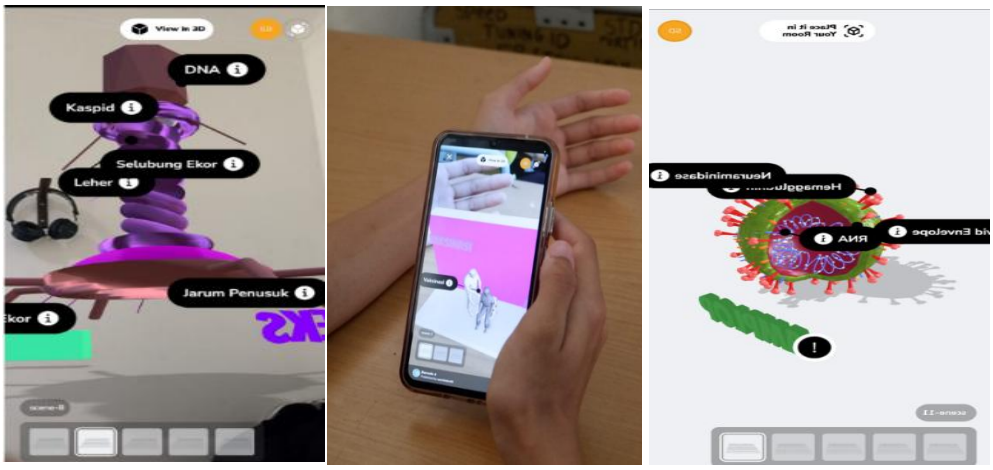

Figure 1. 3D Visualization of AR Media

AR 3D visualization helps students understand the basic characteristics and structure of viruses through learning stages that include observation, discussion, and reflection. In the second meeting, the focus of learning was to understand the virus replication process, which was also carried out very well with a 100% implementation percentage. AR media facilitates students' understanding of the stages of virus replication through direct interaction with 3D models and group discussions, while supporting cognitive achievement at the C2 (understanding) and C3 (applying) levels.

The third and fourth meetings, learning took place with a focus on analyzing the role of the virus and how to prevent its spread. The implementation at the third meeting reached 85.7%, with several aspects that required attention, especially time management for learning reflection. AR media allows students to relate abstract concepts to real phenomena, such as the benefits and impacts of viruses in everyday life. The fourth meeting showed perfect implementation (100%) in learning about measures to prevent the spread of the virus. Students actively observe, discuss, and practice a healthy lifestyle through AR simulations. AR media not only supports interactive scientific learning, but also improves students' cognitive skills, both in understanding concepts and applying them in daily life.

Media *Augmented Reality* (AR) in learning has been proven to improve students' cognitive learning outcomes on viral materials. Conforming to Theory *Cone of Experience* Edgar Dale, learning will be more effective if students are directly involved in real learning experiences. AR media allows students to visualize abstract concepts, such as the structure and replication of viruses, to be more concrete and interactive (Kamaruddin & Thahir, 2021). By providing a

learning experience based on 3D visualization, sound, and direct interaction, it helps students understand the material more deeply. Research by Mustaqim and Kurniawan (2017), supporting this, stating that AR supports more structured learning.

In the context of constructivist theory, AR media helps students actively build their own understanding through the exploration of virtual objects. Students' interactions with AR media, such as observing 3D visualizations and simulating the process of virus replication, create meaningful learning (Ningsih, 2019). With AR media, students can build new knowledge based on the hands-on experience they get, so their understanding of viral material increases. This is also seen in research by Afnan and Puspitawati (2024), which shows that AR effectively facilitates constructive learning through an interactive visual approach.

Contextual learning theory connects everyday life with learning materials, helping students build a deeper understanding of the concepts being learned. (Mashami et al., 2021). In research Wahyuningtyas and Wuryadi (2018), contextual theory shows intellectual development that can be achieved through active participation and meaningful experience in the learning process. Relate experiences that are commonly encountered in daily activities with knowledge that has been learned. This strengthens the ability of reality-based application (C3), where students not only understand concepts but can also use them in everyday life.

The improvement of students' cognitive learning outcomes in this study was shown through the comparison of scores *Pretest* and *posttest.* Results *Pretest* It shows that students in both classes have a similar initial understanding, as evidenced by the results of the Independent Sample T-Test which shows a significance value of 0.81 ($P > 0.05$). After treatment with AR media in the experimental class, the results *Posttest* showed a significant improvement with an average score of 73.08 compared to the control class which had an average of 65.63. The hypothesis test using an independent sample t-test showed a significance value of 0.01 ($p < 0.05$), which means that there is a significant difference between the two classes (Andini, 2023); Nasar et al., 2024). The results of the study also illustrate the improvement of students' cognitive in the domains of C1 (remembering), C2 (understanding), and C3 (applying). Results *Posttest* presented in Figure 1.

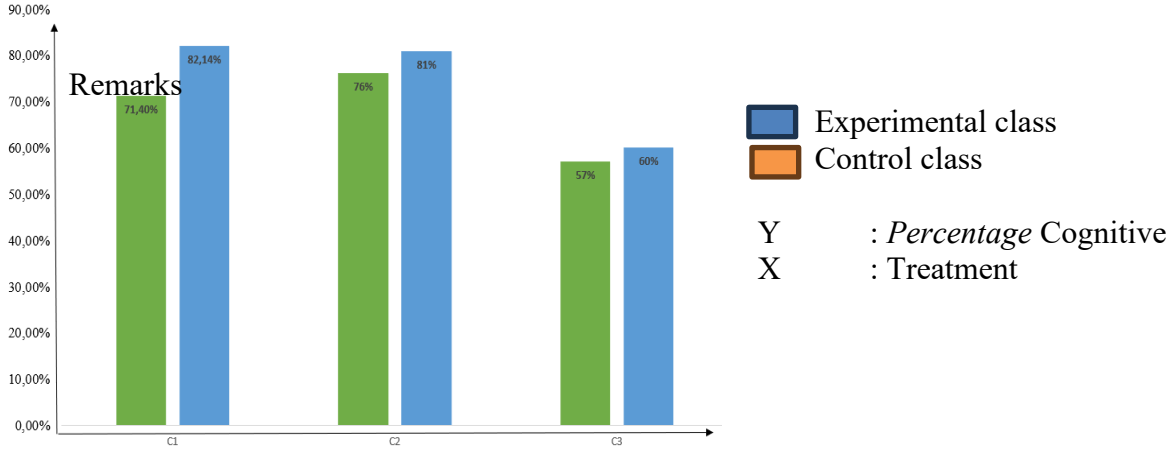

Figure 2. Diagram of Cognitive Learning Outcomes of Experimental and Control Class Students

In the C1 domain, operational verbs (KKO) are seen when students can remember, recognize, pronounce, pronounce, and rewrite what they have learned previously and stored in Long-term memory. The C1 domain showed better scores after using AR, with an average correct answer score of 82.14% in the experimental class compared to 71.40% in the control class. In the C2 domain, the operational verb that is seen is that students are able to explain, summarize, compare, distinguish, and explain the information that has been learned with a score of 81% in the experimental class compared to 76% in the control class. In the C3 realm of KKO is using, determining, interpreting, and executing procedures, so that students can apply their knowledge in a real context with a score of 60% in the experimental class compared to 57% in the control class (Dishinta & Hadi, 2023; Rosmana et al., 2024).

The results of this study support previous theories and findings that AR media have great potential in improving students' cognitive learning outcomes, especially in materials that require visualization of abstract concepts such as viruses. With a technology-based interactive approach, students not only find it easier to understand the material, but also more active in building their own knowledge. These findings are in line with research by Suparlan (2019) and Khotimah et al. (2019), which stated that the use of visual media such as AR significantly improves students' memory, comprehension, and skills. Thus, AR media can be an effective solution for innovative and relevant technology-based learning in the digital era.

Media application *Augmented Reality* (AR) to improve cognitive learning outcomes in viral material effectively supports a scientific approach consisting of five syntax, namely observing (*Observing*), ask (*Questioning*), collect data (*Collecting data*), reasoning (*Reasoning*), and

communicate (*Communicating*). In the observation stage, AR provides an interactive learning experience by presenting virus objects in real 3D visualizations, such as the structure, shape, and replication of viruses. Students can observe the details of the material independently, which improves their memory of basic concepts (Rosmana et al., 2024). AR also allows students to record important information, thus helping the observation process to be more focused and structured (Scott, 2014).

The interrogation and data collection stage is well supported by AR media, where students are encouraged to ask analytical questions about the structure and function of viruses, such as the reason for the difference in viral shape or the stages of replication before the host cell ruptures. This process shows that students can think critically and logically, according to a scientific approach (Agustin & Wardhani, 2023). While collecting data, students explore 3D models, identify virus components, and understand the replication process through interactive simulations. AR also allows students to relate the results of exploration to previous or real-life findings, making the data collection stage more meaningful and effective (Ismail et al., 2018).

Figure 3. Visualization of Virus 3D Models

In the reasoning and communicating stage, students analyze data from AR to formulate logical arguments related to the interaction of the virus with host cells and their impacts. They deduced information based on the group's analysis and presented the learning outcomes using AR visualization. This media makes the delivery of material more interesting and helps students understand complex concepts through simple visuals (Fiqri et al., 2022). Other research shows that AR improves students' communication skills, as they have to explain abstract concepts in a structured and visual way (Agustin & Wardhani, 2023). AR media supports the implementation of a comprehensive scientific approach, improving students' cognitive learning outcomes on viral materials, especially in the realms of C1 (remembering), C2 (understanding), and C3 (applying).

The interactive display of information in 3D format makes it easier for students to recall the material learned at the first meeting. The use of AR media in learning has a significant impact on students' memory, especially at the C1 cognitive level. Students' knowledge in the process when recalling virus material with concepts that have been taught through AR media. Knowledge of the concept of virus structure (first meeting) in the process of students in re-recognizing virus visualization from the material that has been studied according to the principles of constructivism theory. Through AR media, students not only passively receive information, but actively observe and construct new knowledge in a meaningful way. When students write down what they learn, they not only passively recall information, but also organize and reflect on knowledge. Writing facilitates deeper information processing and strengthens the formation of long-term memory.

Reciting is one of the increasing knowledge on the abstraction of the concept of viral material. Recitation information is another effective technique to improve declarative knowledge by involving the repetition of words or terms related to the virus, such as capsid, replication, and prevention of spread

virus. Through oral repetition, students not only recall information, but also paraphrase verbally, thus helping to strengthen relationships in memory.

Knowledge has increased because students are directly involved in observing every material presented through AR media. Interesting and contextual presentation in accordance with the learning material increases the attractiveness of learning while strengthening students' memory or memory of the information conveyed. When students use AR to visualize viruses, students can mention and recite parts of the virus directly based on what is seen on the AR media screen. This interaction with 3D visualization not only strengthens memory, but increases the involvement of the information retrieval process, so that their declarative knowledge is stronger and internalized.

The C2 domain or understanding is the second level of Bloom's taxonomy with a focus on understanding, which involves the operational verb explaining, summarizing, comparing, distinguishing, and explaining the information that has been learned. At the first meeting, AR media has been proven to be effective in increasing student understanding, this can be seen in the enthusiasm of students in learning virus material, especially in the abstract concept of virus structures. Well-designed AR media provides a learning experience that strengthens students' understanding through 3D object visualization and hands-on interaction on AR media. Active interaction between students builds to deepen student understanding (Ridwan et al., 2023).

Understanding (C2) in the study is processed when students can summarize the material obtained from AR media (first meeting), compare the structural functions of the virus (second meeting), and explicitly explain the characteristics of the virus (first meeting), the role of the virus (third meeting), and the prevention of the spread of the virus (fourth meeting). Student understanding is

improved in summarizing activities almost at every meeting. This is because the summarizing activity involves students in a more in-depth information processing process. By summarizing, students sift through important information, organize key ideas, and rewrite the material in a more concise form. AR media visualizes interactively, helping students identify important elements that need to be summarized, such as the structure of viruses and their functions. This can strengthen students' understanding of the concepts being taught.

Comparing is an activity that supports analytical understanding (C2). When comparing the structural functions of viruses, students process information in a more critical way, i.e. recognizing similarities and differences between different elements. Explaining means conveying the concept in one's own words on the characteristics of viruses, the form of viruses, the structure of viruses, virus replication, the role of viruses, and the prevention of virus spread. Students understand basic concepts and are able to relate them to relevant details. AR media plays an important role in supporting learning activities by providing concrete visualizations, such as three-dimensional models of viruses, so that students can provide their own explanations with observed images or animations.

Applying (C3) improves students' understanding of the involvement of identifying differences and similarities between concepts or objects, as well as understanding the unique characteristics of each. Understanding the KKO applies not only improves conceptual understanding but also helps students develop analytical skills in distinguishing the specific characteristics of each virus. Using information from AR media at the second meeting helps students practice the knowledge that has been gained to identify the role of the virus, both beneficial and harmful. This improves applicability (C3), where students not only remember facts but also use the information in new contexts. According to constructivist theory, learning that involves tools such as AR supports an active learning process, in which students build their own understanding through interaction with engaging and interactive visual learning resources.

Interpreting the results of the analysis obtained during the group presentation at the third meeting improves students' ability to analyze and apply information (C3). In learning activities, students use data and knowledge obtained from AR media to make meaningful conclusions and show a deep understanding of the material. The third meeting learning focuses on students in building and gathering knowledge through AR media and connecting the context of findings to daily life. Implementing real-world AR visualizations related to the prevention of the spread of the virus at the fourth meeting involved students' ability to apply abstract concepts in real-life situations. Learning with hands-on practice aims to increase students' understanding of learning materials and improve skills and knowledge to apply in daily life.

Running a procedure in C3 is related to the ability to follow certain steps or methods. AR can provide step-by-step guidance in visual and interactive form, helping students understand and follow procedures more effectively. Students can follow the handwashing steps at the fourth meeting with materials on preventing the spread of the virus. AR can stimulate students' mindset in thinking critically about problems and events in everyday life, because AR can visualize abstract concepts. AR media with visualizations can be used by students to design or recommend preventive measures based on their understanding of how the virus spreads. Relate experiences that are commonly encountered in daily activities with knowledge that has been learned. This strengthens the ability of reality-based application (C3), where students not only understand concepts but can also use them in everyday life.

AR as a medium plays an important role in creating an interactive and contextual learning environment. Through 3D visualization, students actively practice directly the material that has been learned, on how to prevent the spread of the virus. AR media allows students to understand concepts visually first, before applying them in real terms. It is relevant to the theory of constructivism because students not only receive information, but also apply the concepts they have learned to solve problems or answer questions. Integrating visual and practical learning experiences, students not only master concepts but apply them in the context of everyday life.

4. Conclusion

AR learning media on virus material at SMA Negeri 51 Jakarta was carried out very well. All stages of learning that are adjusted to the scientific approach, namely observing, questioning, collecting data, reasoning, and communicating, have been carried out optimally with an implementation rate of 100% in three meetings and 87.5% in one meeting. AR media provides a more interactive and immersive learning experience, thereby increasing student engagement at every stage of learning.

The use of AR media has been proven to have a significant positive influence on students' cognitive learning outcomes on viral materials, especially in the realm of knowledge (C1), understanding (C2), and application (C3). The results of the t-test (*independent sample t-test*) showed a value of sig. (2-tailed) of $0.018 < 0.05$, indicating a significant difference between the learning outcomes of students who use AR and those who do not. The average score of learning outcomes in the group with AR was higher than in the class without AR, which was 82.14% in C1, 81% in C2, and 60% in C3. The results support that AR media is an effective learning medium to improve students' memory, concept comprehension, and application ability.

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6. References

Afnan, M. Z., & Puspitawati, R. P. (2024). Exploration of biological concept understanding through augmented reality : A constructivism theory approach Abstract : *JPBI (Indonesian Journal of Biology Education)*, *10*(3), 1139–1147.

Agustiandini, D. T. (2023). *The Effect of the Use of Infographic Learning Media on Students' Cognitive Learning Outcomes in Social Studies Subjects at MTS Negeri 6 Pasuruan for the 2022/2023 Academic Year*. (Thesis, UIN Jember(.

Agustin, A., & Wardhani, H. (2023). The Influence of Augmented Reality (AR) Media Assisted by Assemblr Edu on the Learning Outcomes of SMP It Robbani Sintang Students. *Edumedia: Journal of Teacher Training and Education*, *7*(2), 7–13.

Aisyiyah, A. T. P., & Amrizal, A. (2020). Application of Scientific Approach in High School Biology Learning. *Journal of Pelita Education*, *8*(4), 215–223.

Andini, A. (2023). The Effect of the Use of Wordwall Learning Media on Student Learning Outcomes in Elemental Periodic System Material. *Journal of Chemical Education Research,10,* (1).

Aripin, I., Sugandi, M. K., Mu'minah, I. H., & Mulyani, A. (2020). 21st Century Biology Training. *BERNAS: Journal of Community Service*, *1*(3), 150–158.

Banila, L., Lestari, H., & Siskandar, R. (2021). The application of blended learning with a STEM approach to improve students' science literacy skills in biology learning during the covid-19 pandemic. *Journal of Biology Learning*, *3*(1), 25.

Dhar, P., Rocks, T., Samarasinghe, R. M., Stephenson, G., & Smith, C. (2021). Augmented reality in medical education: students' experiences and learning outcomes. *Medical Education Online*, *26*(1).

Dishinta, D. D., & Hadi, M. S. (2023). Implementation of Augmented Reality on Students' Cognitive Domain Ability. *JIM: Student Scientific Journal, 8*(3).

Fiqri, M. N., Hanafi, I., & Sugiyanta, L. (2022). The Utilization of Augmented Reality to Develop

Computer Learning Media and Basic Networks at SMK DKI Jakarta. *Journal of Educational Technology*, *11*(1), 1–10.
Indahsari, L., & Sumirat, S. (2023). Implementation of Augmented Reality Technology in Interactive Learning. *Journal of Communication and Educational Media*, *1*(1), 7–11.
Ismail, M. E., Utami, P., Ismail, I. M., Khairudin, M., Amiruddin, M. H., Lastariwati, B., & Maneetien, N. (2018). The Effect of an Augmented Reality Teaching Kit on Visualization, Cognitive Load and Teaching Styles. *Journal of Technology and Vocational Education*, *24*(2), 178–184.
Kamaruddin, R., & Thahir, R. (2021). The Effect of Augmented Reality (AR)-Based Learning Media on Biology Learning Outcomes of High School Students. *Journal of Learning Research and Innovation*, *1*(2), 24–35.
Krisnaningrum, A. L. (2022). Analysis of the Suitability of Class X Biology Final Assessment Questions (PAS) in South Jakarta based on the Revised Bloom Taxonomy. In *Thesis*.
Mustaqim, I., & Kurniawan, N. (2017). Development of Augmented Reality-Based Movie Learning Media. *Jambura Journal of Informatics*, *4*(2), 82–93.
Nasar, A., Saputra, D. H., Arkaan, M. R., Ferlyando, M. B., Andriansyah, M. T., & Pangestu, P. D. (2024). Prerequisite Analysis. *JEBI: Journal of Economics and Business*, *2*(6), 786–799.
Ningsih, N. (2019). Application of Constructivism Learning Theory in Foreign Language Learning. *Journal of Foundasia*, *9*(1), 43–54.
Parani, P. S. R., Sukarso, A., Mahrus, M., & Khairuddin, K. (2023). Using Augmented Reality Virus (VAR) Application Media to Improve High School Students' Disposition and Creative Thinking Skills. *Journal of Science Education Research*, *9*(4), 2288–2295.
Pradana, R. W. (2020). The Use of Augmented Reality in Senior High Schools in Indonesia. *Journal of Learning Research and Development*, *5*(1), 97.
Prasetiyo, T. K., Setyosari, P., & Sihkabuden. (2017). Development of Augmented Reality Media for Building Drawing Engineering Expertise Program in Vocational High Schools. *Journal of Innovation and Learning Technology*, 37–46.
Rhosalia, L. A. (2017). Scientific Approach in Integrated Thematic Learning Curriculum 2013 Version 2016. *Journal of Teaching in Elementary Education*, *1*(1), 73–74.
Rosmana, P. S., Ruswan, A., Lesmana, A. R. D., Andini, I. F., Yuliani, I. P., Ramanda, N., Nurfitria, R., & Citra, W. R. (2024). The Implementation of LKPD on the Learning Effectiveness of Students in Elementary Schools. *Journal of Tambusai Education*, *8*(1), 3082–3088.
Saputri, D. S. C. (2017). The use of Augmented Reality to improve vocabulary mastery and learning outcomes. *Journal of Justice*, *6*(1), 1357–1366.
Suwarna, I. P. (2014). The Influence of Augmented Reality-Based Learning Media on the Learning

Outcomes of Class X Students on the Concept of Particle Dynamics. *Journal of Education in Muslim Society*, *2*(1), 61–72.
Ummah, K. (2021). Development of Biology Learning Module Based on Reading, Questioning, and Answering (RQA) of Class X Virus Material. *Journal of Biology and Its Learning*, *8*(1), 19–25.
Wahyuningtyas, R. S., & Wuryadi. (2018). The Influence of Contextual Teaching and Learning To Improve Students on Critical Thinking Ability and Coceptual Understanding of Skeletal System Materials. In *AIP Conference Proceedings, 080009.*
Wahyuningtyas, R. S. (2019). The Effect of the Project Based Learning Model with Live Aquarium Using Native Indonesian Species on Students' Cognitive Learning Outcomes in Ecosystem Materials. *Pro-Life Journal*, 286–293.
Yuen, S. C.-Y., Yaoyuneyong, G., & Johnson, E. (2011). Augmented Reality: An Overview and Five Directions for AR in Education. *Journal of Educational Technology Development and Exchange*, *4*(1), 119–140.