Indonesian Society for Science Educators
Journal of Science Learning
journal homepage: ejournal.upi.edu/index.php/jslearning

The ARVi Learning App Makes Viruses Visible

Risda Putri Indriani[1]*, Tri Handayani Kurniati[1], Rizhal Hendi Ristanto[1]

[1]Master Biology Education, Faculty of Mathematics and Sciences, Jakarta State University, Jakarta, Indonesia.

*Corresponding author: risda17putri@gmail.com

ABSTRACT In biology learning, the object of a virus cannot be seen directly. Augmented reality (AR) technology can help visualize the object of a virus in 3D, making it easier for students to learn about viruses. Therefore, this research aims to develop an AR-based learning media product called ARVi. ARVi was created using the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The results of the analysis revealed that students need learning media with engaging visualizations. Therefore, ARVi was designed as a mobile application with various colors, images, videos, AR, and quizzes. ARVi underwent validation tests by experts, including biology education lecturers and biology teachers. The user responses were evaluated through a small group test involving 20 students, where questionnaires were distributed. Based on the questionnaire results, the average score for the media expert was 3.84, and for the material expert was 3.80. These scores indicate that ARVi is very valid for use as a learning medium. The results of the small group test were 2.85, indicating that ARVi is valid for use after minor revisions are made. The implementation results for 60 students, as determined through a paired t-test, showed a significant difference between the pretest and posttest results, with the posttest score being higher than the pretest score. The research results concluded that ARVi is suitable as a biology learning media.

Keywords App learning, Augmented reality, Instructional media biology, virus.

1. INTRODUCTION

Viruses around 20-30 nm are microscopic and can only be seen with an electron microscope (Pelczar & Chan, 1986). Viruses cannot be readily isolated, and it is difficult to find the object of study for learning about viruses. This corresponds to the result of the analysis that the concept of viruses is difficult to learn. The reason is that viruses are invisible to ordinary eyes and cannot be experimented with. A learning medium, such as a student's book, Microsoft PowerPoint, or whiteboard, is not optimal for visualizing viruses. To solve the problem, students and teachers should preserve a learning medium capable of visualizing viruses, making the lesson more interesting. The medium is expected to be based on accessible technology.

Technology-based learning media was used to support learning biology. Numerous research studies have employed various media, including Campusflora application for plant lessons (Dimon, Pettit, Cheung & Quinnell, 2019), a virtual laboratory for animal network lessons (Hartono, Tanjung, & Syahputra, 2021), a Powtoon video for metamorphosis lessons (Resmol & Leasa, 2022), a website for reproduction lesson (Djamahar, Rifan & Ristanto, 2020), a mobile game for viruses lesson (Del Piero, Afirianto, & Wardhono, 2019), a digital comic for changing an environment lesson (Dewi & Harini, 2021) and the gastrointestinal system lesson (Roswati, Rustaman, & Nugraha, 2019). Additionally, augmented reality media has been used to classify the creatures (Widodo & Utomo, 2021).

Augmented Reality (AR) is one of the learning media that allows the visualization of viruses. AR is the technology that can project the 3D object in a genuine environment (Mahmud & Pratiwi, 2019). AR assists students in comprehending concepts, building interactive classes, and increasing motivation (Khade & Khade, 2016; Puspitasari, Praherdhiono, & Adi, 2020). AR is useful for creating engaging and enjoyable learning (Celik, Guven, & Cakir, 2020). Yapici & Karakoyun (2021) states that teacher candidates can use AR in the class (Yapici & Karakoyun, 2021). Then, the AR media has the potential to support students in learning viruses, making the class more intense and realistic and increasing students' comprehension of biological concepts, especially viruses.

Received: 09 January 2024
Revised: 28 June 2024
Published: 30 July 2024

Using AR as a learning media is not a new thing in biology. Earlier research had already utilized AR in teaching the classification of creatures (Widodo & Utomo, 2021), the circulatory system (Arslan, R., Kofoğlu, M., & Dargut, 2020), anatomy of animals (Celik, Guven, & Cakir, 2020) 2020; Djati, Widiyatmoko, & Pamelasari, 2022; Erwinsah, Aria, & Yusup, 2019), sensory system (Sylvia, Ramdhan, & Windyariani, 2021), and viruses (Thahir & Kamaruddin, 2021; Kamiana, Kesiman, & Pradnyana, 2019; Meslilesi, Anra, & Pratiwi, 2017; Puspitasari, Praherdhiono, & Adi, 2020). The AR developed in previous research assumed that students find it helpful to comprehend the lesson, especially in the replication step (Puspitasari, Praherdhiono, & Adi, 2020). The characteristic of AR developed in previous research is that it is still marker-based, using images in printed books as markers. It requires two tools to run it: AR apps and a bookmark. This is the weakness of AR in an earlier period. Based on the weakness, AR media developed in this research uses a marker-less technique. The marker-less technique uses particular points in the horizontal area to display an AR object (Lyu, 2012). Markerless allows users to use AR without printed images, making it more accessible and user-friendly.

Augmented Reality Viruses (ARVi) are a learning media that employs a marker-less technique. This application will be complemented by an article that expands students' literacy. The importance of literacy in the 21st century is well documented. Literate students can deliberate their advantages and disadvantages (Indrayana et al., 2022). Subsequently, the ARVi will be accompanied by a high-level cognitive quiz based. The reason is that students with high cognitive abilities can arrange and copy information to complete the task (Jex, 2002). Based on their current state, ARVi's learning media will be developed according to the concept of viruses.

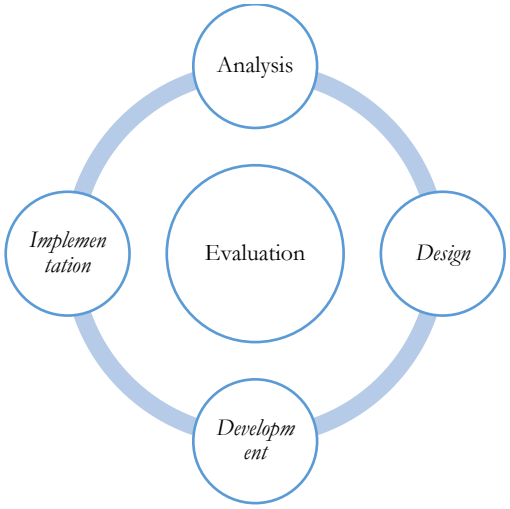


Figure 1 ADDIE Model

2. METHOD

The research to develop the ARVi (augmented reality virus) learning media product was conducted in Bogor and Jakarta, Indonesia. The small group trial was conducted at MAN 1 Kota Bogor. The type of research used was research and development (R&D) with the ADDIE (1990) development model.

Figure 1 shows the stages of the ADDIE, including need analysis, design, development, implementation, and evaluation. The needs assessment stage aims to identify problems, constraints, and situations in schools' biology learning. The needs analysis includes distributing questionnaires to students and teachers. The design stage is to design learning media suitable for students' needs and ARVi features. The development stage involves creating ARVi apps using a blender, Figma, and Unity 3D websites. ARVi apps are validated and tested with small groups. The implementation stage aims to test the effectiveness of using ARVi in biology learning. The evaluation stage is carried out by improving the product based on the result of

Table 1 The data collection process

No.	Data Collection	Instrument	Assessment criteria	Respondent
1.	Need assesment	Questionnaire	• Constraints experienced when learning biology • Learner characteristics • School facilities	• Student • Teacher
2.	Media validation	Material expert questionnaire	Components of : • Curriculum • Subject • Language	• Lecturer • Teacher
		Media expert questionnaire	• Appearance design • Media presentation	• Lecturers
3.	Small groups trial	Questionnaire	Response after using the product	20 Students
4.	Result of implementation	• Posttest • Pretest	• Descriptive test • Normality test • Paired t-test	60 Students

implementation. The evaluation stage is carried out at the end of each needs analysis, design, and development phase.

The data collection involves several steps, such as needs analysis, media validation, and small group testing. Each procedure uses a questionnaire with different scoring criteria, as seen in Table 1.

The instrument for analyzing needs is a questionnaire with assessment criteria regarding the learning process in school, biology learning media, and facilities in school. The instrument was distributed to 30 eleventh-grade students and biology teachers. This information is used to provide solutions for improving biology learning. The need for analysis instruments is described in Susilawati & Khaira (2021).

The feasibility test of the media is conducted by using a questionnaire to experts in the field of subject matter and media. Subject matter experts are needed to assess the suitability of the virus concept in ARVi. The media expert questionnaire instrument is used to assess the suitability of ARVi as a learning media. The questionnaire of material and media experts from Batubara (2021). The student response instrument is conducted to determine the impression of students while using ARVi for learning biology. It is an instrument of student response from Suryani, Rukmini, Bharati, & Hartono (2018).

The learning instruments are designed to assess students learning ability using multiple-choice tests. The tests are administered before and after using ARVi apps via pretest and posttest. The sub-concepts of viruses encompass history and characteristics, structure and classification, replication stages, diseases caused by viruses, benefits of viruses, and the impact and solutions of COVID-19.

Analyze data using descriptive statistics, which makes the data easier to understand. The data is based on the average score that can be interpreted and summarized by criteria from Ratumannan & Laurens (2011) into a conclusion about the product being evaluated. The normality test uses the Kolmogorov-Smirnov (K-S) test with an alpha value of 0.05. Data is normally distributed if the obtained value exceeds the alpha value. The normality test is performed using SPSS Statistics 23. A paired t-test is conducted to determine the effectiveness of ARVi media usage before and after. The paired t-test is performed using SPSS Statistics 23 by comparing the calculated t-value and the table t-value. If the calculated t-value is greater than the table t-value, then there is a difference in learning outcomes between the pretest and posttest (Putrawan & Riadi, 2020).

3. RESULT AND DISCUSSION

The findings of this research and development project have yielded augmented reality viruses learning media, designated as ARVi. The ARVi's app is developed by the ADDIE research and development model that consists of the following stages: analysis, design, development, implementation, and evaluation.

3.1 The Result of Need Analysis

The respondents were 30 students in grade 10 who had been learning about the concept of viruses and consisted of 10 questions. The results are illustrated in Figure 2.

Based on the result, some students felt that learning biology was exciting and enjoyable, while others found it

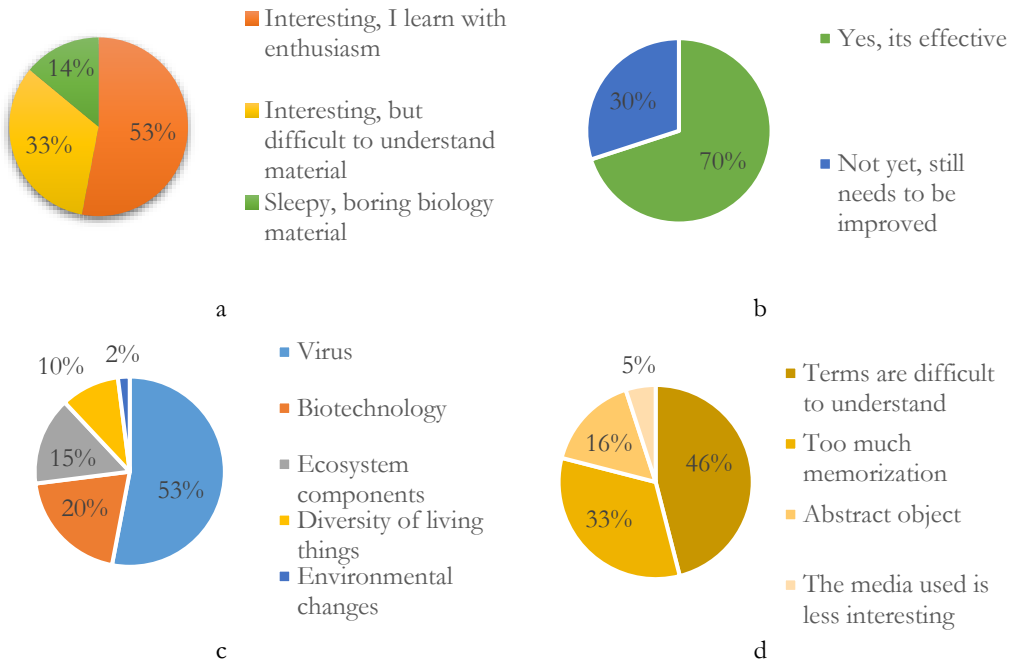


Figure 2 Results of needs analysis, a) Students opinions during biology class, b) Outlook about the effect of learning media, c) Biology concepts that are difficult for students to comprehend, d) Students reason for difficulty of learning biology.

challenging to comprehend and uninteresting (Figure 2a). This approach may lead to a negative attitude towards biology, which could ultimately affect students ability to achieve high scores on the examination (Cimer 2012).

Some students had asserted that the current learning media was ineffective and required further development (Figure 2b). The media include Microsoft PowerPoint, whiteboard, book, and video. The use of traditional media might contribute to the perception that biology is uninteresting. In contrast, technology-based media has been demonstrated to enhance student motivation by 59% compared to traditional media (Maulana, Harahap, & Safitri, 2022).

Some students approve that viruses are a concept that is difficult to comprehend due to the use of new terminology and the complexity of the topic (Figure 2c). Several research has found that viruses are one of the five most challenging topics in biology in grade 10 (Firmanshah, Jamaluddin, & Hadiprayitno, 2020; Hadiprayitno, Muhlis, & Kusmiyati, 2019). Difficulties in understanding viruses include their invisibility, high complexity, and the use of technical terminology that is not commonly understood (Firmanshah, Jamaluddin, & Hadiprayitno, 2020).

Comprehending complex terminology represents a significant challenge for some students (Figure 2d). The difficulty was identified as a consequence of the complexity of the terminology (Etobro & Fabinu, 2017; Firmanshah, Jamaluddin, & Hadiprayitno, 2020; Hadiprayitno, Muhlis, & Kusmiyati, 2019). Students often perceive foreign terms as not being explained in terminology, leading them to assume that they should be memorized as factual knowledge (Cimer, 2012).

Figure 3 illustrates the school facilities that support learning, including all classrooms with a projector. Students bring their phones continuously, and the school network is considered high standard, regardless of whether Wi-Fi is available. It was asserted that there was an effect between the school facilities and the teacher performance, including arranging the media (Angraini, Fitria, & Setiawan 2021; Riniati, Rais, Putri, Al Haddar, & Azis, 2023). A successful learning process will be enhanced if the teachers use the appropriate media supported by the school facilities (Liliawati, 2020). However, students require learning media that are visually engaging, comprehensive, and accessible.

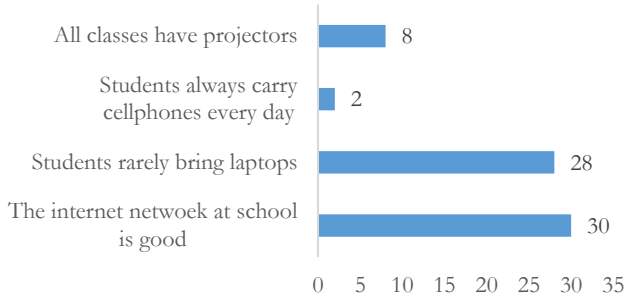


Figure 3 Facilities in the school

3.2 Result of Design

The design of ARVi was based on the needs analysis of the students and teachers, the lesson on viruses, the literacy of biology articles, and the creation of quizzes. The following topics were discussed: the history of viruses, the characteristics of viruses, the structure of viruses, the classification of viruses, the life cycle of viruses, the advantages and disadvantages of viruses, the impact of COVID-19, and the solutions. To enhance the educational experience, the subject encompassed the advantages and disadvantages of viruses, the effects of the COVID-19 pandemic, and potential solutions. Google Scholar searched for articles that met the following criteria: use of the Indonesian language, accessible terminology, and comprehensive material that satisfactorily addressed the theme.

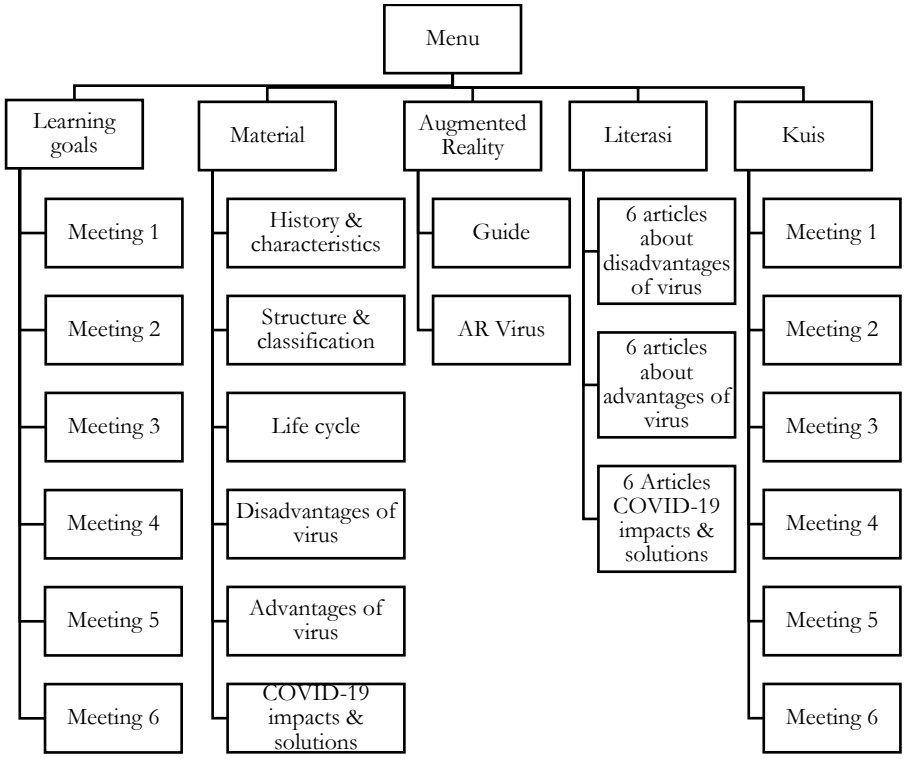


Figure 4. Design of ARVi

Figure 4 illustrates the five primary menu options available on the ARVi apps: purpose of learning, subject, augmented reality, literacy, and quiz. The objective was to ascertain the goal of students' achievement. The subject encompasses viruses' historical discovery and subsequent impact on daily life. Augmented reality (AR) features include a 3D image of a virus designed to assist researchers in visualizing viruses. The augmented reality (AR) component aimed to stimulate interest and facilitate an interactive learning experience (Erwinsah, Aria, & Yusup, 2019). Augmented reality (AR) received a positive response from students because it provided a wealth of features and was engaging, allowing students to gain a clear comprehension of viruses (Celik, Guven, & Cakir, 2020), 2020; Omurtak & Zeybek, 2022; Wu, Lee, Chang, & Liang, 2013).

The article on the role of viruses in biology provides insight into the impact of COVID-19 and potential solutions. The objective was to give students a comprehensive understanding of biology based on reliable sources. The literacy program aimed to develop content that incorporated 21st-century skills students should be able to demonstrate, such as critical thinking and problem-solving. Literate individuals can consider diverse perspectives and make informed decisions (Onel & Durdukoca, 2019). If a reading activity becomes a habit, students will enhance their cognitive abilities and protect themselves from the detrimental effects of decreased memorization (Chang, Wu, & Hsiung, 2021; Yussof, Jamian, Roslan, Hamzah, & Kabilan, 2012).

A menu of quizzes was used to evaluate and practice students' high-level cognitive abilities. Six quiz packages were used in every session. Asking questions in every session is one method to practice students high-level cognitive abilities (Lemons & Lemons, 2013).

3.3 The Result of Development

The development step involves creating ARVi's design into the application: creating a 3D object, designing the user interface, and combining it into the application. Figure 5 shows **s**teps of creating an ARVi application.

The first step was creating a 3D object using the Blender website application to prevent plagiarism. The blender application permitted the creation of 3D object

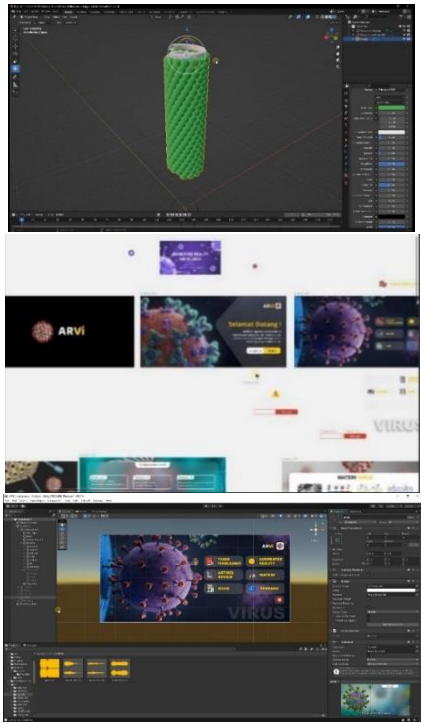
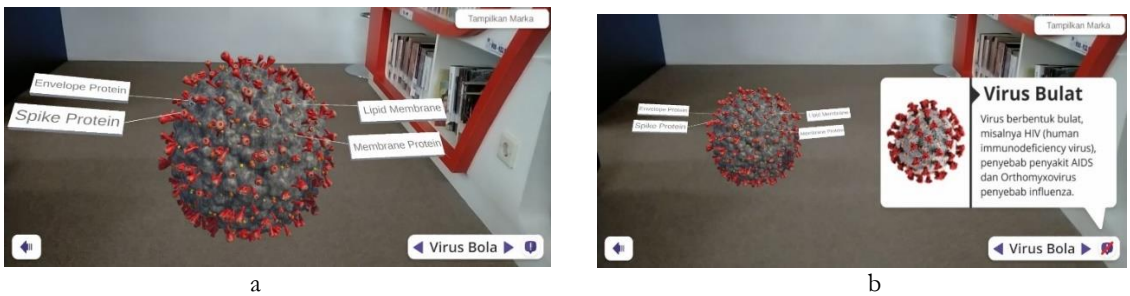


Figure 5 Step of creating an ARVi application, a) Create the 3D objects, b) Designing user interface, c) Combining into an application

models for free (Enterprise, 2016). The 3D object images are T virus complex, the helix virus, the ball-shaped virus, the polyhedral virus, and the fiber-shaped virus. The second step was designing a user interface (UI) using the Figma application. Figma application had permitted the creation of a website-based UI for free (Wibowo, 2023). This step included creating the background, typography, and icon as an image. Afterward, the design was converted into a PNG image.

The third step involved combining UI, 3D objects, and programming language into a complete application using Unity 3D. This programming language application is designed to create a new application (Ariftama, 2017). After combining, the application will be rendered into an ARVi app. The ARVi app is designed for Android smartphones 8.0 generation (Oreo) or later. The Unity platform is widely used for creating 2D and 3D multiplatform experiences



a b

Figure 6 The result of developing ARVi a) AR viruses, b) AR viruses and explanation

and games, and it supports the development of applications for various devices, including Android smartphones (Nida, Mursyidah, & Anwar, 2020).

Figure 6 illustrates the result of developing ARVi. A phone camera will identify areas such as tables, boards, or floors displaying viruses' objects. The types of viruses are T virus complex, helix virus, ball-shaped virus, polyhedral virus, and fiber-shaped virus. The object can zoom in, zoom out, transfer, and come up with information from the structure of viruses. Then, a button in the lower right corner contained brief information about viruses.

ARVi apps are arranged to use various assessments, such as the media validity test. Criteria of the expert validator include a lecture on learning media subjects in the department of biology education and/or a certified validator of a biology teacher.

The validity test of the media was conducted to assess the quality of presentation and features in ARVi's application. Based on Table 2, the ARVi apps were strongly valid and did not require modification. Furthermore, the validators had no feedback or suggestions, so the media did not need to be fixed.

The test of subject validity was conducted to assess the relationship between the subject content related to viruses on ARVi and the curriculum in Indonesia nowadays. Based on table 3 demonstrates that the subject content on ARVi was strongly valid; therefore, the application can be used without further modification.

a b

Figure 7 The result of the revision, a) Before revised, b) After revised

Table 2 The result of media validity

Assessment component	Statement	Validator		Mean
		1	2	
Appearance design	An instruction of usage and clear transcribe	4.00	4.00	
	An interesting design	4.00	4.00	
	The colours had been appropriate and interested	4.00	4.00	
	The relationship between AR and subject	3.00	3.00	3.85
	The relationship between video and subject	4.00	4.00	
	Able to operate	4.00	4.00	
	The application had run seamless	4.00	4.00	
Presentation of the Media	Media presentation supports students engagement	4.00	4.00	
	Picture are interesting and proportional	4.00	3.00	3.83
	Colour using had been appropriate	4.00	4.00	
	Mean			3.84
	Conclusion			Strongly valid

Table 3 The result of subject validation

Assessment component	Statement	Validator		Mean
		1	2	
Curriculum	Topics of ARVi had appropriate with learning achievement	4.00	4.00	4.00
	Topic of ARVi had appropriate with purpose of learning	4.00	4.00	
Presentation of Subject	Presentation has complete and systematic	4.00	4.00	3.75
	Accurate and innovative subject	3.75	4.00	
	Substantial concept	4.00	4.00	
	Using a right role to presentation	4.00	3.00	
Language	Clarity of instruction	3.00	4.00	3.75
	Relationship between language and students' level of thinking ability	4.00	4.00	
	Politeness in language use	4.00	3.00	
	Accuracy between text and subject	4.00	4.00	
	Mean			3.80
	Conclucion			Strongly valid

Table 4 ARVi small group trial test results for students

Assessment component	Statement	Mean
Appearance design	An instruction of usage and clear transcribe	2.85
	An interesting design	2.90
	The colours had been appropriate and interested	2.95
	The relationship between AR and subject	2.65
	The relationship between video and subject	2.65
	Able to operate	2.80
	The application had run seamless	2.90
Presentation of the Media	Media presentation supports students engagement	3.00
	Picture are interesting and proportional	2.90
	Colour using had been appropriate	2.90
Mean		2.85
Conclusion		Valid

A revised version was created based on the feedback and suggestions provided by the validators and students. This evaluation serves as a reference point for the modified ARVi, which was created to make it more effective. Several suggestions were made regarding modifications, including the necessity to cite sources in the picture and the requirement for the text to be legible.

Figure 7 illustrates the revision result, which includes citing sources cited under the picture. This is a crucial aspect to consider, given the function of images that can contain specific information. Therefore, they must originate from a primary source. Moreover, the images have a copyright that others cannot claim (Laksana, 2018). Then, the result was tested on 20 students.

ARVi is also used to test the small group for students. The assessment aimed to determine ARVi's readabilityARVi based on student feedback. The purpose of assessment for minor scale was to reduce the barriers that may arise during the implementation process (Hiwari, Purba, Ihsan, Yuliadi, & Mulyani, 2019). Table 11 illustrates that ARVi was valid and can be used. Based on Table 2-4, ARVi fulfills the criteria. ARVi apps were valid and had minor revisions, according to Ratumanan & Laurens (2011). This indicates that ARVi can be applied to biology subjects.

Table 5 Descriptive data of learning outcomes

No	Data	Pretest	Posttest
1.	Mean	48.30	80.08
2.	Minimum	16.00	68.00
3.	Maximum	81.00	92.00
4.	Standard deviation	14.27	6.56
5.	Variance	203.77	43.03
6.	Total of Students	60.00	60.00

Table 6 The result of normality test

Data	α	Sig.	Suggest
Pretest	0.05	0.06	Normal Data
Postest	0.05	0.09	Normal Data

3.4 The Result of Implementation

ARVi apps were implemented in grades X-8 and X-9. Differences in learning outcomes were conducted using pretest and posttest.

Table 5 illustrates descriptive data from the pretest and posttest. Based on this table, the average posttest score was higher than the pretest. The data was tested for normality test.

Table 6 illustrates that the significance value was higher than the α value, then the data were normally distributed. The normality test was a prerequisite for the paired t-test to determine the average difference between the pretest and posttest results.

Table 7 illustrates that the t-value of 15.87 was greater than the t-table of 0.68, it can be concluded that there was a difference between the pretest and posttest results. This indicated an influence of ARVi apps in the experimental class compared to visual media in the control class. This is because the ARVi app is a multimedia platform that assists students in reducing excessive cognitive load, which allows them to maximize their working memory, as it has limited capacity (Sweller, 1994).

Learning with ARVi's apps begins with a surprising fact to attract students' attention by presenting facts about viruses. This initial engagement helps students prepare to receive further information, encouraging active participation. This approach maintains students attention and fosters active participation in the learning process (Robinson & Cook, 2018).

Augmented reality plays a vital role in helping students focus. This helps students understand information through the senses, memory, and cognition. Simple information in the form of a 3D object and a brief description of the virus type is stored in working memory and reselected into helpful information in short-term memory. Iconic storage

Table 7 The result of Paired t-test

Data	Mean	t-count	t-table	Df	α	Suggest
Pretest	48.30	15.87	0.68	59	0.05	There is a difference between pretest
Posttest	80.08					and posttest results

(visual impressions) stores visual information with imagery coding in the form of photo archives (Solso, Maclin, & Maclin, 2007).

Information stored in short-term memory must be consolidated to achieve long-term memory storage. Combining several pieces of information helps create more complex ideas, which can be stored in a thinking scheme in long-term memory. Students who use ARVi's apps can access information from literacy. Literacy enables students to explore diseases affected by viruses, which allows them to provide methods to treat these diseases as part of the benefits of using ARVi apps. This makes the information more meaningful and relevant and provides a strong reason for students to retain the memory. This information is stored in long-term memory, which helps solve complex problems in everyday life (Musi & Nurjannah, 2021).

Information stored can be reminded through repeated practice, in this case, using quizzes on ARVi's apps. Students who take quizzes can remember information previously stored in long-term memory. When you practice regularly, it strengthens the memory that is encoded in the brain. This process helps to sort out the necessary information, identifying gaps that can be studied (Ebbinghaus, 2013).

3.5 The Result of Evaluation

In the evaluation stage, ARVi's mobile application helps students learn about viruses effectively. Students gave a positive impression by asserting that the ARVi's apps were complete and transparent and made it easy to practice questions about viruses. Some of ARVi's advantages include complete subjects according to the Indonesian curriculum, 3D augmented reality virus objects, biological literacy, and quizzes for daily practice. ARVi's apps can be used without an internet connection, making it more economical. Figure 8 shows QR for access ARVi apps.

Figure 8 QR for access ARVi apps.

ARVi's apps have various weaknesses that require to be reflected. First, accessing the application on iOS devices and its large size is difficult, which can be challenging. Second, the literacy menu design lacks the image's empty areas (negative space). Negative space can lead to cognitive overload and decreased retention {Formatting Citation}. However, negative space is used well when displaying augmented reality, which can enhance students' focus. Another drawback is using viral videos in English on YouTube, which can be a barrier for students who have not mastered English. However, this can be overcome with direct explanation by the teacher. The use of an English video represents a virus replication similar to the original, not a cartoon animation. Compared with similar applications, ARVi has the advantage that it does not use augmented reality markers, making it easier to display AR anywhere. This advantage makes it possible to display AR without markers (Lyu, 2012). Overall, ARVi is a valuable learning media for students to learn about viruses anytime and anywhere.

4. CONCLUSION

The ARVi application developed is suitable for use as a biology learning medium based on the research results. The use of ARVi apps can improve learning outcomes compared to traditional media. ARVi apps help students observe virus objects in augmented reality, making virus learning interactive and engaging. In connection with these research results, it is hoped that the ARVi media apps be disseminated so that more students can use it. Further research is expected to utilize AR to depict other biological objects such as bacteria, protists, biotechnology, etc.

ACKNOWLEDGMENT

A gratitude to Mr. Refirman Djamarah M.Biomed from Universitas Negeri Jakarta, Mr. Sujiyo Miranto M.Pd, and Ms. Meiry Fadillah Noor from UIN Syarif Hidayatullah Jakarta as the expert validators. Researchers are also grateful to Mr. Drs. Cep Anwar, M.Pd as the head of MAN 1 Kota Bogor, for allowing us to carry out the research, Ms. Sugihartini S.Pd as the Biology teacher, and the grade 10 students who had participated, therefore the study can be done well.

REFERENCES

Angraini, S., Fitria, H., & Setiawan, A. A. (2021). The effect of teacher performance and learning media on learning outcomes of elementary school students. *Journal of Social Work and Science Education*, *2*(2), 137-146.

Arslan, R., Kofoğlu, M., & Dargut, C. (2020). Development of augmented reality application for biology education. *Journal of Turkish Science Education*, *17*(1), 62-72.

Batubara, B. M. (2021). The Problems of the World of Education in the Middle of the Covid-19 Pandemic. *Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences*, *4*(1), 450-457.

Budi, A. (2017). Panduan Mudah Membuat Augmented Reality. *Yogyakarta: Andi*.

Celik, C., Guven, G., & Cakir, N. K. (2020). Integration of mobile augmented reality (MAR) applications into biology laboratory: Anatomic structure of the heart. *Research in Learning Technology*, *28*.

Chang, Y. H., Wu, I. C., & Hsiung, C. A. (2021). Reading activity prevents long-term decline in cognitive function in older people: evidence from a 14-year longitudinal study. *International Psychogeriatrics*, *33*(1), 63-74.

Cimer, A. (2012). What makes biology learning difficult and effective: Students' views. *Educational research and reviews*, *7*(3), 61.

Del Piero, H. H., Afirianto, T., & Wardhono, W. S. (2019). Pengembangan Gim Edukasi Mengenai Virus Menggunakan

Teknologi Augmented Reality. *Jurnal Pengembangan Teknologi Informasi Dan Ilmu Komputer*, *3*(10), 9533-9542.

Dewi, L. K., & Harini, N. W. (2021). Development of Digital Comics as a Media for Biology Learning of Environmental Change for Senior High School Students. *Journal of Biology Education*, *10*(3), 296-302.

Dimon, R., Pettit, L., Cheung, C., & Quinnell, R. (2019). Promoting botanical literacy with a mobile application-CampusFlora-using an interdisciplinary, student-as-partners approach. *International Journal for Students as Partners*, *3*(2), 118-128.

Djamahar, R., Rifan, M., & Ristanto, R. H. (2021, February). Bio-repropedia website based on reading, mapping, and sharing (RMS): A way to improve biological literacy. In *Journal of Physics: Conference Series* (Vol. 1796, No. 1, p. 012067). IOP Publishing.

Djati, W. R., Widiyatmoko, A., & Pamelasari, S. D. (2022, August). Penerapan Media Augmented Reality Pada Pembelajaran Ipa Untuk Melatih Kemampuan Berpikir Tingkat Tinggi Siswa. In *Proceeding Seminar Nasional IPA* (pp. 167-172). https://proceeding.unnes.ac.id/index.php/snipa/article/view/1350%0Ahttps://proceeding.unnes.ac.id/index.php/snipa/article/download/1350/862.

Ebbinghaus, H. (2013). Memory: A contribution to experimental psychology. *Annals of neurosciences*, *20*(4), 155. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4117135/.

Enterprise, J. (2016). *Blender untuk pemula*. Jakarta: Elex Media Komputindo.

Erwinsah, R., Aria, M., & Yusup, Y. (2019, December). Application of augmented reality technology in biological learning. In *Journal of Physics: Conference Series* (Vol. 1402, No. 6, p. 066090). IOP Publishing.

Etobro, A. B., & Fabinu, O. E. (2017). Students' perceptions of difficult concepts in Biology in senior secondary schools in Lagos State. *Global Journal of Educational Research*, *16*(2), 139-147.

Firmanshah, M. I., Jamaluddin, J., & Hadiprayitno, G. (2020). Learning difficulties in comprehending virus and bacteria material for senior high schools. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *6*(1), 165-172.

Hadiprayitno, G., Muhlis, & Kusmiyati. (2019, June). Problems in learning biology for senior high schools in Lombok Island. In *Journal of Physics: Conference Series* (Vol. 1241, No. 1, p. 012054). IOP Publishing.

Hartono, A., Tanjung, I. F., & Syahputra, I. (2021). Virtual laboratory of Andaliman tissue culture integrated with islamic values. *Biosfer: Jurnal Pendidikan Biologi*, *14*(2), 285-305.

Hiwari, H., Purba, N. P., Ihsan, Y. N., Yuliadi, L. P., & Mulyani, P. G. (2019, June). Kondisi sampah mikroplastik di permukaan air laut sekitar Kupang dan Rote, Provinsi Nusa Tenggara Timur. In *Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia* (Vol. 5, No. 2, pp. 165-171).

Indrayana, I. P. T., Manik, S. E., Lisnasari, S. F., Br, R. H., Suryaningsih, N. M. A., Marlinda, N. L. P. M., ... & Sulistyani, U. (2022). *Penerapan strategi dan model pembelajaran pada Kurikulum Merdeka Belajar*. Media Sains Indonesia.

Jex, M. (2002). *Organizational psychology: A scientist practioner approach*. USA: John Willet & Sons Inc.

Kamiana, A., Kesiman, M. W. A., & Pradnyana, G. A. (2019). Pengembangan augmented reality book sebagai media pembelajaran virus berbasis android. *KARMAPATI (Kumpulan Artikel Mahasiswa Pendidikan Teknik Informatika)*, *8*(2), 165-171.

Khade, S. N., & Khade, P. S. (2016). Diversity and statistical analysis of marine gastropod, Raigad District, Maharashtra. *International Journal of Fauna and Biological Studies*, *3*(3), 01-04.

Laksana, R. (2018). *Himpunan Lengkap Undang-Undang Republik Indonesia Tentang Guru dan Dosen*. Laksana.

Lemons, P. P., & Lemons, J. D. (2013). Questions for assessing higher-order cognitive skills: It's not just Bloom's. *CBE—Life Sciences Education*, *12*(1), 47-58.

Liliawati, K. (2017). Peningkatan Kinerja Guru Dalam Memanfaatkan Media Pembelajaran Melalui Supervisi Akademik Bagi Guru Kelas Sd Negeri 1 Temon Semester 1 Tahun Pelajaran 2016/2017. *Jurnal Mitra Swara Ganesha*, *4*(2).

Lyu, M. R. (2012). *iDigitable*. Hongkong: The Chinese University of Hongkong.

Mahmud, M. R., & Pratiwi, I. M. (2019). Literasi numerasi siswa dalam pemecahan masalah tidak terstruktur. *Kalamatika: Jurnal Pendidikan Matematika*, *4*(1), 69-88.

Maulana, I., Harahap, R. D., & Safitri, I. (2022). Use of learning media through technology for biology education students. *BIO-INOVED: Jurnal Biologi-Inovasi Pendidikan*, *4*(3), 282-290.

Meslilesi, M. I., Anra, H., & Pratiwi, H. S. (2017). Penerapan Augmented Reality Sebagai Media Pembelajaran Virus Dalam Mata Pelajaran Biologi Kelas X SMA (Studi Kasus: SMA Negeri 7 Pontianak). *JUSTIN (Jurnal Sistem Dan Teknologi Informasi)*, *5*(2), 80-84.

Musi, M.A., & Nurjannah. (2021). *Neurosains: Menjiwai sistem saraf dan otak*. Jakarta: Kencana.

Nida, H., Mursyidah, M., & Anwar, A. (2020). Rancang Bangun Aplikasi Virtual Reality Wahana Kebun Binatang. *Jurnal Teknologi Rekayasa Informasi dan Komputer*, *3*(2).

Omurtak, E., & Zeybek, G. (2022). The effect of augmented reality applications in biology lesson on academic achievement and motivation. *Journal of Education in Science Environment and Health*, *8*(1), 55-74.

Onel, A., & Durdukoca, S. F., (2019). Identifying the Predictive Power of Biological Literacy and Attitudes Toward Biology in Academic Achievement in High School Students. *International Online Journal of Educational Sciences*, *11*(2).

Pelczar, M. J., & Chan, E.C.S. (1986). *Elements of Microbiology*. USA: McGraw-Hill Book Company.

Puspitasari, D., Praherdhiono, H., & Adi, E. (2020). Pengembangan suplemen augmented reality animation pada buku ajar biologi untuk penguatan kognitif siswa. *Jurnal Kajian Teknologi Pendidikan*, *3*(1), 29-39.

Putrawan, G. E., & Riadi, B. (2020). Technology and language learning: English as a foreign language learners' use of smartphones for online informal learning in Indonesia. *Texto Livre*, *13*(3).

Ratumanan, T. G., & Laurens, T. (2011). Assessment of learning outcomes at the education unit level 2nd edition.

Resmol, K., & Leasa, M. (2022). The effect of learning cycle 5E+ Powtoon on students' motivation: The concept of animal metamorphosis. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *8*(2), 121-128.

Riniati, W. O., Rais, R., Putri, R. S. W., Al Haddar, G., & Azis, F. (2023). Role Of School Facilities And Infrastructure On Performance Of Senior High School Teacher. *Journal on Education*, *5*(3), 5805-5814.

Robinson, A., & Cook, D. (2018). "Stickiness": gauging students' attention to online learning activities. *Information and Learning Science*, *119*(7/8), 460-468. https://doi.org/10.1108/ILS-03-2018-0014.

Roswati, N., Rustaman, N. Y., & Nugraha, I. (2019). The Development of Science Comic in Human Digestive System Topic for Junior High School Students. *Journal of Science Learning*, *3*(1), 12-18.

Solso, R. L., Maclin, O. H., & Maclin, M. K. (2007). *Psikologi Kognitif,* Jakarta: Erlangga.

Suryani, F. B., Rukmini, D., Bharati, D. A. L., & Hartono, R. (2018). Promoting EFL student teachers' life-long learning through microteaching lesson study. *Celt: A Journal of Culture, English Language Teaching & Literature*, *18*(2), 267-281.

Susilawati, E., & Khaira, I. (2021). Web-based learning implementation to improve students' learning outcomes on understand evaluating the public policies' impact material during the covid-19 pandemic. *Nusantara Science and Technology Proceedings*, 95-102.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and instruction*, *4*(4), 295-312. https://www.sciencedirect.com/science/article/pii/0959475294900035.

Sylvia, F., Ramdhan, B., & Windyariani, S. (2021). Efektivitas Augmented Reality Terhadap Higher Order Thinking Skills Siswa Pada Pembelajaran Biologi:(The Effectiveness of Augmented Reality Towards Studentsâ€™ Higher Order Thinking Skills in Biology Subject). *Biodik*, *7*(2), 131-142.

Thahir, R., & Kamaruddin, R. (2021). Pengaruh Media Pembelajaran Berbasis Augmented Reality (Ar) Terhadap Hasil Belajar Biologi Siswa Sma. *Jurnal Riset dan Inovasi Pembelajaran*, *1*(2), 24-35.

Wibowo, H. S., (2023). *Desain interaktif dengan Figma panduan praktis untuk pemula dan profesional*. Semarang: First Publishing.

Widodo, A., & Utomo, A. B. (2021). Media Pembelajaran Taksonomi Hewan Berbasis Augmented Reality dengan Fitur Multi Target. *Edu Komputika Journal*, *8*(1), 1-8.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & education*, *62*, 41-49. http://dx.doi.org/10.1016/j.compedu.2012.10.024.

Yapici, İ. Ü., & Karakoyun, F. (2021). Using augmented reality in biology teaching. *Malaysian Online Journal of Educational Technology*, *9*(3), 40-51.

Yussof, Y. M., Jamian, A. R., Roslan, S., Hamzah, Z. A. Z., & Kabilan, M. K. (2012). Enhancing reading comprehension through cognitive and graphic strategies: A constructivism approach. *Procedia-Social and Behavioral Sciences*, *64*, 151-160.