



Development of Augmented Reality on Sub-Material Mushroom Sexual Reproduction to Improve Analytical Thinking Ability

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Abstract: This study aims to determine the characteristics of learning media based on Augmented Reality in the mushroom sexual reproduction sub-material, determine the feasibility of learning media based on Augmented Reality, and determine the effectiveness of learning media based on Augmented Reality to improve students analytical thinking skills. The data analysis used was the Manova test. The results of the study are the characteristics of media have 3D objects with moving animation, are interactive, for Android users, have AR manuals, are independent, and real-time. Learning media based on Augmented Reality on the mushroom sexual reproduction sub-material is declared feasible to use in the process of learning activities. The results of the Manova test get a Sig. 0.000 which means there is a significant difference in the analytical thinking skills who use and do not use AR media.

Keywords: Augmented Reality, Analytical Thinking Skills

Introduction

The quality of learning is related to how the learning process takes place, the interactions between teachers and students, students and their peers, and how the interactions between students and learning resources. So that effective learning depends on the effectiveness of learning (Setyosari, 2014). According to Arief (2012), the media is an intermediary or delivery agent for the sender's message to the recipient of the message. Learning media can help the learning process of students who are expected to achieve student learning outcomes. Learning media can be used in learning activities to attract the attention of students so that they can foster students' enthusiasm for learning, the material being taught will be easier to understand and enable students to master the learning objectives to be achieved. The use of learning media can help the learning process so that learning objectives can be achieved effectively and efficiently. The presentation of the material will be

more systematic and the presentation of the material will be more interesting so that the quality of learning will increase. So the latest technology-based media is needed that can attract the attention of students in learning (Nurrita, 2018).

One of the technologies that are currently developing and can be used as a learning medium is Augmented Reality (AR). Augmented Reality (AR) is a technology that can combine two-dimensional or three-dimensional objects into a three-dimensional real environment and project these objects in real-time. AR has experienced very rapid development, including in the world of education which has been used as a medium of learning. Augmented reality can be used without for expensive equipment and can enhance its power application in the school environment. Increase reality is the ultimate technique that represents reality virtual world with contextual information powered by computer technology for the purpose of providing users

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a feeling very similar to the real interaction with the real environment (Cai et al., 2014; Zhang et al., 2014).

Augmented reality is an innovation in which AR technology capable of projecting computer-generated images in the real world (Ramadhanti et al., 2021). Other AR of Virtual Reality (VR) in the sense that in VR people should experience a virtual computer-generated experience environment. In AR, the environment is real but expanded with system information and images. In other words, AR bridges the gap between reality and subtly virtual (Lee, 2012). AR provides an effective learning experience because it displays 3D images so that students can easily accept them and keep students interested in learning (Mustaqim, 2010). Equipment for the eye system contains various abstractions such as parts of eye and its functions, eye diseases or abnormalities, how the shadow is formed to the vision process happen, and so on. This abstract concept can be explained details using AR. AR technology is considered suitable for use in optical materials. In addition, the results of Initial needs analysis shows that students still experience Misconceptions about teaching asynchronous in the eyes documents so they need suitable and complete media to facilitate their understanding.

The advantages of Augmented Reality (AR) are visually attractive displays because they use 3D objects that seem to exist in the real world, and are interactive. After all, they use markers or images to display certain 3D objects and make them quite easy (Mustaqim, 2017). Digital-based science learning can be applied by exploiting numerical learning multimedia. This is supported by research showing that studying science can enhance analytical thinking by use multimedia learning. Analytical thinking skills are essential for biology students and honing in self-study for prepare students for the competitive world of work and cope with the changing times and times of globalization. Analytical thinking skills are one aspect Cognitive taxonomy is blossoming and becoming one of the high-level reflex activities (Sadhu, 2018). Or Students have the ability to analyze and apply the knowledge they have learned (Muhsin & Laksono, 2023).

According to Sanjaya (2008) saying that through the means of learning, teachers can present concrete abstract materials so that they are easy to understand and can eliminate wordism. Learn can works effectively and achieves expected goals Arrosyida and Suprpto (2015); Rezeki (2017), a learning medium can be understood as a tool used by educators in the learning process. Learning medium is one tool for the learning process by helping educators convey learning materials for students effectively and efficiently path (Juariah, 2016). A good means of learning is a means has a bidirectional

nature to facilitate the interaction between students and teachers (Hartanti, 2019). According to (Simamora & Yogica, 2022) vehicles used in The media of the learning process acts as an intermediary used by educators in the learning process who can make it easier for educators to deliver materials to students.

Students use analytical thinking skills by processing information in solving problems. Analytical thinking skills are included in higher-order thinking skills or better known as HOTS (High Order Thinking Skills). Students need to have the ability to sort information. Analytical thinking is the ability to solve a problem based on the information you have. The first step that needs to be done is to collect information, identify the problem, and find a solution (Fuadi, 2020). Based on the research results of Fidan & Tuncel (2019) the results show that the use of AR applications is more interesting, useful, and realistic in learning activities and can help students in analyzing a problem. Learning biology in schools generally only uses media in the form of PowerPoint, so researchers want to provide a different learning experience for students who are more interested in learning activities.

The learning model used in applying learning media based on Augmented Reality (AR) is using the card sort learning model. Card sort is a learning model that uses pieces of paper shaped like cards and contains information or subject matter. This learning model is expected to increase the activeness of students in learning, where in the learning activities each student will be in groups and each group will be given cards containing information about the material to be discussed, then students will group and sort the cards according to the cards they have. After that student will discuss and present the results of their discussions. The cards given to students contain images that will be scanned using a smartphone camera which will display 3D images in the form of objects from Augmented Reality (AR) (Herwin, 2021). One of the characteristics of using the card-sort learning model is that the educator acts as a facilitator and explains material that needs to be discussed or material that students have not understood after the presentation is over. So that the material being taught is truly understood by students, thus students become more active and motivated in learning activities (Fitriani, 2020).

Mushroom literature, especially in the fungal reproduction supplement in student print books, is often limited to pictures of how reproduction takes place. Availability of augmented reality-based learning materials that can be used in learning activities on fungal sexual reproduction, allowing students to observe things that are difficult to observe directly. According to Utari (2017), sexual reproduction of fungi only occurs

when environmental and nutritional conditions are not guaranteed, making it difficult to observe directly under the microscope. Using this application, students will easily observe the sexual reproduction process of fungi step by step. Developing augmented reality-based learning materials can provide learning experiences using technology to engage students in learning activities. Based on the research results of Fidan & Tuncel (2019), the results show that the use of augmented reality applications is more interesting, useful and realistic in learning activities and can help students learn more. analyze a problem. Learning Biology in schools often only uses media in the form of PowerPoint, so the researchers wanted to provide a different learning experience to make students more interested in learning activities.

Based on the results of observations by researchers at SMA Negeri 4 Berau in class X in September 2022, the learning that takes place is learning a new post-pandemic adaptation period. The obstacles encountered during learning are the lack of maximum delivery of material because learning at school sometimes uses media in its delivery, such as using videos available on YouTube, and PowerPoint which is available on the internet, but time is limited and equipment preparation is time-consuming so they rarely use media. in delivering material. Teachers rarely make learning media because of limited time so they only use what is on the internet. Based on the results of interviews with researchers' students' analytical thinking skills, in the assessment process, the teacher has used HOTS or higher-order thinking skills, one of which is the ability to think analytically. Based on the results of learning in the previous semester regarding biology learning, the average ability of students in analyzing still needs to be improved because most students still experience difficulties in analyzing questions and problems. Therefore, researchers want to develop learning media that can be accessed offline without using the internet but can support student learning activities.

Method

Research Design

The procedure for developing instructional media was modified from the opinion of Chaeruman (2008) in Ishak et al. (2020) research development model using the ADDIE development method (Analysis, Design, Development, Implementation, Evaluation). This study used a pretest-posttest control group design. This study used one class as a limited trial and two classes in field trials, namely the control class and the experimental class.

Subject and Locations

The experimental class uses learning media based on augmented reality with a card-sort learning model and the control class uses a card-sort learning model. This research was conducted at SMAN 4 Berau, East Kalimantan on Jl. Bukit Berbunga Street KM 1 Sambaliung. Research data collection was carried out from March to November 2022. The population in this study were students of SMA Negeri 4 Berau from class XI, totaling 30 students for the limited trial sample and 2 class X, each of which had 32 students as the field trial sample. Sampling using simple random sampling or random sampling regardless of the existing strata or without consideration.

Instrument

The data collection instrument used in research on the development of augmented reality-based learning media is an expert validation sheet for both media experts and material experts, teachers and colleagues as well as students who each have aspects of assessment.

Development Design

In this study, the procedure for developing augmented reality-based learning media consists of the analysis stage, namely the analysis of the needs of learning media and the learning problems being faced by schools. Curriculum analysis to identify the depth and breadth of competencies that must be developed and analysis of student characteristics with interviews to determine the use of smartphones and learning media in learning activities. The design stage consists of 2 activities, namely the preparation of the material framework design and its presentation in learning media and the collection of materials needed in developing learning media. The development stage consists of 3 activities, namely developing augmented reality-based learning media, developing AR Book manuals, and developing research instruments. The implementation phase consists of limited trials and field trials. The evaluation stage looks at the results of the characteristics of learning media and the effectiveness of learning media on students' analytical thinking abilities. The data analysis technique used in this development research is to assess the quality of the learning media developed. Assessment of the quality of teaching materials includes:

Descriptive analysis

Qualitative Data Analysis

Analysis of qualitative data namely in the form of assessing the feasibility of learning media based on augmented reality by material experts, media experts, biology teachers, colleagues, and students' responses to learning media.

*Quantitative Data Analysis**Augmented reality-based learning media assessment questionnaire*

The categories used in scoring use 4 categories, namely very good (4), good (3), not good (2), and very bad (1). The results obtained are then converted into product quality categories with the assessment guidelines in the following table:

Table 1. Determination of Product Criteria Intervals

| Score Range | Grade | Criteria |
|--|-------|------------|
| $X > (\bar{X}_l + 1.8Sb_i)$ | A | Very good |
| $(\bar{X}_l + 0.6Sb_i) < X \leq (\bar{X}_l + 1.8Sb_i)$ | B | Good |
| $(\bar{X}_l - 0.6Sb_i) < X \leq (\bar{X}_l + 0.6Sb_i)$ | C | Enough |
| $(\bar{X}_l - 1.8Sb_i) < X \leq (\bar{X}_l - 0.6Sb_i)$ | D | Not enough |
| $X \leq (\bar{X}_l - 1.8Sb_i)$ | E | Very less |

Source: Widyoko (2011)

Information:

X = Empirical score

\bar{X}_l = ideal mean ($1/2(\text{maximum score} + \text{minimum score})$)

Sb_i = ideal standard deviation ($1/6(\text{maximum score} - \text{minimum score})$)

Test instrument

Analysis data on students' analytical thinking skills tests were collected in the form of pretest and posttest results. Before testing the hypothesis, a prerequisite test is carried out first. This prerequisite test includes multivariate normality tests, and multivariate homogeneity tests. The multivariate normality test used the Mahalanobis distance, the multivariate homogeneity test used box's M test and the multivariate hypothesis test used the Manova test.

Result and Discussion

In this study, researchers developed learning media based on augmented reality, AR Books, and their instruments. The development method consists of 5 stages, analysis, design, development, implementation, and evaluation.

Analysis

At this stage, an initial analysis was carried out which included collecting information by conducting interviews with biology teachers at schools. Based on the results of these interviews, the teacher conveyed that the use of instructional media depends on what material is taught, such as taxonomy cards, classification tables, PowerPoint which can be downloaded via the internet,

and printed books as learning resources and the learning model used by the teacher, namely using the lecture and discussion method. Analysis of student characteristics aims to determine student character by interviewing about the use of media and smartphones in learning activities. Classroom learning activities use smartphones as learning resources. The learning media developed were adjusted to the curriculum that was in effect at that time, namely the 2013 Curriculum. Based on an analysis of core competencies and basic competencies, Fungi material, especially the mushroom sexual reproduction sub-material, can be developed in learning media.

Design

At this stage, the drafting of the material framework is carried out, its presentation in learning media, and collecting the materials needed in developing the media are. The preparation of the learning media framework includes the creation of a storyboard that aims to provide an overview of the composition of the learning media to be developed.

At the initial design stage of learning media, the researcher compiled several components needed in Augmented Reality-based learning media such as preparing mushroom material, especially sexual reproduction of mushrooms according to the basic competencies to be developed, questions to be used in evaluating learning activities and designing learning media in the form of storyboards.

Development

Three things need to be developed at this stage, namely the AR Book guidebook, Augmented Reality (AR) based learning media applications, and research instruments.

The preparation of research instruments used in this study were validation instruments for media experts and material experts, test instruments in the form of pretest questions and posttest questions to measure analytical thinking skills, observation sheets of learning implementation, media assessment questionnaire for teachers, colleagues, and students, and lesson plans (RPP). The process of making learning media applications based on Augmented Reality (AR) uses computer software, namely Blender, Canva, QR Code Generator, Vuforia Engine, and Unity Hub 3.3.0. The components of learning media based on Augmented Reality (AR) consist of:

Icon

This learning media has an icon that appears on the smartphone screen when the user opens the media. The icon display can be seen in the following image.



Figure 1. Learning Media Icon

Splash Screen

The image of the splash screen display can be seen in Figure 2.



Figure 2. Splash Screen Display on Learning Media

Cover Page

The image of the initial page display can be seen in Figure 3.



Figure 3. Display of the Cover Page on Learning Media

Menu

The main page image can be seen in Figure 4

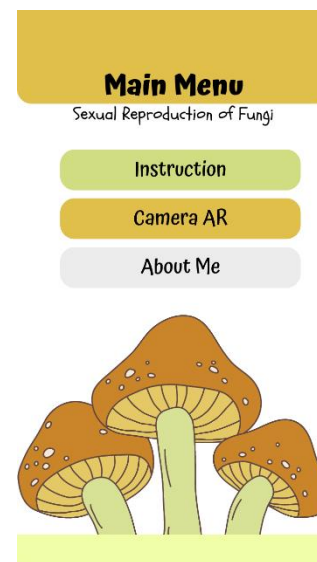


Figure 4. Main Menu Display in Learning Media

Instructions for use

The image of the user manual page can be seen in Figure 5.

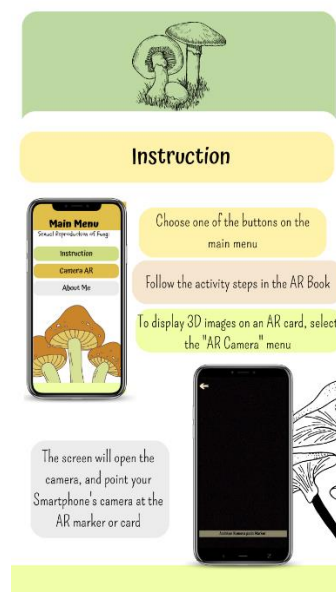


Figure 5. Display of the Instructions for Use page on Instructional Media

AR Camera

The AR Camera page is a page that contains a camera that has been integrated with AR to read target markers on learning media cards. Users can point the camera at the card provided by the developer contained in the AR Book manual, then a 3D object will appear according to the target marker read. Pictures of the AR Camera page display can be seen in Figure 6.



Figure 6. AR Camera Page Display on Learning Media

About Developer

The about developer page is a page that contains learning media developer data. On this page, there is a back button that functions to return to the main menu page. The image of the page displayed about the developer can be seen in Figure 7.



Figure 7. Page Display About Developer on Instructional Media

Feasibility of Learning Media Based on Media Expert Assessment

The validation results are based on media experts' assessment of learning media by media experts in terms of 2 aspects, namely software engineering and visual

communication. Data on the results of the media expert's assessment can be seen in Table 1.

Table 1. Media Expert Assessment Results

| Assessment Aspects | Rating result | Eligibility Category |
|----------------------|---------------|----------------------|
| Software engineering | 20 | Very good |
| Visual Communication | 25 | Very good |

Based on Table 1 it can be seen that the results of the assessment on the software engineering aspect get a score of 20 with a very good feasibility category, and on the visual communication, aspect get a score of 25 with a very good category. This shows that learning media based on Augmented Reality (AR) is feasible to use in the biology learning process in the Mushroom Sexual Reproduction sub-material with several revisions.

Feasibility of Learning Media Based on Material Expert Assessment

The assessment given by material experts is reviewed from 5 aspects, namely material feasibility, material accuracy, didactic, construction, and technical. Data on the results of the material expert's assessment can be seen in Table 2.

Table 2. Results of Assessment by Material Experts

| Assessment Aspects | Rating result | Eligibility Category |
|----------------------|---------------|----------------------|
| Material Eligibility | 11 | Very good |
| Material Accuracy | 10 | Good |
| Didactic | 20 | Very good |
| Construction | 39 | Very good |
| Technical | 16 | Very good |

Based on Table 10 it can be seen that the results of the assessment on the material feasibility aspect get a score of 11 with a very good feasibility category, on the accuracy aspect of the material get a score of 10 with a good feasibility category, on the didactic aspect get a score of 20 with a very good feasibility category, on the construction, aspect get a score 39 in the very good feasibility category, and on the technical aspect a score of 16 is in the very good feasibility category. This shows that the material in the AR Book, a guidebook for learning media based on Augmented Reality (AR) is suitable for use in the biology learning process in the Mushroom Sexual Reproduction sub-material with several revisions.

Implementation

At the implementation stage, the product that has been developed and validated will be tested. The aim is to see if the learning media that has been developed can be used or not. The application of learning media was carried out in a limited trial in class XI IPA 1 SMAN 4 Berau and field tests in the control and experimental classes, namely class X1 and X5.

Small Group Trial Results

A limited trial was conducted on 30 class XI IPA 1 student at SMAN 4 Berau who had previously gone through the process of learning mushroom material. students were asked to work on post-test questions and continued by filling out a questionnaire to find out how students responded to learning media in the sub-material of mushroom sexual reproduction that had been used in learning activities. the results of the limited trial conducted at SMAN 4 Berau are as follows:

Feasibility of Learning Media Based on Practitioners' Assessment, Student Responses and Peers

The assessment carried out by biology teachers and colleagues consisted of 7 aspects, namely software engineering, visual communication, material feasibility, material accuracy, didactic, construction, and technical. The following is a recapitulation of the assessment of biology teachers at SMAN 4 Berau and colleagues who are postgraduate students who are researching the development of instructional media.

Table 3. Average Results of Media Ratings by Biology Teachers and Peers

| Aspect | Biology Teacher | Average | Category |
|----------------------|-----------------|---------|-----------|
| Software engineering | 12 | 10.6 | Very good |
| Visual Communication | 9 | 11 | Very good |
| Material Eligibility | 6 | 7 | Very good |
| Material Accuracy | 10 | 10.3 | Very good |
| Didactic | 18 | 20.3 | Very good |
| Construction | 32 | 35 | Very good |
| Technical | 11 | 13.6 | Very good |

Based on the results in Table 3, the evaluation of the biology teacher and colleagues on the software engineering aspect obtained an average score of 10.6 with very good criteria, on the visual communication aspect an average score of 11 was obtained with very

good criteria, on the feasibility aspect of the material, an average score of 7 was obtained with a very good category, on the accuracy aspect of the material, an average score of 10.3 was obtained with very good criteria, on the didactic aspect a score was obtained with an average of 20.3 with very good criteria, on the construction aspect, an average score of 35 was obtained with very good criteria and on the technical aspect, an average score of 13.6 was obtained with very good criteria.

Based on the assessment of the biology teacher and colleagues, learning media based on Augmented Reality (AR) is feasible to be tested on students with several revisions. Assessment of learning media carried out by students consists of 4 aspects, namely aspects of presentation, language, visual communication, and usefulness. the average results of media assessment by students can be seen in Table 4.

Based on the results in Table 4, the assessment of students on the presentation aspect obtained an average score of 9.1 with good criteria, on the linguistic aspect an average score of 9.2 was obtained with good criteria, on the visual communication aspect a score was obtained with an average of 10 with very good criteria and on the benefit aspect a score with an average of 6.1 with good criteria is obtained. Based on the results of student assessments, learning media is feasible with several revisions.

Table 4. Average Results of Media Assessment by Students

| Aspect | Average | Category |
|----------------------|---------|-----------|
| Presentation | 9.1 | Good |
| language | 9.2 | Good |
| Visual Communication | 10 | Very good |
| Benefits | 6.1 | Good |

Results of the Large Group Trial

Field trials were conducted in two classes, namely the experimental class and the control class. The subjects of this study were 32 students of class X SMAN 4 Berau each. The experimental class is a class whose learning activities use Augmented Reality Learning Media with a card-sort learning model and the control class is a class whose learning activities use a card-sort learning model without using Augmented Reality learning media.

Evaluation

Measurement of analytical thinking skills was carried out by giving pretest questions before the learning activities of the mushroom sexual reproduction

sub-material in the control class and the experimental class.

Multivariate Normality Test

The results of the multivariate normality test can be seen in the following table.

Table 5. Multivariate Normality Test Results

| Class | Sig. | Correlation |
|--|-------|-------------|
| Pretest for Analytical Thinking Ability Experiment class | 0.000 | 0.947 |
| Pretest for Analytical Thinking Ability Control Class | 0.000 | 0.801 |
| Posttest Experiment Class on Analytical Thinking Ability | 0.000 | 0.876 |
| Posttest Control Class Analytical Thinking Ability | 0.000 | 0.621 |

Based on Table 5, if the correlation coefficient $> r$ table or sig. < 0.05 then there is a significant correlation. In the pretest of the experimental class, students' analytical thinking skills had a significance value of 0.000 and a correlation coefficient value of 0.947 which showed a very high correlation coefficient meaning that the data came from a sample that was normally distributed multivariate. In the control class pretest, the ability to think analytically has a sig value. 0.000 and a correlation value of 0.801 which shows a high correlation coefficient meaning that the data comes from samples that are normally distributed multivariate. In the posttest experimental class, the ability to think analytically and digitally has a sig. 0.000 and a correlation coefficient value of 0.876 which shows a very high correlation coefficient meaning that the data comes from multivariate normally distributed samples. In the control class posttest the ability to think analytically has a sig value. 0.000 and a correlation coefficient value of 0.621 which indicates a high correlation coefficient means that the data comes from multivariate normally distributed samples.

Multivariate Homogeneity Test

The homogeneity of the variance-covariance matrix was carried out using the Box's M Test. Homogeneity test results can be seen in the following table.

Table 6. Box's M Test Homogeneity Test Results

| Class | Test Type | Significance |
|----------|-----------|--------------|
| Pretest | Box's M | 0.000 |
| Posttest | | 0.000 |

Based on table 6 shows that both significance values are less than 0.05 or $0.000 < 0.05$ so it can be concluded that the covariance variance matrix of the dependent variable is not the same. However, in the opinion of Johnson and Wichern (2007) although showing rejection of H_0 the Manova test can still be carried out as usual, so that the hypothesis testing is continued using the Manova test with Pillai's Trace.

Multivariate Hypothesis Test

The manova test was carried out after the prerequisite tests for multivariate normality and multivariate homogeneity were fulfilled. The results of the Manova test to see the effect simultaneously can be seen in the following table.

Table 7. Manova Test Results

| Test Type | Sig. |
|----------------|-------|
| Pillai's Trace | 0.000 |

Based on Table 7 it is known that the results of the Pillai's Trace test have a sig value. $0.000 < 0.05$. This means that H_0 is rejected, which means that there are significant differences in the analytical thinking skills of class X students who use and do not use Augmented Reality-based learning media.

Discussion

The characteristics of the learning media developed are in the form of learning media that use 3D objects as learning objects which are equipped with moving animations, are interactive because students can freely control the course of the media used, and have text, images, and buttons to switch slides. According to Munir (2015), interactive media is media that is made with a display that fulfills the function of conveying information. If the user has freedom in managing the course of the media coupled with interactive components. The characteristics of the next media are specifically developed with the Android operating system because the Android operating system is the smartphone most widely used by students. The developed learning media is accompanied by an AR book which contains guides and materials as well as cards containing AR markers to be scanned. Learning media is independent because it makes it easy for students to download and use without guidance from the teacher. The main characteristic of Augmented Reality-based learning media is that it combines the real world with the virtual world in real-time.

The ability to think analytically has 3 indicators, namely the ability to differentiate, organize and connect. Students start learning activities using Augmented

Reality card media which has been scrambled by the teacher so students start the thinking process by distinguishing which mushroom groups are Ascomycota, Basidiomycota, and Zygomycota. After students succeeded in differentiating the cards into 3 groups of mushrooms, students began to find ideas to arrange the cards into a stage of sexual reproduction of mushrooms. Students are given the freedom to take sources from books and articles on the internet. In its implementation, it was seen that the students worked smoothly and correctly, there were only a few groups that were still wrong in grouping the cards. After students search for relevant sources, they begin to organize the cards into a complete stage. In practice, only a few groups correctly arrange the cards into a stage of sexual reproduction of the fungus. In the final stage of the activity, students begin to think about linking the stages of mushroom reproduction with the concepts they find in sources that are still related to the sexual reproduction of mushrooms. After they try to relate it to the concept, then they can arrange the AR cards into a reproduction stage correctly. The use of AR learning media is considered by students to be very fun and not boring in their learning activities because they can see real objects directly on their smartphones, moreover, they can see spores moving in 3D objects. This is in line with the opinion of Mustaqim (2017) the use of Augmented Reality learning media is very useful for interactive and real learning media directly by students and can help students in the learning process wherever and whenever.

Augmented reality is a three-dimensional medium supports such a tangible interface and allows a seamless interaction between people and information. Augmented reality technology is different from virtual practical technology in that it retains information from user's real environment. Augmented reality too increase the user's sense of reality, add virtual information into its real environment (Kye et al., 2008).

Researchers want to see how the effectiveness of Augmented Reality-based learning media in improving analytical thinking skills simultaneously. To use the multivariate test, a prerequisite test is carried out first, namely the multivariate normality test and the multivariate homogeneity test. The multivariate normality test uses the Mahalanobis Distance test which gives results for both variables having a normally distributed multivariate distribution of data, while the multivariate homogeneity test uses the Box's M test which gives the result that data on analytical thinking skills in the experimental and control classes do not have significant covariance variants. The same. However, in the opinion of Johnson and Wichern (2007) even though the homogeneity test shows rejection of H_0 , the manova

test can still be carried out as usual so that the manova test is continued with Pillai's Trace.

In multivariate analysis, several types of test statistics can be used, namely Pillai's Trace, Wilk's Lambda, Hotelling's Trace, and Roy's Largest Root. Pillai's Trace is a test statistic that is suitable for use if the assumptions of homogeneity of the variance-covariance matrix are not met, the sample size is small and if the results of the tests are contradictory to each other, that is, if there are some vectors on average while others are not. Wilk's Lambda is a test statistic that is suitable for use if there are more than two groups of independent variables and the assumptions of homogeneity of the variance-covariance matrix are met. Hotelling's Trace is a test statistic that is suitable for use if there are only two groups of independent variables and Roy's Largest Root is a test statistic that is only used if the assumption of homogeneity of variance-covariance is met (Olson, 1974).

This is in line with the opinion of Mustaqim (2017) the use of Augmented Reality learning media is very useful for interactive and real learning media directly by students and can help students in the learning process wherever and whenever. Bramastia & Vari (2021) Augmented Reality technology provides a new learning experience so that it has a positive impact on students' analytical thinking skills.

The results of the Manova test using Pillai's Trace are the Sig. 0.000 where the value of Sig. < 0.05 , it can be concluded that there is a significant influence on the use of Augmented Reality learning media on students' analytical thinking skills.

Conclusion

Based on the results of the research, development, and analysis as well as the discussion that has been carried out, it can be concluded that several things related to this research are the characteristics of the developed Augmented Reality-based learning media are learning media using 3D objects which are equipped with moving animations, are interactive, developed specifically for Android users, have AR manuals and AR cards, are independent, and these media combine the real world with the real world. virtual in real-time. The developed Augmented Reality-based learning media has met the eligibility criteria which can be seen in the media aspects, material aspects, and research instruments. The results of the validation given by the media expert validator stated the value was in the very good category, from the material expert validator and the instrument stated the value was in the very good category. So that learning media based on Augmented Reality on the mushroom sexual reproduction sub-

material is declared feasible to be used in the process of learning activities. Learning media based on Augmented Reality in the mushroom sexual reproduction sub-material affects improving analytical thinking skills of class X students of SMAN 4 Berau as shown by the Mann-Whitney U test it is known that the Asymp.Sig (2-tailed) value is 0.008 <0.05 with the gain score category being quite effective in increasing students' analytical thinking skills.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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