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Development of augmented reality learning media on human reproductive system using discovery learning models to improve students' cognitive ability of Grade XI in SMAN 13 Jambi City

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ABSTRACT

Human reproductive system is an important topic to be mastered by students in high school, however, the learning results of this topic in National Exam was still reported unsatisfactory. Therefore, developing a 3D-based learning media could be a potential solution to ease students in learning about this topic. We aimed to develop an Augmented Reality (AR) media on the human reproductive system topic, determine the feasibility and determine the effectiveness of using the media to improve students' cognitive abilities. This study used the ADDIE model (Analysis, Design, Development, Implementation, & Evaluation) and was conducted at SMAN 13 Jambi City. The test subjects were students of class XI in Science class. Data collection was performed with questionnaires to obtain product feasibility data based on validation results from experts, Biology teachers, and student responses. Multiple choice tests were used to obtain data on the effectiveness of using the media. The questionnaire data for the feasibility of the media were analyzed descriptively, while the effectiveness of the developed media were analyzed with Mann-Whitney test. The results showed that validation from both material and media experts are in very good category, scoring 100% and 95%, respectively. The response from biology teachers was also in good category, showing 92% as well as the result from the student's response (83.5%). Therefore, the developed AR media is considered suitable to be used in learning. The cognitive ability of students who are taught with and without AR media was not significantly different. The average post-test score for the treatment class was 49.23, gain=0,2; and the control class was 43.5, gain=0.1, p= 0.125). Although there is no significant difference in students' cognivite ability, there is a tendency of increasing students' learning outcomes using the AR media rather than not using the AR media.

Introduction

The Covid-19 pandemic not only has affected health problems, but also caused problems in almost all aspects of life. In education, as reported by the Center of Education Assessment (Puspendik, 2019), the data from Indonesian National High School Exam demonstrated that the students' learning outcomes were still considered low. There were only 49.5 % students who answered correctly the questions on the structure and function of living things, and 51.95 % students on the human reproductive system topic. In line with that, our observation to gather data on learning outcomes and need assessment of human reproductive system topic, demonstrated that the students' mastery in learning human reproductive system topic at SMAN 13 Jambi City was also still low. There were only 46.2 % students who have completed the minimum mastery criteria.

The students have different learning outcomes due to various factors, one of which is the differences in their cognitive abilities. This difference is caused by cognitive development that occurs during a student's life. Kamelia et al. (2018) states that without cognitive function, students will not be able to understand what is conveyed by the teacher. Rosa (2017) adds that cognitive ability is one of the most important areas of assessment in the learning process. This ability consists of six stages, namely memory, understanding, application, analysis, evaluation and creation according to Bloom's taxonomy.

Cognitive ability is related to students' learning outcomes that represent the effective condition of students on certain subjects. The learning outcomes are obtained through assessment (Febriana, 2019). The realm of cognitive ability assessment according to UU Nomor 23 Tahun 2016 is the activity used to measure students' mastery of knowledge (Ituga, 2021). Assessment of cognitive abilities can be conducted with written tests, oral tests, assignments or giving problems or case studies (Nurzannah & Carlina, 2021). Thus, low learning outcomes can indicate low cognitive abilities as well.

Based on our needs analysis study, the cognitive ability of students at SMAN 13 Jambi City in human reproductive system topic is also still quite low. Needs analysis was also conducted through interviews with Biology teachers at the high school. According to the teachers, one of difficult topics to teach was the human reproductive system. The mastering of this topic requires good visualization while access to deliver this was very limited during the pandemic. The teacher stated that he had difficulty delivering the material optimally because learning during the pandemic was carried out online. Teachers could only convey material briefly and give assignments through google classroom and whatsapp groups. Supporting this, needs analysis carried out in class XI using a questionnaire via google form, revealed that around 57.6 %

students experienced difficulties when learning human reproductive system topic. The number of Latin terms that are difficult to remember and the many organs that make up the reproductive system are factors that make it difficult for students to understand the topic (Achmad et al., 2020). Students need to recognize the structure and relate the structure to its function, besides that there are processes that are difficult for them to imagine such as hormonal mechanisms in the menstrual cycle (Hikmawati et al., 2014). Supporting this, Syahdiani et al. (2017) said that there are some parts of the reproductive system topic that are difficult to explain using the lecture method. Yasin & Ducha (2017) added that this topic consists of concepts that require visualization and there are many terms that are difficult to remember.

On the other hand, although the human reproductive system topic is difficult for students to understand but it is actually an interesting topic (Billik, 2021). Students said that by studying this topic, they can find out what reproductive organs are in the body, know how the system works, know the ins and outs of the human reproductive process, and remember to always maintain the health of reproductive organs and. Ilhami et al. (2021) stated that the topic of human reproduction is booming in Indonesia, especially those related to sexual deviant behavior in the school environment. One of the factors is the low understanding of students' sex because this topic is still considered taboo by the public. Therefore, the human reproductive system topic has an important role as an appropriate means of sex education for high school students. Tenzer et al. (2022) added that scientific sex education topic is closely related to daily life.

All in all, problems related to learning human reproductive topic, need to be resolved soon (Tanuwijaya & Tambunan, 2021); Dzalila et al. (2020) said that if obstacles in learning were not resolved immediately, it would lead to long-term negative effects. An example is the decrease in enthusiasm for learning and student achievement. Furthermore, Lubis & Simatupang (2014) said that the reproductive system topic contains concepts that are difficult to observe (intangible) directly so that the provision of learning media will help the student learning process. This is fitted with our observation that another problem experienced during learning is the difficulty of finding suitable media due to the lackness of innovative media. The media that teachers have used so far to deliver topic has not yet fully helped students understand the topic. Similarly, students also said that they needed other media to understand the topic. The teacher further stated that she wanted to teach with media that was easily accessible by students via smartphones.

There are various types of media that can be developed in learning, one of which is Augmented Reality (AR) learning media. The term AR was first introduced by Morton Heilig, a cinematographer in the 1950s. AR is the latest technology that combines computer-generated objects and text into real images

and videos (Cho et al., 2017). AR media is not only an interactive medium so that the learning environment becomes interesting and fun, but also a medium that can help students understand concepts and theories, stimulate students to conceptualize and interpret topic with a three-dimensional display and strengthen perceptions (Ivanova & Ivanov, 2011). This media also has interesting features, is flexible and provides a complex learning experience (Radu, 2012). In addition, AR media can reduce educational costs because application updates are cheaper than reprinting textbooks (Hassan, 2019).

Aditama et al. (2019) states that in the field of education, AR technology can help increase the effectiveness of learning, especially in visualizing concepts. In line with that, Qumillaila et al. (2017) said that AR had a positive influence on education. Although still relatively new, this content is interesting. Nonetheless, it is still quite difficult for teachers and students to create the AR media, because it requires significant technical knowledge during the media design process. In line with this, our needs analysis also found that only 30% of students at SMAN 13 Jambi City have heard of the AR media and only 15% have used it in learning. Meanwhile, the teacher had never even heard of the AR media. Andriyana et al. (2013) further added that the development of AR-based media in the field of education is still a little, so that the opportunities for developing this media is the big chance.

AR media can be used in various subjects including Biology. The use of AR media is expected to help students to clearly see the morphological structure of the organ being studied and the mechanisms that occur in the human reproductive system. This is because AR is able to visualize the concept being taught to make it look real. Kawuryan & Raharjo (2012) explained that to be more effective, students must interact with the visual for information processing to occur.

Visualization of the topic is related to cognitive abilities. If a material requires good visualization in its delivery, but cannot be accomplished with limited media, it will result to incomplete concept received by the students. Visualization problems can be overcomed by using AR media because this media is based on three dimensions (3D). Objects that are spherical in shape can be presented as round as in reality, while two-dimensional media are not able to present such information. Slamet (2020) states that 3D media tends to be more realistic than two-dimensional media.

One of the models that can that can be combined with AR media in learning is a discovery learning model. Cheah et al. (2014) stated that AR has been widely introduced including its learning with discovery models. In addition, at the beginning of its development, the portable AR version was designed to illustrate the ability to improve hands-on experiences through discovery-based learning. Cabiria (2012) added that AR media with discovery learning models is a learning process that provides a practical alternative to combine

information in one platform that is difficult to do in the real world. In line with this explanation, learning in this study uses a discovery learning model. One of the functions of this model is to help students improve and enhance cognitive processes (Septiawan et al., 2016). This cognitive process is related to the ability of students to understand the topic which ultimately leads to their cognitive abilities.

AR media that is able to visualize the concept and the discovery learning model which objects to improve the thinking process, both can potentially be alternative solution to overcome learning problems related to cognitive abilities. The combination of AR media and discovery learning models is considered suitable to overcome problems in learning. We conducted research to develop AR media for human reproductive system topic using discovery learning models to improve the cognitive abilities of students from Grade XI high school SMAN 13 Jambi City, Indonesia.

Method

This research used the Design and Development Research (DDR) approach developed by Richey & Klein (2007). The DDR approach can use several product development models such as ADDIE, ASSURE, and the Dick & Carey model (Wahid, 2019). In this study, the ADDIE model consists of Analysis, Design, Development, Implementation & Evaluation was chosen. The stages of development in this research are described in detail as follows:

Analysis

The analysis phase in this research consisted of needs analysis and literature study. Needs analysis was conducted by interviewing Biology teachers and giving questionnaires to students via google form. Based on the results of the needs analysis, a literature study was then conducted to obtain relevant information related to the problems found. Literature study was done by searching for information through books and internet sites.

Design

The next stage was the product design. In this study, product design consists of conceptualizing and designing products with the consideration that AR products are based on aspects of material characteristics that require visualization. The design stage produced story boards, as well as samples of 3D objects related to the description of organ structures and diseases in the human reproductive system.

Development

The concept that had been created was then put on through product development activities. The making of AR media used several software, including CorelDRAW 2019, Adobe Audition CC 2019, Blender 3D, Substance Painter 3D, Adobe Photoshop CS6, Unity 3D 2019 and EasyAR. After the product was finished, validation was carried out by material and learning media experts using a questionnaire instrument. Suggestions and comments from experts were then used as the basis for revision. The revised product was then tested through a limited trial to get responses from students and

Biology teachers, using a questionnaire instrument. Sampling was performed with purposive sampling technique. Inclusion criteria in this study include Grade XI students who will study this topic, have never used AR media on human reproductive system topic, have smartphones and provide respondents, while the exclusion criteria include students who are sick and absent at the time of the study. Suggestions from students and teachers were also used as the basis for revising the product.

Implementation

This stage was carried out to obtain information on the effectiveness of using AR media in learning to improve students' cognitive abilities. This stage was carried out with a quasi-experimental nonequivalent control group design. Sampling was done with convenience sampling technique. The sample in this study was class XI SMAN 13 Jambi City, consisted of an experimental class (XI MIPA 2) and a control class (XI MIPA 3). The experimental class was taught with AR media using discovery learning models, while the control class used ordinary student worksheet media with the same discovery model.

Evaluation

The evaluation stage of the ADDIE development model can basically be carried out throughout the implementation of the five research steps (Panggabean & Danis, 2020). The evaluation carried out in this study at the analysis stage was to review the results of the analysis and the literature study that had been carried out. At the design stage, evaluation was carried out on the story board and object samples by re-checking all components starting from writing, clarity of story board flow, clarity of object samples, clarity of application design, and so on. At the development stage, evaluation was carried out together in product revision activities. At the implementation stage, evaluation was carried out after implementing stage whereby learning using AR media was carried out.

Data collection techniques in this study used non-test and test techniques. The non-test technique used an interview sheet and a questionnaire instrument. Data collection was carried out during needs analysis, expert validation, and limited trials. Data obtained from non-test instruments was analyzed descriptively. The analysis results were then interpreted into qualitative data, and categorized into qualitative categories according to the percentages as seen in table 1.

Table 1. Range of Percentages and Categories of Qualitative Assessment

No.	Range of Percentages (%)	Categories
1	75 < score ≤ 100	Very Good
2	50 < score ≤ 75	Well
3	25 < score ≤ 50	low
4	0 ≤ score ≤ 25	Not Good

Source: Modification of Riduwan (2011)

The analysis technique of the test instrument used a gain score by Hake (1999) to determine the increase of students' cognitive abilities The results of the gain score calculation were then interpreted into the value (g) in Table 2. In addition, hypothesis testing was also used to see the effectiveness of using AR media in students' learning, using the Mann-Whitney test.

Table 2. *Gain Score Interpretation*

No	Score (g)	Classification
1	$g < 0.3$	Low
2	$0.7 \leq g \leq 0.3$	Medium
3	$g > 0.7$	High

Source: Susanto (2012)

Results and Discussion

This study follows a DDR research approach, belong to a DDR type one. Susilawati et al. (2021) explained that DDR type one, namely development research, directly produces products with certain conditions such as software for teaching materials. In addition, type one is also used contextually, that the product development process is based on the conditions described in the needs analysis and on an evaluation of the final product. Kamarulzaman (2021) explains that ADDIE is a model that is in line with the DDR approach.

The results of the development of AR media can be seen in Figure 1. This study produces 3D-based AR media that can be easily accessed by students via smartphones. The AR developed by the researcher is markerless AR, so it can be used without the need for a specific marker. The use of this kind of AR is more practical because it does not require printed markers, so AR can be used flexibly.

This AR media also displays the organs of the human reproductive system in detail because they are separated into several 3D objects. There are six 3D objects each in the male and female reproductive systems consisting of reproductive organs (normal), gamet cells and reproductive organs that are affected by certain diseases or disorders. Each object is also equipped with an audio explanation. In addition, 3D objects can be rotated 360^0 and has a zoom in, zoom out feature. The developed AR media is also equipped with information about indicators of competency achievement that must be achieved by students in learning. In addition, there is a student worksheet that can be used as a supporter in learning. There are pre-test and post-test questions in this media which are equipped with explanations for each question.

Figure 1. AR Media Display

Expert Validation Results

After the AR media has been developed, the next process is the validation by the material and media experts. Validation aims to determine the feasibility of the resulting media (Dewi et al., 2018). The results of the material and media expert validation can be seen in Table 3 and Table 4, respectively. Both results show that the feasibility of AR media is overall in the very good category. Based on these results, it can be concluded that the developed AR media on human reproduction is suitable to be used in Biology learning activities.

Table 3. Material Expert Validation Assessment Results

No	Assessment Aspect	Percentage (%)	category
1	Relevance	100	Very Good
2	Construct	100	Very Good
3	Language	100	Very Good
4	Serving Equipment	100	Very Good
	Average	100	Very Good

Table 4. Media Expert Validation Assessment Results

No	Assessment Aspect	Percentage (%)	category
1	Efficiency	94	Very Good
2	Appearance	92	Very Good
3	Usefulness	100	Very Good
	Average	95	Very Good

Limited Trial Results

After revisions were made based on expert suggestions and comments, then limited trials on teachers and students were carried out. The results of the assessment by the Biology teacher and of student responses are presented in Table 5 and in Table 6, respectively, showing the overall feasibility of AR media is in the very good category. Based on these results, it can be concluded that the developed AR media on human reproduction is suitable to be used in Biology learning activities.

Tabel 5. Assessment of the Developed AR Media by Biology Teachers

No	Assessment Aspect	Percentage (%)	category
1	Theory	84	Very Good
2	Appearance	88	Very Good
3	Application	100	Very Good
4	Language	88	Very Good
5	Achievement	100	Very Good
	Average	92	Sangat baik

Tabel 6. Students' Responses on the Developed AR Media

No	Assessment Aspect	Percentage (%)	category
1	Theory	84	Very Good
2	Application	86	Very Good
3	Appearance	86	Very Good
4	Audio	80	Very Good
5	Achievement	83	Very Good
6	Usefulness	82	Very Good
	Average	83.5	Sangat baik

Students' Cognitive Ability Results

Based on the results from the assessment of cognitive abilities in experimental and control class, it is known that the minimum pre-test and post-test scores of the experimental class are higher than the control class. Although the maximum pre-test and post-test scores for the experimental class were lower than the control class, the average value of the pre-test and post-test of the experimental class was higher than that of the control class. The graph mapping the results of the average cognitive ability scores of the experimental class and the control class can be seen in Figure 2.

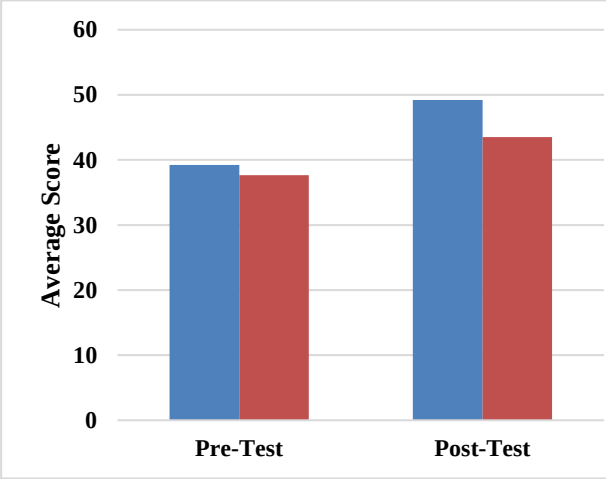

Figure 2. Results of Average Cognitive Ability Score in Experiment and Control Class

The results of the cognitive ability improvement test are presented in table 7. It can be seen that the increase of student learning outcomes in the experimental class is higher than the control class, but the increase is in the low category.

Table 7. Cognitive Ability Improvement Test Results

No	Average Score	Experiment Class	Control Class
1	*Pre-Test*	39,23	37,63
2	*Post-Test*	49,23	43,5
	Gain	0,2	0,1

Hypothesis Test Results

The results of the hypothesis test can be seen in table 8. It shows that there is no difference in the increase of cognitive abilities between students who are taught with and without AR media. Although the difference of effectiveness is not significant, there is still a tendency to increase student learning outcomes on reproductive system topic using AR media compared to without AR media.

Table 8. Mann-Whitney Test Results

	Learning Results	Conclusion
Asymp. Sig. (2-tailed)	.125	H0 accepted

Our study has succeeded in developing AR media using discovery model on human reproductive topic and it was declared feasible according to expert validation, teacher's assessment, and students' responses. Although there was no significant difference of students' cognitive abilities between learning with and without AR media, the results still show an increase trend of cognitive abilities when students used AR media in their learning. There are several possible causes for this, firstly the learning process did not run optimally during the pandemic because schools still enforce an odd-even system, so that only 50% of students study offline and 50% of other students study online. Students who study online take part in learning through whatsapp groups and google classroom. Learning with a system like this causes teachers to be unable to monitor student learning activities as a whole, especially for students who study online. The evidence could be seen when filling out the pre-test and post-test, students who study online are mostly late for work and must be contacted one by one to immediately fill out the test. Second, some students have difficulties in installing applications because of some reasons, either their smartphones are not Android-based, or their smartphone memory is full so they cannot access AR media. Juannita & Adhi (2017); Qumillaila et al. (2017) stated that this was one of the inhibiting factors for the use of AR media in learning. Third, AR-based learning allows interaction between users and computer systems. However, interaction problems may arise due to inexperienced users and possible limitations of the camera's viewing area. AR that is difficult to use for this reason, as well as complex instructions can increase cognitive load (Ibili, 2019). In line with this statement, AR media used in learning is relatively very new for students. Smartphones used by students are also different, so there may be differences in the limitations of the AR display area.

Fourth, learning with AR in this study also uses a discovery learning model. This model is also a new learning model for students. At the time of learning, they felt unfamiliar with this model, especially with regard to syntax instruction during learning. This allows the emergence of interaction problems when using AR media. Moreover, the model used is discovery learning which requires students to be able to learn independently following

the existing syntax. Based on the students' explanation, they have never learned to use a particular learning model. The teacher only uses the lecture and discussion method in several learning. In addition, this model takes a long time for students to find theory (Darmadi, 2017). This is also one of the problems in the research because the allocation of learning time is reduced during the pandemic period by 35 minutes per 1 hour lesson. Thus, the learning process becomes less effective and efficient. Ngabidin (2021) also said that this model is oriented to HOTS (Higher Order Thinking Skill) and requires students to learn independently in the form of searching, finding and formulating learning concepts. Darmadi (2017) adds that this model helps students improve and enhance cognitive processes, but there is an assumption that the mind is ready to learn, so that student who are less intelligent will have difficulties in thinking or expressing the relationship between written and oral concepts.

Furthermore, AR media may be ineffective in particular with regard to significant pedagogical issues (e.g., need for more class time, inappropriateness in crowded classrooms, inadequate experience of instructors with technology) and technical issues with AR technology that need to be resolved (Akcayir & Akcayir, 2016). In some cases, it was also known that the use of AR media was dominated by teachers in discussions and thus limited student involvement. On the other hand, there are also differences in abilities between one student and another. For some students, AR is not an effective teaching strategy. In some cases, low achieving students do show the benefits of learning through experience with AR media but have not been able to get high achievements (Radu, 2012).

Based on this explanation, it is known that the use of AR media which is classified as effective or ineffective is caused by several factors, including teachers, students, and conditions during learning. The media developed is not always appropriate and suitable for use by each student and in a certain time and environment. Purba et al. (2021) stated that there is no perfect media. Each media must have advantages and disadvantages. Accordingly, there is no best media because a media may be suitable for certain purposes but might not suitable for other purposes.

There are several limitations in this study: first, AR media only focuses on the anatomical structure and morphology of the human reproductive system and has not been able to visualize the microscopic structure of the human reproductive system organs (histology) and reproductive system physiology processes (such as gametogenesis, menstrual cycles and fertilization). Thus, further research is expected to develop AR media which covers this material in more detailed. Second, this media is android-based, so it can only be used on android-based student smartphones, hence future research is expected to be able to develop AR media on various types of operating systems.

Conclusion

The resulting developed AR media is declared as suitable for use in learning based on the results of the validation of media experts and material experts. This media also received a positive response from students and teachers in the limited trial phase. Although, the effectiveness of using AR media to improve students' cognitive abilities in learning human reproductive system is not significantly different from learning without AR media, still there is an increase trend of students' cognitive abilities when using the AR media. The limitation of AR media can be used as the basis for further research to develop a more complete AR media, especially with regard to a more detailed microscopic structure and physiological processes in the human reproductive system.

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