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Augmented Reality Media Development on Human Excretory System Material to Improve Digital Literacy and HOTS

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Abstract: Excretory system material is one of the materials that is difficult to understand the concept because it has a lot of memorization, terms, and mechanisms. Excretory system material is less preferred and tends to be boring because it requires students to memorize terminology and Latin language to introduce organs involved in the human excretion process. The use of learning media integrated with AR technology can be an effective solution in improving learning. Through this technology, various abstract concepts that are usually invisible can be displayed in 3D or 2D, making them appear more real. This study aims to assess the feasibility, practicality, and effectiveness of AR-based learning media on human excretory system material to improve HOTS and digital literacy of grade VIII junior high school students. This research uses the ADDIE development model with a pretest-posttest control group design. The study used control and experimental classes with a total sample of 140 students. The instruments used were questionnaires and tests of digital literacy and HOTS. Data analysis included descriptive and inferential statistics. The results showed that AR media was feasible, with media and material expert assessments based on the Aiken index of 0.909 and 0.835. Practicality scores from teachers and students received scores of 90.62% and 91.12%. N-Gain test showed a substantial increase, and the one-way manova test showed statistical significance ($p < 0.05$). The AR media developed has met the values of feasibility, practicality, and effectiveness in improving digital literacy and HOTS.

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INTRODUCTION

Entering the 21st century, education is critical to prepare the next generation, who have the skills to learn, innovate, use technology and information media, work, and survive by using skills for life (Arifin, 2017). In the era of Society 5.0, literacy is the main requirement for every human being to fulfill their life needs (Anggraeni, Fauziyah, & Fahyuni, 2019). One of the important literacies developed in the Society 5.0 era is digital literacy. Digital literacy is an individual's interest, attitude, and ability to use digital technology and communication tools to access, manage, integrate, analyze, and evaluate information, build new knowledge, and create and communicate with others in order to participate effectively in society (Setyaningsih, Abdullah, Prihantoro, & Hustinawaty, 2019).

According to Fitriyani & Nugroho (2022), the importance of digital literacy in learning activities is that students become more creative and innovative using digital tools such as graphic design, programming, and multimedia content production. So, with digital literacy, students are also helped in learning activities and solving problems. Sani (2019) said that problem-solving is included in HOTS.

High-level thinking is the ability to think critically and creatively, which students can use to solve problems (Lailly & Wisudawati, 2015; Husamah & Pantiwati, 2014). This is in accordance with Abruscato's statement in (Yuriza et al., 2018), which states that the main purpose of science education is to form humans who have creativity, think critically, become good citizens, and realize a broad career, therefore, current science teaching directs learners to become literate in science so that it has implications for HOTS and problem-solving. So that they can understand and be critical, not only remembering information but also achieving learning objectives in a broad sense, namely, a science-savvy personality.

Previous studies in the research results found that two schools in the Kuala sub-district identified that students did not have a high level of digital literacy in the sense that they were still in the low and sufficient categories. This shows that educators still do not apply the application in schools related to multimedia and the use of information technology. In addition, the application of digital literacy outside of school has not been well developed or applied by students (Oktavia, 2019). This is also supported by research (Perdana, 2019), which concluded that the digital literacy skills of high school students in Yogyakarta City are very low.

Based on the results of evaluations conducted by world organizations in the field of education that assess the development of education in the world. Based on the 2022 PISA results, Indonesia's reading literacy score decreased by 12 points from the 2018 PISA results. The results also explain the lag of Indonesian students by 117 points from the average global literacy score. Sadly, only 25.46% of Indonesian students reached the minimum competency standard for reading from PISA (OECD, 2023). PISA questions are included in the category of high-level thinking by demanding students' ability to analyze, evaluate, and create in the process of working. Therefore, PISA questions contain high-level thinking skills, which in Bloom's taxonomy, are in the C4, C5, and C6 domains. Furthermore, Ramadhan (2018) explained that the evaluation conducted by TIMMS (Trends in International Mathematics and Science Study) & PIRLS (Progress in International Reading Literacy Study) in 2015 showed similar results, Indonesia was ranked 45 out of 56 countries participating in TIMMS. These results identify that Indonesian children's higher-order thinking skills are still relatively low for elementary and junior high school-age children.

Furthermore, the results of research (Gunawan, 2024) found that the overall high-level thinking ability of SMA Negeri 01 Mempawah Hulu students was still very low, with a percentage of 15.24% and the percentage of achievement of each HOTS indicator, namely analyzing 29.83%, assessing 7.61% and creating/creating 12% with a very low category. Similar to the conditions in several schools, based on the results of teacher interviews at Yadika 12 Junior High School and PGRI 2 Junior High School in South Tangerang, most students still have difficulty in adjusting learning that applies HOTS learning and are confused about how to solve HOTS-based questions.

Digital literacy and HOTS need to be developed in the learning process at school. However, the learning process has not fully implemented learning media that can develop students' digital literacy and higher-order thinking. Learning in schools is still dominated by teachers, and students tend to be passive in learning (Saputra, 2023).

The ability to process and analyze information can be easily channeled when using media as an element in learning. As stated by (Prasetya Adi, 2018), problem-solving using media utilization by integrating Information and Communication Technology (ICT) in learning is considered appropriate to improve students' higher-order thinking in the learning process. The technology that is considered capable of meeting the needs of students in both digital literacy and HOTS is augmented reality (AR). AR is a smartphone-based media that can display computer graphics to the real world. Thus, AR allows users to see the real and virtual worlds simultaneously (Billinghurst, 2002).

Augmented Reality (AR) is a concept that combines digital information (images, video, audio, text) into a virtual environment and is displayed in real time (Fernández- García, 2021). Augmented Reality (AR) based media is a learning media whose technology combines virtual objects into a real environment to make users see the real world with virtual objects that have been generated from this technology (Al-Ansi, 2023; Firdanu et al., 2020; Panduwinata et al., 2021; Zhao, 2023).

Using augmented reality can help students learn better. This is because augmented reality media can visualize abstract concepts into 3D objects. Augmented reality can be used to learn concretely the structure of abstract concepts. Students can become motivated and excited to learn more. (Liono, 2021). The use of augmented reality is presented to stimulate ideas and increase the degree of cognitive abilities of students (Alshehri, 2021; Fidan, 2019).

Furthermore, Augmented Reality Media can improve learning outcomes and provide a fun experience in learning human anatomy in 3D (Ma, et al., 2016; Moro, et al., 2017; Kugelmann, et al., 2018; Chytas, et al., 2020). Students are no longer limited to computers in a certain area, but teaching and learning activities can be dynamically carried out. Augmented reality, which is used on smartphones, can support students in carrying out teaching and learning activities anywhere (Maulana, 2019).

The results of previous research (Arulanand, 2020; Sylvia, 2021) also explain that AR media can increase students' HOTS. Then, based on the results of research (Fajari, 2022; Fajariyah, 2024), it can be concluded that AR media effectively improves the critical thinking skills and digital literacy of elementary school students.

The material selection in this learning innovation is the material of the human excretory system. The reason for choosing this material is because the excretory system material is less preferred and even tends to be boring because it requires students to memorize terminology and Latin language on the introduction of organs involved in the human excretory process (Simorangkir, Napitupulu & Sinaga, 2020). This is also supported by research (Amini, Nasution, Mulkan & Sugito, 2018), which states that excretory system material is one of the materials that is difficult to understand the concept because it has a lot of memorization, terms, and mechanisms.

Based on the existing problems, the use of learning media integrated with AR technology can be an effective solution in improving learning. Through this technology, various abstract concepts that are usually invisible can be displayed in 2D or 3D so they will appear more real (Saifulloh, 2020). Therefore, the application of AR technology is expected to improve students' digital literacy and HOTS in the science learning process.

METHOD

Participants

The test subjects related to this AR media development research include teachers and students of class VIII SMP PGRI 2 Ciputat and SMP Yadika 12 Depok. The limited trial subjects consisted of 2 science teachers and 10 students. Meanwhile, the field trial consisted of experimental and control classes, with a total of 140 students. The sampling technique used in this study was simple random sampling.

Research Design and Procedure

This research was conducted to develop Augmented Reality media on human excretory system material (ARSEM). The development research was conducted using the ADDIE development model shown in Figure 1. The implementation of this research includes several stages, including analysis, design, development, implementation, and evaluation (Sugiyono, 2023). Description of the procedure of each stage shown in Figure 2.

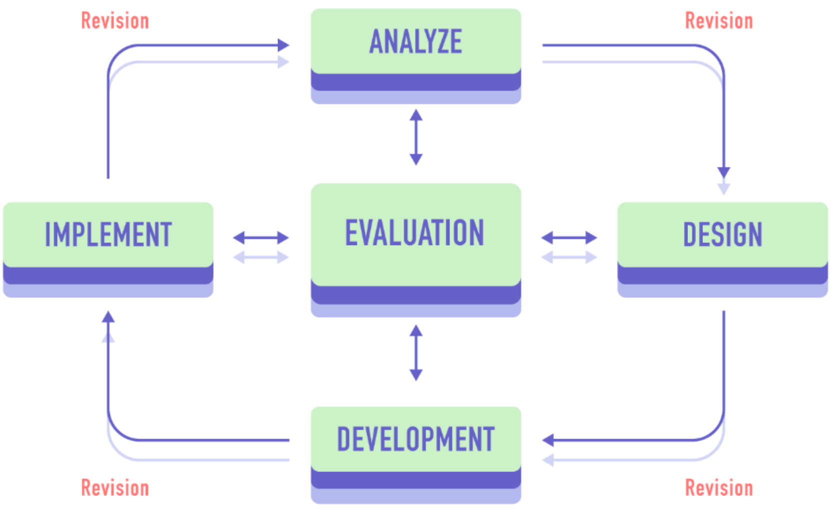

Figure 1. ADDIE Development Stages

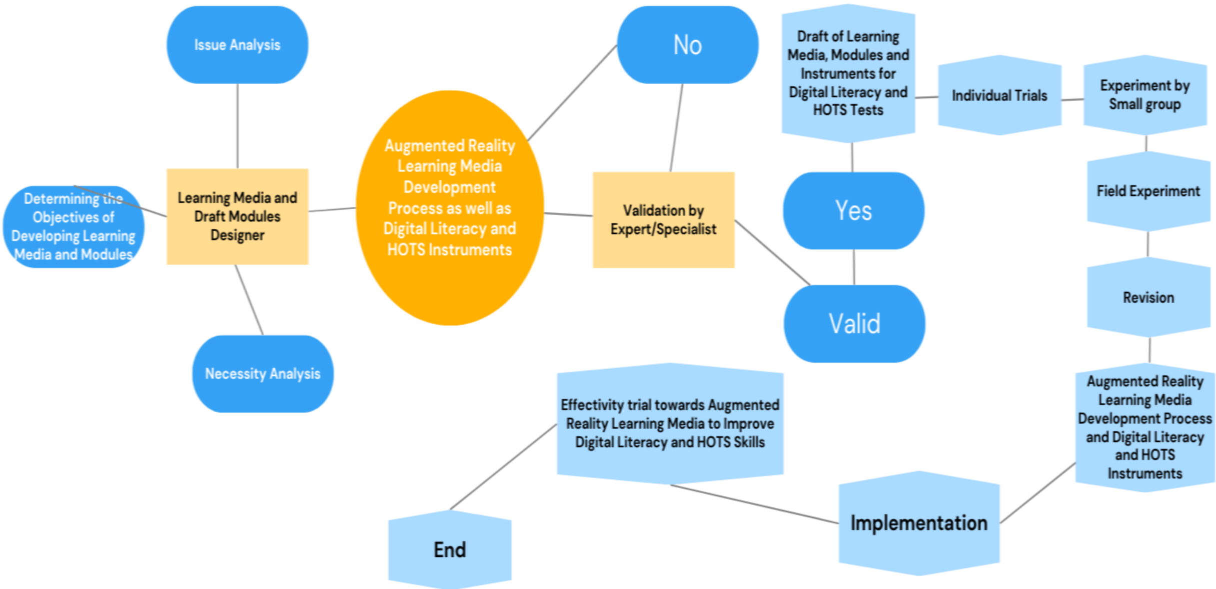

Figure 2. Development Procedure

Data Collection Techniques and Instruments

Data collection techniques in this study were in the form of questionnaires and tests. The data collection instruments in this study consisted of: a) the feasibility of AR media on the topic of the human excretory system using a questionnaire instrument described as follows: 1) media expert feasibility sheet with 14 items adapted from (Maharani, 2022 & Khoirina, 2024). 2) material expert feasibility sheet with 15 items adapted from (Maharani, 2022 Khoirina, 2024). 3) evaluation expert feasibility sheet with 15 items adapted from (Sari, 2022) 4) teacher and student response sheet with 20 items adapted from (Lorenza, 2024) (b) the effectiveness of AR learning media on the topic of the human excretory system is assessed using digital literacy and HOTS test instruments. The digital literacy instrument consists of 10 items developed by UNESCO 2018, and the HOTS instrument consists of 10 items based on aspects from (Nurwahidah, 2020).

Data analysis

This study uses two types of data, namely quantitative and qualitative data. Quantitative data is obtained from the assessment score from the validation assessment sheet of science learning material experts, science learning media experts, practicality, and questions, while qualitative data is obtained from input/suggestions given by science learning material experts, science learning media experts, and practicality from teachers with students.

The data collection instrument used in the feasibility and practicality questionnaire uses a Likert scale (Sugiyono, 2023), which includes (1) very bad, (2) not good, (3) quite good, (4) good, and (5) very good. The data collected from the assessment of the practicality of the media by teachers and students were analyzed by calculating the percentage with the interpretation of criteria based on Table 1 (Riduwan, 2013).

Table 1. Media Feasibility Assessment Criteria

No.	Score Range (%)	Category
1	81-100	Very feasible
2	61-80	Worth
3	41-60	Simply
4	21-40	Less feasible
5	<21	Very less feasible

Meanwhile, the validation questionnaire assessment from the experts was then analyzed using Aiken's v formula to obtain the validity coefficient. The results of data analysis using Aiken's v formula are expected to provide information related to the assessment of the instrument being developed. If the validation results > 0.8, then Augmented reality Learning Media on human excretory system material is considered valid (Lewis, R. Aiken, 1985).

$$V = \sum S \,/\, \{n(C\text{-}1)\}$$
$$S = R\text{-} Lo$$

Description:
V = Aiken Index
S = the score given by the rater minus the lowest score in the category
R = the score given by the rater
Lo = highest assessment score
n = number of validators (raters)

Then, after obtaining the feasibility and practicality of the media, the research continued by looking for the effectiveness of the AR media's pre-test and post-test N-Gain values of the learning process. The N-Gain value was analyzed using the equation developed by (Ramadhanti, 2021) shown in Table 2.

Table 2. Score categories

Value (g)	Category
g < 0,3	Low
0,3 < g < 0,7	Medium
g > 0,7	High

Analysis of product effectiveness was carried out using SPSS 26. Data analysis of digital literacy and HOTS was collected in the form of pre-test and post-test results from the control class and experimental class. To determine the effectiveness of AR media, hypothesis testing is carried out with the condition that the data is normally distributed and homogeneous, then testing is carried out with inferential statistical analysis using one-way MANOVA.

RESULT

A. Analysis

At this stage, the researcher analyzes the material and media needs needed in schools with the following description: First, for material analysis, this analysis is carried out to find out which material is included in the type of abstract and concrete concepts. Then the second is related to the needs analysis. Needs analysis is carried out to find out what information is related to the problems contained in learning (Yuhdi, 2017). The results of the needs analysis are used as the basis for determining alternative solutions and recommendations for augmented reality media specifications to be developed. The following is a description of the material analysis data and the needs presented:

1. **Material Analysis of the Human Excretory System**
   At the initial stage, material analysis was carried out to determine the achievements and the learning objectives that would be expected after the learning. The learning outcomes on the material of the human excretory system in class VIII are "Students can analyze to find the relationship between the organ system and its functions and abnormalities or disorders that arise in the human excretory organ system".
2. **Media Needs Analysis**
   Based on Figure 3, we can see that 76% chose augmented reality applications as the preferred media for learning science. Then 12% of students choose books and the rest choose to multiply practice questions. This is also supported by teacher interviews who need AR media for detailed explanations of excretory organs with 3D images, and schools have never implemented AR to

increase students' HOTS and digital literacy.

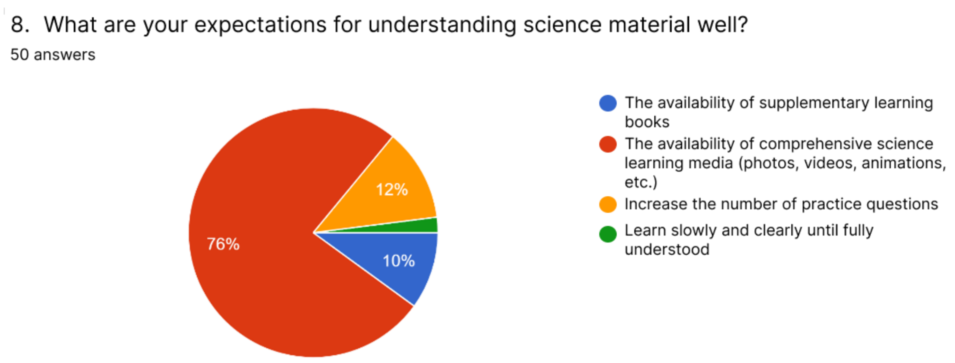

Figure 3. Diagram of Learning Media Needs

B. Design

The stage carried out after analysis is the design of making learning media. In making learning media designs, researchers first create a *storyboard*. After that, researchers also designate the appearance of learning media to make it easier for researchers to determine the appearance that will be shown to learning media users. A storyboard of augmented reality learning media is developed using Balsamiq Wireframes software. The following is a display of some parts of the learning media that will be developed by researchers.

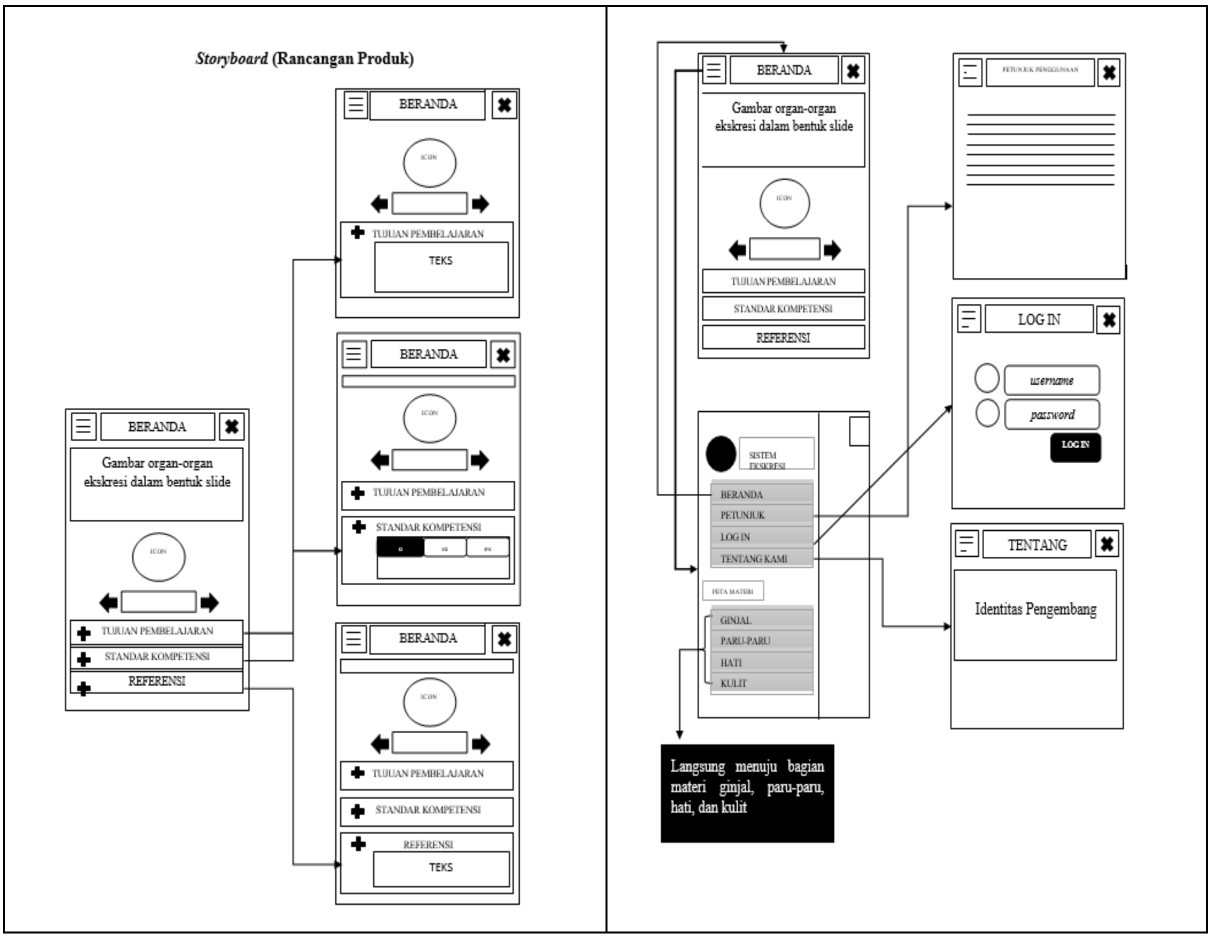

Figure 4. Augmented Reality Media Storyboard Display

C. Development

1. Product Description

This stage is where the media designed on the storyboard will be continued and done at the development stage with the software used in the AR media development stage is Unity 3D. Some parts of the design of AR media development results are described in the following figure:

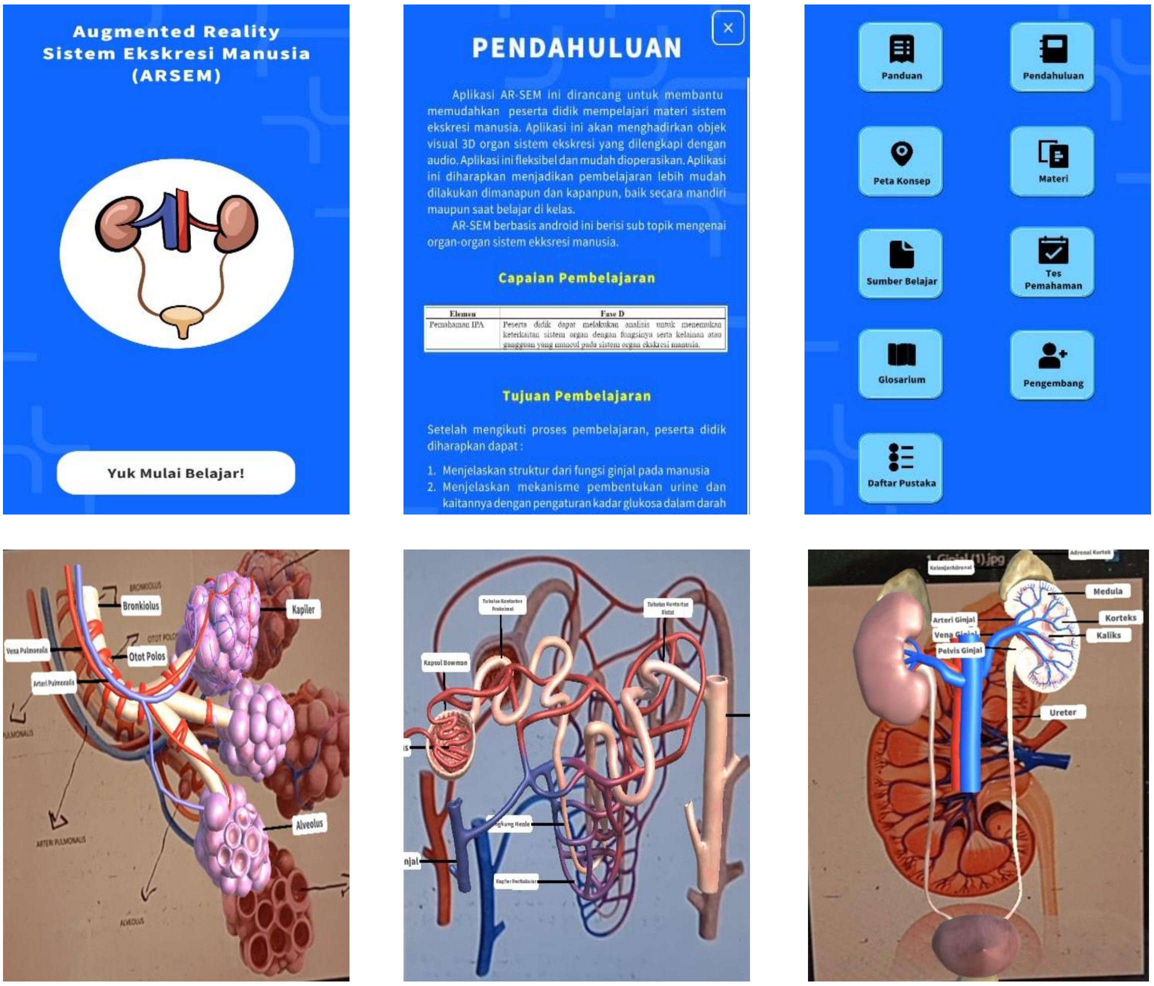

Figure 5. Menu Display and 3D Augmented Reality Media Application

2. Product Feasibility

The feasibility of AR learning media on the topic of the human excretory system was validated by six lecturers, namely two material expert lecturers, two media expert lecturers, and two evaluation expert lecturers. The following is a description of each product feasibility assessment;

Feasibility

Media assessment by material expert lecturers includes design, application, and benefits aspects. It is known that the assessment results from the validator for the media aspect consisting of 18 statement items and 3 aspect components have an Aiken V index with an average of 0.909. this shows that the media aspect has high validity because the index value is> 0.8. Based on these results, it can be said that the media made is declared to be very valid. This is also supported by research (Krishna et al., 2015; Pratiwi & Wiarta, 2021), which shows that the assessment by learning media experts obtained a good percentage of 88.33%. The evaluation criteria include design, operation, accuracy, technology, and clarity. The use of appropriate learning media can impact the achievement of maximum learning objectives.

Material feasibility

The assessment results from the validator for the material aspect, which consists of 19 statement items and 4 aspect components of material accuracy, material presentation systematics, language, and suitability of evaluation tools, have an Aiken V index with an average of 0.835. this shows that the material aspect has high validity because the index value is> 0.8. Based on these results, it can be said that the material in the media made is declared very valid.

Feasibility of Evaluation Questions

Then, for the validation aspects of digital literacy involving 3 aspects, namely content, construction, and language, with an average Aiken Index value of 0.818 with a high category, and for validation of HOTS questions, which include aspects of material, construction, and language with an average Aiken Index value of 0.887 with a high category. The digital literacy and HOTS test items were empirically tested on 29 students and analyzed using ITEMAN 4.3 software, as seen in Tables 3 and 4. The results of validation and empirical tests showed that 10 questions from each ability measured were valid and reliable, so they were suitable for assessing digital literacy and HOTS.

Table 3. HOTS Problem Test Results

Questions	Differentiating Power		Difficulty Level		Reliability	
	(Rpbis)	Description	Prob (P)	Description	Alpha	Description
1	0,318	Moderate	0,333	Difficult	0,650	High
2	0,398	Moderate	0,267	Difficult		
3	0,408	Good	0,233	Difficult		
4	0,242	Quite Good	0,233	Difficult		
5	0,208	Quite Good	0,433	Moderate		
6	0,300	Moderate	0,400	Difficult		
7	0,337	Moderate	0,200	Very Difficult		
8	0,226	Quite Good	0,467	Moderate		
9	0,315	Moderate	0,300	Difficult		
10	0,333	Moderate	0,467	Moderate		

Table 4. Digital Literacy Question Test Results

Quest-ions	Differentiating Power		Difficulty Level		Reliability	
	(Rpbis)	Description	Prob (P)	Description	Alpha	Description
1	0,479	Good	0,448	Moderate	0,734	High
2	0,312	Moderate	0,276	Difficult		
3	0,314	Moderate	0,379	Difficult		
4	0,492	Good	0,345	Difficult		
5	0,483	Good	0,241	Difficult		
6	0,327	Moderate	0,517	Moderate		
7	0,250	Quite Good	0,448	Moderate		
8	0,518	Good	0,379	Difficult		
9	0,281	Quite Good	0,379	Difficult		
10	0,436	Good	0,310	Difficult		

3. **Product Practicality**

After the developed AR media has been validated and judged to be suitable for use, the next stage is testing. The limited-scale trial of AR learning media was conducted on two teachers and 10 students of class VIII SMP Yadika 12. The aspects assessed were media display, effectiveness, and usefulness of AR media. Based on the data from the teacher's practicality assessment of the learning media, it was obtained with a total score of 145 with a maximum total score of 160, so the percentage of practicality assessment obtained was 90.62%. Thus, it can be concluded that this learning media has a very high practicality. Based on the data from the student practicality assessment results, the learning media obtained with a total score of 729 with a maximum total score of 800, so the percentage of practicality assessment obtained is 91.12%. Thus, it can be concluded that this learning media has a very high practicality.

D. Implementation

The implementation stage was conducted after revisions from experts and feedback from teachers and students to demonstrate the utilization of AR media in an educational environment. The implementation stage was conducted at SMP PGRI 2 and SMP Yadika 12, involving two groups, X1 as the control group (70 students) and X2 as the experimental group (70 students), using a pretest-postest control group design.

The pretest was given to assess students' initial abilities before being given treatment. The control group used material from the textbook, while the experimental group used AR media for three sessions (9 JP in total). After the learning process, both groups were given a posttest to assess digital literaticy's and HOTS's final results.

1. Descriptive analysis

The product effectiveness test begins with a descriptive analysis of students' digital literacy and HOTS. The results showed that the experimental class using AR media had a higher value than the control class that did not use AR media. The descriptive statistical results of digital literacy and HOTS can be seen in Table 5.

Table 5. Descriptive Analysis Results of Digital Literacy and HOTS

Ability	Data description	Control class	Experimental class
Digital literacy	Average	49,84	61,42
	N-Gain	0,19	0,37
	Criteria	Low	Medium
HOTS	Average	34,33	47,38
	N-Gian	0,13	0,30
	Criteria	Low	Medium

Based on the research results on students' digital literacy skills in the control and experimental classes, the average scores were 49.84 and 61.42. N-gain value in the control class with a score of 0.19 in the low category and N-gain in the experimental class with a score of 0.37 in the medium category. Then, for students' HOTS in the control and experimental classes, the average scores were 34.33 and 47.38. The N-gain value in the control class was a score of 0.13 in the low category, and the N-gain in the experimental class was a score of 0.30 in the medium category. Table 4.3 shows that the AR developed significantly affects students' digital literacy and HOTS.

2. Prerequisite test

a. Multivariate Normality Test

Pretest Data

Based on Figure 6, the scatter plot tends to form a straight line, indicating that the data is normally distributed. Meanwhile, based on the table shows that the correlation coefficient is very high, namely 0.983. The significance value obtained is 0.000 <0.05, so it can be concluded that there is a significant correlation. So, it can be concluded that the data comes from a normally distributed population, so it can be said that the population fulfills the assumption of multivariate normality.

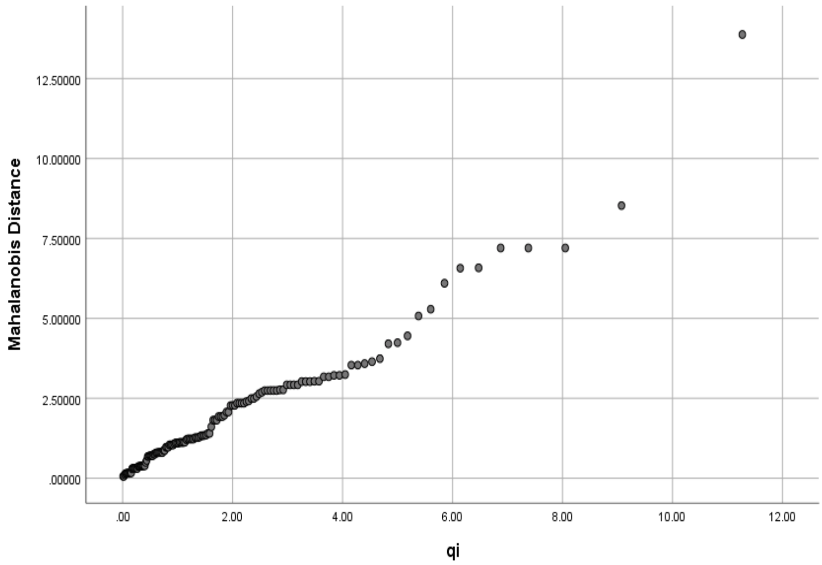

Figure 6. Scatter Diagram of Pretest

Posttest Data

Based on Table 5, the scatter plot tends to form a straight line, indicating that the data is normally distributed. Meanwhile, based on the table shows that the correlation coefficient is very high, namely 0.989. The significance value obtained is 0.000 <0.05, so it can be concluded that there is a significant correlation. So, it can be concluded that the data comes from a normally distributed population, so it can be said that the population fulfills the assumption of multivariate normality.

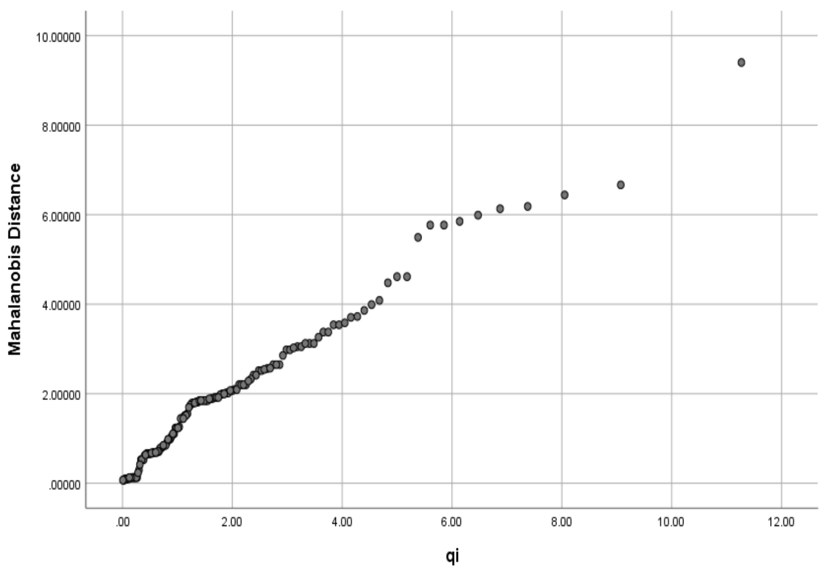

Figure 6. Scatter Diagram of Posttest

b. Variance Homogeneity Test

Pretest Data

Table 6 shows that the significance value for the covariance matrix homogeneity test is 0.219, where the value is greater than 0.05. So, it can be concluded that the covariance variance matrix is the same. Or it can be concluded that the covariance matrix of the experimental and control classes is homogeneous. Based on Table 7, it can be seen that the significance values for the Levenes test homogeneity test are 0.113 and 0.153, respectively, where the values are greater than 0.05. So, it can be concluded that the variance of digital literacy data in experimental and control classes is homogeneous, and the variance of HOTS data in experimental and control classes is homogeneous.

Table 6. Box's Test of Equality of Covariance Matrices For Pretest

Box's M	4.491
F	1.474
df1	3
df2	3427920.000
Sig.	.219

Table 7. Levene's Test of Equality of Error Variances For Pretest

		Levene Statistic	df1	df2	Sig.
Digital Literacy	Based on Mean	2.551	1	138	.113
HOTS	Based on Mean	2.070	1	138	.153

Post-test Data

Based on Table 8, it can be seen that the significance value for the covariance matrix homogeneity test is 0.519, which is greater than 0.05. So, it can be concluded that the covariance variance matrix is the same. Or it can be concluded that the covariance matrix of the experimental class and control class is homogeneous. Based on Table 9, it can be seen that the significance values for the Levenes test homogeneity test are 0.293 and 0.833, respectively, where the values are greater than 0.05. So, it can be concluded that the variance of digital literacy data in experimental and control classes is homogeneous, and the variance of HOTS data in experimental and control classes is homogeneous.

Table 8. Box's Test of Equality of Covariance Matrices for Post-Test

Box's M	2.300
F	.755
df1	3
df2	3427920.000
Sig.	.519

Table 9. Levene's Test of Equality of Error Variances for Post-Test

		Levene Statistic	df1	df2	Sig.
Digital Literacy	Based on Mean	1.113	1	138	.293
HOTS	Based on Mean	.045	1	138	.833

c. MANOVA Test

Based on Table 10, it can be seen that the significance value of Hotelling's Trace is 0.000, where the value is smaller than 0.05. So, it can be concluded that learning by using AR learning media affects students' digital literacy and HOTS. That is, there is a difference in the average digital literacy and HOTS of students in groups taught using AR learning media with groups of students taught without using AR learning media.

Table 10. Manova Test of Digital Literacy and HOTS

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Hotelling's Trace	17.017	1165.665[b]	2.000	137.000	.000	.944
Group	Hotelling's Trace	.410	28.102[b]	2.000	137.000	.000	.291

d. Effect Size Test

Table 11 shows that (1) The Partial Eta Squared value in the "Group" row with the digital literacy variable is 0.103, where the value is smaller than 0.14 and greater than 0.06. So, it can be concluded that learning using AR learning media has a moderate effect that tends to be large on digital literacy. (2) The Partial Eta Squared value in the "Group" row with the digital literacy variable is 0.234, where the value is greater than 0.14. So, it can be concluded that learning using AR learning media has a large effect on higher-order thinking.

Table 11. Effect Size Test of Digital Literacy and HOTS

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Group	Digital Literacy	4920.714	1	4920.714	15.802	.000	.103
	HOTS	8800.714	1	8800.714	42.126	.000	.234

e. Correlation Test

Based on Table 12, it can be seen that the 2-tailed significance value is 0.037, where the value is smaller than 0.05. So, it can be concluded that digital literacy has a significant relationship with higher-order thinking. The Pearson correlation value obtained is 0.177. This shows that the relationship between digital literacy and higher order thinking is a very weak relationship.

Table 12. Correlation test of digital literacy and HOTS

		Digital Literacy	HOTS
Digital Literacy	Pearson Correlation	1	.177*
	Sig. (2-tailed)		.037
	N	140	140
HOTS	Pearson Correlation	.177*	1
	Sig. (2-tailed)	.037	
	N	140	140
*. Correlation is significant at the 0.05 level (2-tailed).			

E. Evaluation

The evaluation stage is carried out after expert experts validate and trials have been conducted (Rini et al., 2021). By integrating AR into learning, educators can create a more dynamic and engaging learning experience that allows students to visualize and explore concepts in new and interesting ways (Savale, 2023). Based on the validation results of material and media experts, the human excretory system augmented reality application is feasible to use in learning. Furthermore, based on the trial results, the AR learning media developed received positive and very good responses from teachers and students, so it is very practical to use as a learning media. This is also supported by (Siahaan, 2023), which states that the results of these positive responses indicate that using this AR media in the learning process can increase effectiveness, especially in understanding abstract concepts, and simplify the student learning experience.

DISCUSSION

The experimental results clearly show that in terms of learning outcomes, the learning effect of students in the experimental group shows a significant difference compared with the control group, indicating that AR-based learning methods can effectively improve students' grades. This shows that students' satisfaction is generally high, and it can be concluded that AR is helpful in improving students' learning motivation and can effectively support teachers in classroom teaching (Tsai, 2021).

In this regard, AR learning is essential for both teachers and students as it presents digital content in an actual physical environment, creating an immersive learning experience. For teachers, AR enables more dynamic and engaging educational materials, making learning more interactive. Students can deepen their understanding by directly “seeing” and manipulating objects and concepts. In addition, AR can stimulate students' curiosity and motivate them to engage with learning content. Therefore, the use of AR in learning can improve the effectiveness and quality of learning. In addition, the use of AR in biology classes can display 3D visualizations, which help students understand abstract biological concepts more realistically, especially when studying human anatomy (Aripin, 2019).

Based on research from (Anggia, 2022) shows that the digital literacy of IT AlHikmah junior high school students, as measured by the utilization of mobile learning applications, is classified in the “high” category. This shows that the use of multimedia and information technology in schools has been carried out quite well. Then, the results of research (Fajari, 2022) obtained the average N-gain score for digital literacy in experimental learning is 63%, and it can be concluded that the use of AR in experimental learning effectively improves the digital literacy of elementary school students.

Furthermore (Sylvia, 2021) concluded that learning with the help of augmented reality can train students' higher-order thinking skills in teaching materials related to the sub-topic of the human sensory organs, namely the coordination system. This is reinforced by the increase in student learning outcomes as evidenced by the pre-test and post-test results showing good and very good categories after using augmented reality learning media.

After applying AR-based learning media in the experimental class, the average value of the post-test was 75.98, while the average value of the post-test in the control class without using Augmented Reality-based learning media was 63.56. The results of the Independent Sample T-Test test obtained a value of 0.00 with the provisions of the test decision. If the significance value is less than 0.05, then there is a significant significant difference between the posttest of the experimental class and the control class. The test results obtained a significance value of 0.000 <0.05, so it is synthesized that there is a significant difference between the experimental class and the application of AR-based learning media that increases the thinking skills of elementary school students. Elementary school students and N-Gain results get a value of 56.52, which is included in the category quite effective, so it is synthesized that the application of AR-based AR-based media improves the thinking skills of elementary school students thinking elementary school students, especially class V on IPAS material (Pamorti, 2024).

Research Advantages and Limitations

The AR-based learning media products developed have several advantages, among others, namely 1) The application used can easily be installed on students' smartphones that are connected to the internet so that students can easily access it; 2) The media can display the three-dimensional shape of the object so that students can visualize the image easily (Bwariat, 2024).

The limitations in this research and development are: 1) Researchers' knowledge is limited to developing AR media; 2) Device limitations only include Android types, and students experience technical difficulties related to device compatibility. As one of the main challenges in implementing AR in education, a potential solution is to standardize devices or develop applications that are more compatible with various types of devices (Akçayır & Akçayır, 2017).

CONCLUSION

Based on the AR media development research that has been carried out, the following results are obtained: The validation results on the media aspect consisting of 18 statement items and 3 aspect components have an Aiken V index with an average of 0.909. Then, the material aspect, which consists of 19 statement items and 4 aspect components of material accuracy, material presentation systematics, language, and suitability of evaluation tools, has an Aiken V index with an average of 0.835. This shows that the media and material aspects have high validity.

Furthermore, the aspects of digital literacy questions involve 3 aspects, namely content, construction, and language, with an average Aiken Index value of 0.818 with a high category, and for the validation of HOTS questions, which include aspects of material, construction, and language with an average Aiken Index value of 0.887 with a high category. The digital literacy and HOTS test items were empirically tested on 29 students and analyzed using ITEMAN 4.3 software, as seen in Tables 4.1 and 4.2. The results of the media implementation show that students' digital literacy skills in the control and experimental classes obtained an average score of 49.84 and 61.42. With N-gain in the control class with a score of 0.19 in the low category and N-gain in the experimental class with a score of 0.37 in the medium category. Then, for students' HOTS in the control and experimental classes, the average scores were 34.33 and 47.38. The N-gain value in the control class was a score of 0.13 in the low category, and the N-gain in the experimental class was a score of 0.30 in the medium category. Table 4.3 shows that the AR developed significantly affects students' digital literacy and HOTS.

The effectiveness test seen in Hotelling's Trace significance value is 0.000, where the value is smaller than 0.05. So, it can be concluded that learning using AR learning media has an effect on students' digital literacy and HOTS. That is, there is a difference in the average digital literacy and HOTS of students in groups taught using AR learning media with groups of students taught without using AR learning media. Based on several summaries of the research results, it shows that the AR media application developed has a very valid and practical value, so it can be concluded that AR media has met the feasibility and practicality values required for learning. The effectiveness value of AR media is based on the N-gain value and one-way Manova, which shows significant results in improving students' digital literacy and HOTS.

The recommendations that can be given are that it is important to develop AR materials on different science materials so that media development is not only limited to one scope of material but adds to the desire of other researchers to further refine previous AR research. This is in accordance with the recommendations of Wu et al. (2013) and Bacca et al. (2014) on the importance of developing AR content that is aligned with the curriculum and learning needs. Another recommendation is that more comprehensive AR content development is needed. Cheng & Tsai (2013) emphasize the importance of AR content design that is not only visually appealing but also supports meaningful learning.

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