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The Development of Augmented Reality-based Geometry Module (AR-Geo) to Improve Spatial Ability in Learning 3D Geometry Material in SMA Negeri 3 Medan

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ABSTRACT

This research aims to develop an augmented reality-based teaching material, namely the AR-Geo module on 3D Geometry material at SMA Negeri 3 Medan. These teaching materials are able to determine the level of validity, practicality, and effectiveness of the AR-Geo module and student responses to learning. This research method used research and development (R&D) through the ADDIE model. The subjects of the study involved students of class XII IPS 1 SMAN 3 Medan in the academic year 2023/2024 totaling 36 students. The research instruments employed AR-Geo module assessment sheets by media and material expert lecturers, mathematics teachers, peers, student ability tests and student response questionnaires, as well as student spatial ability tests. The results indicate that the material expert score is 91,53% and the design expert score is 90,53%, classified as very valid. The practicality of the module can be identified from the teacher response questionnaire score of 80,00% classified as practical, and the questionnaire score in the small group trial of 84,26%, field test 84,38% classified as very practical. The effectiveness is shown by 83,33% of students completing the learning outcomes test, and the results of the N-Gain calculation are 17 students experiencing an increase in medium spatial ability and 19 students experiencing an increase in high spatial ability. As a result, the development of augmented reality-based modules for 3D geometry material that has been developed is feasible to use.

Keywords: ***ADDIE model, Augmented Reality, 3D geometry, Module, Student's Spatial Ability.***

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1. INTRODUCTION

Math lesson, particularly geometry, is often considered as the difficult and boring lesson by most students. Math lessons are filled with formulas and calculations, making it a challenge for many students. However, geometry is more than a set of formulas. From a psychological point of view, geometry represents an abstraction derived from visual and spatial experiences, such as planes, patterns, measurements, and mapping. Meanwhile, from a mathematical point of view, geometry provides approaches to problem solving, such as drawings, diagrams, coordinate systems, vectors, and transformations. Geometry is also an environment for studying mathematical structures (Nopriana, Tri, 2013).

At the higher educational (SMA/MA) levels in the Merdeka Curriculum, the Geometry study field discusses various forms of flat and spatial shapes in both Euclides and Non-Euclides studies and their characteristics in flat geometry and space geometry subelements. Spatial geometry is the study of spatial objects, relations, and transformations that have been formed (made into mathematics) and systems of mathematical axioms that have been constructed to make them (Imamuddin, 2018).

Although the importance of geometry is recognized in the education curriculum, the reality shows that there are still numerous students and teachers who face difficulties in understanding and teaching geometry materials, especially spatial geometry. Spatial ability, which is key to understanding geometry, often shows low ability in students. Based on the observations by the researcher, the difficulty of learning geometry dimension 3 is in imagining the representation of flat/space shapes that represent the problems posed. As in the research conducted by (Budiarto, M. T., & Artiono, R, 2019), they mentioned that the characteristics of the form of student errors in solving a geometry problem include visual skills, verbal skills, and applied skills. Visual skills include insufficient understanding of geometric elements needed to describe geometric correlation and unsatisfactory perception of space. Errors related to verbal skills include misconceptions in understanding geometry concepts; weak ability to analyze problems; ambiguous use of terms such as rib and side; cube and square; quadrilateral and quadrilateral pyramid of disorderly use in conventions, such as notation for line, line segment, line ray, angle and angle magnitude; not understanding what is known and what will be proven from the given problem; unable to use what is known or use what will be proven as what is known; unable to relate one knowledge with other knowledge in geometry; and less resilient and easily discouraged if facing challenging geometry problems. Errors related to applied skills include: not being able to use axioms, definitions, theorems to solve proof problems; failing to learn the basic concepts of geometry; not understanding that two perpendicular lines intersect; not understanding that the plane can be expanded; not being able to make the intersection of a plane with a space due to low spatial vision; and not being able to use the acquisition of geometry in high school or flat geometry to solve space geometry problems.

In order to overcome these challenges in learning geometry in the classroom, teachers usually present real objects as props related to the material being studied. The props presented are not only based on real objects that can be seen, held, or touched, but can also be computer simulations that combine the sophistication of various information and communication technology devices. One technology that is currently starting to be considered at is augmented reality (AR). Hosch (2021) in Encyclopaedia Britannica states that augmented reality is the process of combining video or photo displays by overlaying images with related computer data. Meanwhile, Azuma (1997) also states that augmented reality (AR) is a form of virtual reality (VR) that allows users to see the real world through virtual objects that are combined with the real world.

In the context of math learning, AR offers an innovative way to present geometry concepts visually and interactively, increasing students' interest and understanding, as well as spatial abilities. As in various studies in the field of geometry, they mention that augmented reality can be a solution to make it easier for students to understand various complex spatial problems compared to traditional methods (Kaufmann, 2009).

Based on this explanation above, the researcher is interested in developing an interactive learning module that combines geometry with AR technology, called AR-Geo. Therefore, the researcher can develop new products of augmented reality in SMA Negeri 3 Medan as a result of the development of existing research based on geometry module (AR - Geo) to improve spatial abilities in 3-D geometry learning at SMA Negeri 3 Medan.

2. RESEARCH METHOD

This study used the Research and Development (R&D) using the ADDIE model development method (Analysis, Design, Development, Implementation, Evaluation), which aims to develop Learning Media in the form of augmented reality-based AR-Geo module with the help of smartphone devices and certain applications on 3D geometry material in class XII SMA Negeri 3 Medan. Products produced in the research in the form of learning media in the form of AR-Geo module based on augmented reality with the help of smartphone devices and certain applications on 3D geometry material in class XII SMA Negeri 3 Medan is to follow all the stages in the ADDIE model. The stages in the ADDIE model describe the feed back process at the research stage, which is shown in the following figure:

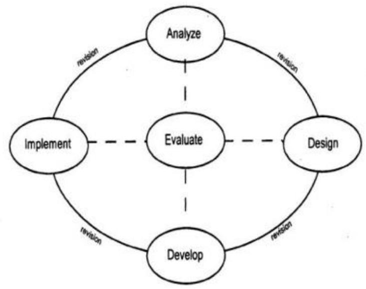

Fig 1: Stages of ADDIE Model Development

The analysis stage was carried out with two stages, namely problem analysis and material analysis. Problem analysis was carried out to find out the problems and obstacles occurred in the learning process by interviewing math teachers and initial tests regarding students' spatial abilities.

In the design stage, the researcher designed an augmented reality-based AR-Geo module developed by systematically detailing and compiling the principles of 3D geometry was implemented to be taught for the research subjects to improve maximum students' spatial abilities

The development stage of the AR-Geo teaching module development product testing process involved the implementation and concrete creation of all the elements that have been planned during the design stage.

At the Implementation stage, the researcher conducted classroom trials with the AR - Geo module, and learning to students in class XII IPS 1 SMA Negeri 3 Medan in the next small group according to the results of responses worthy of use. Furthermore, the researcher implemented the product in class XII students in a large group involving all students of class XII IPS 1 SMA Negeri 3 Medan.

Last, at the evaluation stage, assessment was carried out in two forms, namely formative evaluation in the form of feedback so that it is in accordance with the objectives of developing teaching modules.

Data collection techniques used observation sheets, interviews, questionnaires, evaluation test sheets. Testing was carried out based on testing the level of validity, practicality, and effectiveness of the AR-Geo module, and student responses to learning.

In order to calculate the percentage validity of the data obtained from the assessment item scores using the following formula:

$$Validity\ Level = \frac{Total\ of\ score\ obtained}{Total\ of\ maximum\ score}\, x\ 100\%$$

The validity results percentage obtained was then classified in percentages as described in Table 1 below.

Table 1. Product Validation Criteria

No.	Percentage (%)	Criteria
1	0 – 20	Invalid
2	21 – 40	Less Valid
3	41 – 60	Valid Enough
4	61 – 80	Valid
5	81 - 100	Very Valid

(Akbar, 2013)

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The data that has been obtained was then analyzed descriptively quantitatively to calculate the percentage of practicality, then it was described using data frequency analysis techniques using the formula:

$$Practicality\ Level\ (p) = \frac{Total\ of\ score\ obtained}{Total\ of\ maximum\ score}\ x\ 100\%$$

The results of the percentage of data obtained was classified in percentages as described in Table 2 as follows:

Table 2. Product Practicality Criteria

No.	Percentage (%)	Criteria
1	0 – 20	Not practical
2	21 – 40	Less Practical
3	41 – 60	Practical enough
4	61 – 80	Practical
5	81 - 100	Very Practical

(Akbar, 2013)

The difference between the *pre-test* and *post-test* was calculated to calculate the improvement of students' spatial abilities. The difference in the two tests is called Gain. The formula for calculating N - Gain is presented as follows:

$$N - Gain = \frac{posttest\ score - pretest\ score}{max\ score -\ pretest\ score}$$

Furthermore, the results of the N Gain calculation were percented using the criteria in Table 3.

Table 3. N-Gain Interpretation

N - Gain	**Criteria**
N – gain	High
0,3 N-gain < 0,7	Medium
N-gain < 0,3	Low

Table 4. aims to examine the effectiveness interpretation category based on the N-Gain value.

Table 4. Categories of Effectiveness Gain Interpretation

Persentase	Kriteria
< 40	Ineffective
40 – 55	Less effective
56 – 75	Effective enough
>76	Effective

3. RESULTS AND DISCUSSION

This research aims to develop an augmented reality-based teaching material called the AR-Geo module on 3D Geometry material at SMA Negeri 3 Medan to determine the level of validity, practicality, and effectiveness of the AR-Geo module, as well as the student responses to learning. The development process was carried out with the ADDIE model. The ADDIE development model consists of 5 (five) phases, namely analysis, design, development, implementation and evaluation.

At the stage of result analysis of interviews obtained, the students are more interested in using the media when learning space geometry because of the difficulties experienced by students when learning flat-sided space that is imagining and visualizing the shape of space geometry. The results of preliminary observations show that the spatial abilities of students on the material space geometry is low.

At the Design stage, the results obtained to improve students' spatial abilities are designed on each material that requires visualization of space geometry on the augmented reality markers. The use of augmented reality markers can bring up the real form if scanned using the space geometry application.

At the development stage, this augmented reality-based module was printed using HVS paper using a purple cover with a combination of pink and black. The researcher reproduced augmented reality-based modules to be used in the testing phase.

In the implementation stage, the first step taken by researcher was to validate research instruments, material validation, and design validation.

A. Instrument Validation

Table 5. Results of validation by instrument experts

No.	Instrument	Total Score obtained	Total Ideal Score	P %	Criteria
1	**2**	**3**	**4**	**5**	**6**
1	Material Validation Questionnaire	42	45	93,33%	Very Valid
2	Design Validation Questionnaire	43	45	95,56%	Very Valid
3	Practicality Questionnaire (teacher)	41	45	91,11%	Very Valid
4	Practicality Questionnaire (students)	39	45	86,67%	Very Valid
5	Individual and Small Group Trial Observation Sheet Questionnaire	37	40	92,50%	Very Valid
6	Questionnaire Observation Sheet Teacher Activity	55	60	91,67%	Very Valid
7	Observation Sheet Questionnaire Student Activity	55	60	91,67%	Very Valid
8	Interview Guidelines Questionnaire, Individual Trial and Small Group Trial Small Group Trial	38	40	95,00%	Very Valid
9	Learning Outcome Test	45	50	90,00%	Very Valid
10	Special Ability Test	45	50	90,00%	Very Valid

Based on Table 5, the assessment results of all research instrument validations obtained a percentage of 87% with a "very valid" category.

B. Material Validation

The validation of augmented reality-based module material was reviewed from the aspects of content feasibility, language, and component feasibility aspects. The results of the validation of augmented reality-based module material by material expert validators used the Material Validation Questionnaire. The results of validation by material experts amounted to 91,43%. Thus, based on the

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criteria for the level of validation of material experts obtained Augmented Reality-based modules are on very valid criteria.

C. Design Validation

The results of the validation of augmented reality-based module design by the design expert validators used the design validation questionnaire. Meanwhile, the results of validation by the design experts amounted to 90,53%. Therefore, based on the criteria for the validation level of design experts, the Augmented Reality-based module is obtained in very valid criteria.

The second step was carried out field trial activities, the researcher conducted research to see the practicality and effectiveness of the augmented reality-based module designed during the learning process, namely four meetings where in one week two meetings were held. The results of the field trial obtained the following results.

Table 6. Observation Results of Teacher and Student Activities

Activities	Observation Results		
	Meeting 2	Meeting 3	Meeting 4
Teacher	88,54 %	89,58 %	89, 29 %
Students	75 %	79,19 %	79, 29 %

Based on the results of the student response questionnaire, the practicality level of the augmented reality-based module is 84,38% with a very practical category.

At the Evaluation stage, the learning outcomes test consisted of 5 (five) items in the form of essays and a test of students' spatial abilities consisting of 10 (ten) items in the form of multiple choice questions accompanied by the reason students chose the option. The results obtained the percentage of completeness reached 83,33%, it can be concluded that the augmented reality-based module is included in the criteria very effective.

The following is the data from the normality test results on the pre-test and post-test.

Table 7. Normality Test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
pre-test	.161	24	.111	.901	24	.023
post-test	.223	24	.003	.914	24	.044

Table 8. Wilcoxon Test Rating Results pre-test and post-test

	N	Mean Rank	Sum of Ranks
Negative Ranks	0[a]	.00	.00
Positive Ranks	36[b]	12,50	300,00
Ties	0[c]		
Total	36		

Table 9. Wilcoxon Test Significance Results

	post-test - pre-test
Z	-4.294[b]
Asymp. Sig. (2-tailed)	.000

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Table 10. N-Gain Calculation Results

No.	Name	*PreTest*	*PostTest*	Post – Pre	NM – Pre	*N – Gain*	Criteria
1	AN	7	31	24	33	0,73	High
2	AP	4	28	24	36	0,67	Medium
3	AFR	6	29	23	34	0,68	Medium
4	AW	3	39	36	37	0,97	High
5	AZ	6	31	25	34	0,74	High
6	BA	11	31	20	29	0,69	Medium
7	CA	8	36	28	32	0,88	High
8	DA	2	36	34	38	0,89	High
9	FL	2	30	28	38	0,74	High
10	FG	15	31	16	25	0,64	Medium
11	J	6	34	28	34	0,82	High
12	KAN	3	36	33	37	0,89	High
13	MAA	5	29	24	35	0,69	Medium
14	MRS	5	28	23	35	0,66	Medium
15	MA	7	34	27	33	0,82	High
16	MFAA	7	30	23	33	0,70	High
17	NRS	3	28	25	37	0,68	Medium
18	NZE	3	30	27	37	0,73	High
19	NFS	11	29	18	29	0,62	Medium
20	NZ	7	34	27	33	0,82	High
21	PNL	4	28	24	36	0,67	Medium
22	RAS	5	26	21	35	0,60	Medium
23	RK	8	31	23	32	0,72	High
24	RFTS	5	28	23	35	0,66	Medium
25	RMS	2	36	34	38	0,89	High
26	RSS	5	29	24	35	0,69	Medium
27	SS	7	28	21	33	0,64	High
28	SP	2	34	32	38	0,84	Medium
29	SD	25	39	14	15	0,93	Medium
30	SHA	2	28	26	38	0,68	High
31	SJH	6	30	24	34	0,71	High
32	SS	11	36	25	29	0,86	High
33	TPS	8	34	26	32	0,81	High
34	TAF	2	28	26	38	0,68	High
35	VFS	3	28	25	37	0,68	Medium
36	YVL	7	29	22	33	0,67	Medium
Average						0,74	High

Percentage	75%	Effective Enough

As for the category of the effectiveness interpretation of gain is based on the percentage obtained N-Gain of 75%, with the interpretation category is quite effective. Thus, based on the analysis of N-Gain data, the augmented reality-based module on space geometry material is effective for use in learning.

Based on the above data, it can be known about the validity, practicality, and effectiveness of the augmented reality-based module. The module is stated to be effective if students succeed in the learning process and there is consistency between the learning experience and the achievement of learning outcomes. As a result, it can be concluded that the augmented reality-based module for space geometry material is effectively to be used in learning activities and can be known that augmented reality-based modules have met the criteria of good teaching materials.

4. CONCLUSION

Based on the results of the research described above, it is concluded that the development of learning media, specifically in the form of augmented reality-based AR-Geo modules using smartphone devices and certain applications on 3D geometry material in class XII SMA Negeri 3 Medan, has a significant influence on enhancing students' spatial abilities. This conclusion is supported by test evaluating the AR-Geo module's validity, practicality, and effectiveness as well as by the student responses to learning. Comparison made before and after using the augmented reality-based module indicates its influence on improving students' spatial skills. Therefore, Augmented Reality-based modules for space geometry materials are stated to be feasible and can be used to improve students' spatial abilities by fulfilling valid, practical, and effective criteria.

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