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Development of an E-Module Based on Geogebra Augmented Reality Technology for Learning Spatial Geometry

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Abstract: ***The main characteristic of 21st century learning is the use of technology as a learning tool, and e-modules are technology-based learning media. In learning so far, images/shapes of spatial shapes are only abstract or 2D. Integration of Augmented Reality technology with GeoGebra is a technique of combining real objects with virtual objects in two or three dimensions which are projected simultaneously into the real environment. This development research aims to produce an e-module based on Augmented Reality GeoGebra Geometry Material for Building Spaces that is valid, practical and effective. This research method is R&D with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). This research was conducted at Adventist Middle School 5 Kairagi Weru Class VIII, Even semester of the 2023/2024 academic year. The research instruments used were interviews, observations, questionnaires and learning outcomes tests. The data analysis technique used is descriptive statistics. Based on the research results, the validity test results of the GeoGebra Augmented Reality e-module material on geometric shapes are in the very valid category with a percentage of 90.83%. The results of the practicality assessment based on observation analysis data on the implementation of learning e-modules are in the very practical category with an average percentage of 93.17%, based on the analysis of teacher response questionnaires they are in the very practical category with a percentage of 89.29% and based on the analysis of student response questionnaires is in the very practical category with a percentage of 91.50%. The results of the effectiveness test are in the very effective category with a percentage of 85.71%. So it can be concluded that the Geogebra Augmented Reality E-Module Geometry Material for Building Spaces meets the criteria of Valid, Practical and Effective.***

Keywords: e-Module, Augmented Reality, GeoGebra, Geometry, Build Space

1. Preliminary

Learning in the 21st century refers to learning approaches and models that are adapted to the needs and demands of the times. One of the main characteristics of 21st century learning is technology as a learning tool. Technology is used to increase student engagement, provide access to abundant resources, and create more engaging and engaging learning experiences. The development of technology-based learning media continues to be an important trend in the world of education (Widianto, 2021). Technology has brought major changes in the way we learn and teach, and the use of this technology can provide a more interactive, interesting and effective learning experience for students (Nursyam, 2019). Nahdi et al. in Harry et al., (2023:68. The aim of developing learning media in the field of mathematics is to improve learning achievement. The learning media used in the field of mathematics apart from making understanding easier is being able to visualize abstract material. By taking advantage of current technological advances, electronic forms of learning modules can be found or often called e-modules. E-module is also a website-based IT learning module. In reality, students often experience learning difficulties which can certainly hinder the teaching and learning process. Barriers to learning geometry include (1) students have difficulty using geometric concepts (2) students have difficulty using geometric principles (3) students have difficulty using geometric principles to solve story problems. Students have difficulty imagining a block that has a hole inside. Geometry learning for middle school students requires specific visualization of geometric objects so that students can fully understand geometric objects such as cubes and prisms. This is also supported by the theory put forward by Peaget (Izzaty, et al. 2008:34-35) that from a cognitive perspective, junior high school age children have limitations in understanding abstract statements or concepts. In reality, students' geometry learning outcomes are currently still low. OECD (2018) and Purnomo and Dafik (2015) in Rhilmanidar et.al. (2020:143) said that "Indonesian students are weak in geometry in terms of spatial and shape content. Rhilmanidar (2020) also found that student learning outcomes in flat-sided geometric material were still low. Students' low academic achievement is caused by their inability to imagine the shape of space or image a shape. Teachers realize that all of this can be overcome with the help of learning materials that can visualize geometric concepts. This is very possible because schools often have facilities in the field of information technology. Technologies that are very interesting to develop in the context of teaching geometry are GeoGebra and Augmented Reality (AR). GeoGebra is a mathematics software that combines geometry, algebra and calculus tools. Untari et.al.; Muwahiddah et al. in Herman (2023:6033) said that "currently in GeoGebra there is also a new feature called AR. Utilizing GeoGebra and AR can improve the quality of mathematics learning by providing

a more interesting interactive experience and helping students gain a deeper understanding of mathematical concepts. GeoGebra was created to help students better understand mathematics, students can easily manipulate variables, including by simply dragging objects freely, objects in the drawing area or by using a pointer students can create these objects. According to Mursyidah, Guntur (Herman et al.: 2023), AR is a technology that combines two-dimensional and three-dimensional virtual objects into a three-dimensional real environment and then projects these virtual objects into the real world so that humans can interact with computers. more naturally. Therefore, from the explanation above it can be seen that combining teaching materials with learning media based on computer/electronic technology is expected to make the learning process interesting and stimulating and more enjoyable for students. Teaching materials that adapt to technological developments enable learning to be more effective and productive because they bring joy to students. Electronic module books and the use of Augmented Reality GeoGebra can help students solve three-dimensional geometry problems involving abstract objects.

Based on the background of the problem above, the problem identification obtained is as follows: (1) Lack of understanding of mathematical concepts in spatial geometry material in understanding abstract objects concretely. (2) Students need digital teaching materials and interesting technology-based learning media so that the learning process is not monotonous and can help students understand the concept of spatial geometry. (3) Students' geometry learning outcomes are still low. In its development, learning media has been grouped into four groups, namely: (1) Media resulting from print technology, (2) Media resulting from audio-visual technology, (3) Media resulting from computer-based technology, (4) Media resulting from a combination of print technology and computer technology. Taking advantage of current technological advances, electronic forms of learning modules can be found or often called e-modules. E-module is also a website-based IT learning module. Other advantages of e-modules are (1) students can carry out learning activities independently and e-modules can be widely accessed on various devices. (2) Learning is presented in stages with supporting elements such as images, video, sound and animation. (3) Attractive images. However, electronic learning still has several disadvantages, namely (1) Students need to have a sense of independent learning. (2) Appropriate devices and internet connection are required to access the electronic modules. According to Laila et al., learning in electronic modules is "learning using modules which are implemented using electronic media (Fazrina et al.: 2022). The characteristic of e-modules is that they can provide easy-to-understand explanations of subjects, e-module learning tools allow students to practice learning activities. In the module creation process there are several preparation steps which are packaged systematically, as follows: Needs analysis, module preparation, validation, trial, revision. Augmented Reality is a technology that combines two-dimensional and three-dimensional virtual objects into a three-dimensional real environment and then projects these virtual objects into the real world so that humans can interact with computers more naturally (Berryman, 2012). There are three principles of Augmented Reality, namely first, AR is a combination of the real world and the virtual world. Second, AR runs interactively in real time and third, there is integration between virtual objects and the real world (Andriyani & Buliali, 2021). Augmented Reality is an application that combines the real world with the virtual world in two-dimensional or three-dimensional form which is projected in a real environment at the same time. AR is a technology that combines two-dimensional or three-dimensional virtual objects into a real three-dimensional environment and then projects these virtual objects in real time. GeoGebra is an abbreviation of the words Geometry and Algebra, which is mathematical software specifically for geometry and algebra problems. GeoGebra was created in 2001 by Markus Hohenwarter while completing his thesis on a master's program at the University of Salzburg, Austria. Osman, Hatice (2020:3). GeoGebra is free and open source mathematics, easy-to-use software that combines geometry, algebra, and calculus features. GeoGebra is a dynamic geometry software that supports construction with points, lines and all conic sections. GeoGebra also encourages student projects in mathematics, various presentations and experimental and guided discovery learning. GeoGebra can be used for teaching and learning mathematics from elementary school level through college to university level. GeoGebra has various features including: points, lines, curved curves, intersection of two lines, perpendicular lines, creating planes and many more. Some of the benefits of the Geogebra program in learning mathematics are as follows: (1) Can produce geometric drawings quickly and accurately, even complex ones. (2) There are animation facilities and manipulation movements that can provide a visual experience in understanding geometric concepts. (3) Can be used as feedback/evaluation material to ensure that the geometric painting that has been created is correct. (4) Makes it easier to investigate or show the properties that apply to a geometric object. Three-dimensional geometry is a part of geometry that discusses spatial shapes or three-dimensional shapes (Iswadji, 2001). This research was conducted to develop learning media with Augmented Reality GeoGebra technology that students can use and utilize to improve their understanding of geometric concepts of geometric shapes. The results of this development research are in the form of electronic modules or e-modules. It is hoped that the use of e-modules in learning can simplify and increase students' understanding of geometric shapes.

2. Research Procedure

This type of research is development research (Research and Development), carrying out research and product trials carried out at SMP Advent 05 Manado on class VIII students. The development research procedures that will be used in this research are in accordance with the ADDIE R&D model.

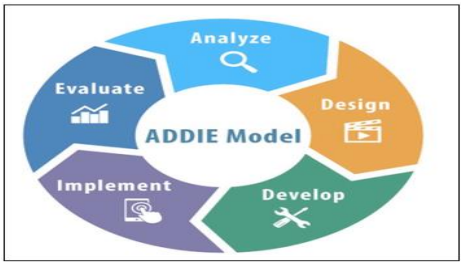

Figure 3.1 Research Phase of the ADDIE Development Model

The ADDIE development model has 5 development stages, namely: analysis stage, initial product design stage, product development stage, product implementation stage, and product evaluation stage. To collect data for the e-module trial, research instruments were used including interviews, e-module validation sheets, learning implementation observation validation sheets, teacher response questionnaire validation sheets, student response questionnaire sheets, and learning outcomes tests. After the data is collected and presented, data analysis is then carried out, the results of which will be used to revise the e-module being developed to produce a good e-module according to the specified criteria. The analysis carried out includes analysis of expert validation data, data analysis of teacher skills in implementing learning, analysis of teacher responses, analysis of student responses, and analysis of learning outcomes test data. An e-Module is said to be good if it meets the criteria, namely valid based on expert validation. Teachers are able to implement the learning that has been developed, students respond positively to the learning e-module, and the learning outcomes test meets validity and reliability. The expert assessment data for each learning support device was analyzed using descriptive statistical analysis techniques, then the expert validation results were analyzed by considering input, comments and suggestions from the validators. Next, each analysis is explained as follows: (1) Validity Data Analysis, (2) Practicality Data Analysis, (3) Effectiveness Data Analysis.

3. Results and Discussion

The product resulting from this development research is an e-module based on GeoGebra Augmented Reality technology, material on Space Building Geometry. The development of this e-module was developed based on the ADDIE Research and Development model method. The development stages of this e-module are as follows: (1) The Analysis Stage carried out by the researcher was an analysis of student needs. The results of the analysis of students' needs were obtained by researchers from interviews and observations of students' conditions when studying material in the classroom. The observations made were by giving questions related to the geometry of flat-sided geometric shapes. From the results of the students' answers, it was found that students still did not understand the concept of flat-sided geometric shapes, because there were difficulties in understanding abstract geometric shapes. The next needs analysis was obtained from the results of interviews with mathematics teachers. The conclusions obtained from the interviews were the different understanding abilities of students, limited teaching materials or mathematics learning media, the methods used were still in the form of lectures and questions and answers, where the teacher's role in learning activities was still very dominant. The teaching materials or learning media chosen by researchers are in the form of e-modules which are able to increase students' understanding, are able to visualize the material and support students' independent learning activities. The e-module provided contains Augmented reality GeoGebra visualization of Space Building Geometry material. (2) In the Design Stage, the researcher creates a conceptual design for the e-module product being developed, its supporting devices and research instruments. The conceptual design of the e-module at this design stage is as follows: (a) Opening section, consisting of cover, introduction. (b) Core part, consisting of learning activities, summary, evaluation. (c) Closing section, this closing section consists of answer key, conclusion, bibliography. (3) Development Stage Activities carried out by researchers at the e-module development stage are the validation process for validators. Validation carried out by researchers is used to measure the validity of e-modules, learning support tools and assessment instruments. The validation results at this stage are in the form of questionnaire scores and suggestions from the validators. The researcher asked for the willingness of 3 validators consisting of 1 Mathematics lecturer at Manado State University as an expert, namely Dr. Santje M. Salajang, M.Si, along with 2 practitioners, namely Drs. Hendro Pungus, M.Pd and Mandanne Wuryanto, S.M, S.Psi Mathematics teachers at Advent 05 Middle School Manado. Learning tools that have been validated will then be revised according to the comments and suggestions on the validation sheet. (4) Implementation Stage: In this implementation stage, after the teaching materials and research instruments have been validated by validators and have been revised, the e-module which has been validated by experts and declared valid will be tested. (a) Initial field trials. Initial field trials were carried out at different schools from the research subject trials. (b) Field trials, this stage will produce an effective e-module. The effectiveness of the e-module is obtained based on effectiveness testing. The instrument used is a test instrument. The quality of this test instrument is tested using validity and reliability tests. After each question item was declared valid and reliable and had been validated by experts, the question items were tested on research subjects, namely class VIII students, in the form of a test. At the first meeting with respondents in class, the researcher gave the e-module and instructions regarding its use to the respondent. Respondents were asked to access the e-module and study it in class. The use of e-modules in class was carried out for five meetings with a time allocation for each meeting of 40 minutes / lesson hour. In the next stage, respondents were asked to study the e-module independently at home. Researchers directed respondents to note down or mark things they did not understand when studying the e-module at home. At the next meeting, respondents continued studying independently in class. At the end of the meeting, the researcher gave the respondents learning result test questions. After the respondent completes the test questions, the test instrument sheet along with the respondent's answers is collected to the researcher. (5) Evaluation Stage At this evaluation stage the researcher evaluates the entire development stage. The needs analysis stage was obtained based on observation data from students and interviews with subject teachers. Based on needs analysis, the e-module was designed using Canva and realized. Next, the e-module is validated by expert validators to meet the valid category and is suitable for testing. The results of validation by experts are in the form of an assessment questionnaire and suggestions. Apart from that, student test results were obtained during the implementation stage. Validation with experts determines the validity of the e-module. The results of implementation for students show the effectiveness and practicality of the e-module. Thus, the overall conclusion is that the e-module with the title "E-Module Augmented Reality GeoGebra Geometry Bangun Ruang" is declared valid, effective and practical and suitable for use as a learning medium.

Validity Data Analysis: Validation of the RPP. Data from the overall validation results of the RPP are in the attachment. The following are the results of the validation of the RPP in brief, which can be seen in Table 4.2**.**

Table 4.2: RPP Validation Results

Indikator	Nilai Validasi	Kriteria
Rata-rata Keseluruhan	84,50%	Sangat Valid

E-Module Validation. The results of the validation assessment by the validator can be seen in Table 4.3.

Table 4.3: Recapitulation of E-Module Validation Results

No	Indikator	Nilai		
		V1	V2	V3
1	Tujuan	8	8	8
2	Isi Materi	7	8	8
3	Tampilan	8	7	7
4	Penyajian	7	7	7
5	Bentuk Fisik	7	6	6
Jumlah Skor		37	36	36
Total Skor Maksimal		40		
Persentase		92,5 %	90 %	90 %
Rata-rata		90,83 %		
Kriteria		Sangat Valid		

Validation of Learning Outcomes Test Questions, the validity of learning outcomes tests consists of construct validity and content validity followed by validity and reliability tests of question items. Construct validity and content validation use experts as validators who will assess each aspect of the Learning Outcomes Test in the validation sheet.

Table 4.4: Validation Results of Learning Outcome Tests

No	Aspek yang dinilai	Nilai keseluruhan
1	Isi	93,75
2	Bahasa	95,83
3	Petunjuk	84,38
Rata - rata		91,32%
Kriteria		Sangat Valid

Test Validity Analysis: Validity test is a test used to determine whether the question items are valid or not. Questions with valid results will be used as evaluation questions. Validity testing uses Bivariate Pearson correlation (Pearson Moment Product) with the help of Excel. With the criteria, a question item is declared valid if r count > r table, and the significance value (Sig) < 0.05.

Table 4.5: Question Validation Results

	Soal 1	Soal 2	Soal 3	Soal 4	Soal 5
Correlation	0.612	0.744	0.739	0.804	0.611
r tabel	0.497	0.497	0.497	0.497	0.497
Keputusan	**Valid**	**Valid**	**Valid**	**Valid**	**Valid**

Based on table 4.5, it can be seen that based on N = 14 trials with a significance level of 5%, the r table is 0.497, so the question item is said to be valid if the calculated r is > 0.4973 and the Sig value is < 0.05.

Test Reliability Analysis: Reliability tests are used to determine the level of consistency of answers. Test the reliability of the test instrument using Cronchbach's Alpha.

Table 4.6: Question Reliability Test Results

Varian	0.18	0.57	0.53	0.26	0.34
Jumlah Varian	1.88				
Varian Total	4.53				
Keputusan	0.73	**Reliabel**			

Based on Table 4.6, it can be seen that the reliability test shows that the Cronbach Alpha number is 0.73 > 0.60 with a reliable classification. This shows that the items used are said to be reliable. **Validation Results of Teacher Response Sheets**: Student response questionnaire sheets were used to analyze the effectiveness of the learning tools that researchers developed.

Table 4.7: Results of Teacher Response Questionnaire Validation

No	Aspek yang dinilai	Validator		
		1	2	3
1	Kejelasan tujuan	4	4	4
2	Bahasa yang digunakan sesuai EYD	4	3	4
3	Kalimat tidak mengandung makna ganda	4	4	3
4	Mengidentifikasi proses pembelajaran	3	3	4
5	Mengidentifikasi media yang digunakan	4	4	4
Jumlah Skor		19	18	19
Persentase		95%	90%	95%
Persentase Keseluruhan		93,33%		
Kriteria		Sangat Valid		

The total average percentage result of the Teacher Response Questionnaire Validation score was 93.33% with very valid criteria, so it can be concluded that the Student Response Questionnaire that the researcher has prepared is valid and can be used without revision.

Validation of Student Response Questionnaire:

Table 4.8: Student Response Questionnaire Validation Results

No	Aspek yang dinilai	Validator		
		1	2	3
1	Kejelasan tujuan	4	4	4
2	Bahasa yang digunakan sesuai EYD	4	3	3
3	Kalimat tidak mengandung makna ganda	4	4	3
4	Mengidentifikasi proses pembelajaran	4	3	4
5	Mengidentifikasi media yang digunakan	4	4	4
Jumlah Skor		20	19	19
Persentase		100%	95%	95%
Persentase Keseluruhan		96,66%		
Kriteria		Sangat Valid		

The results of the total average percentage value of the Student Response Questionnaire Validation were 96.66% with very valid criteria, so it can be concluded that the Student Response Questionnaire that the researcher has prepared is valid and can be used without revision. Results of the Validation of the Learning Implementation Observation Sheet: The practicality of the learning tools can be measured by looking at the level of teacher ability in managing learning through observing the implementation of learning.

Table 4.9: Results of Validation of Learning Implementation Observation Sheet

No	Aspek yang dinilai	Validator		
		1	2	3
1	*E-Module* Siswa	18	18	18
2	Petunjuk Guru	19	18	17
Jumlah Skor		37	36	35
Presentase		92,5%	90%	87,5%
Presentase Keseluruhan		90%		
Kriteria		Sangat valid		

The average percentage result of the total score for the validation of the learning implementation observation sheet was 90% with a very valid predicate. So it can be concluded that the learning implementation observation sheet that the researcher has prepared is valid and can be used without revision.

Practicality Data Analysis:

Table 4.10: Learning Implementation Data

Pertemuan	Pertemuan 1	Pertemuan 2	Pertemuan 3	Pertemuan 4
Persentase (%)	92,5	92,5	82,5	82,5

Based on Table 4.10, the results of the practicality data analysis show that the learning e-module developed has met the practical criteria.

Analysis of Teacher Response Questionnaires:

Table 4.11: Data on the Practicality of Teacher Response Questionnaires

Persentase	Kriteria
89,29%	Sangat Praktis

Analysis of Student Response Questionnaires:

Table 4.12: Data on the Practicality of Student Response Questionnaires

No	Pernyataan	Peserta Didik									
		1	2	3	4	5	6	7	8	9	10
Aspek Tampilan *E-Module*											
1.	Gambar ilustrasi yang digunakan pada *e-module* menarik	4	4	3	4	4	3	4	3	3	4
2	Warna yang digunakan pada *e-module* sesuai dan menarik	4	3	4	4	3	2	3	4	3	3
3	Jenis dan ukuran huruf yang digunakan pada *e-module* jelas dan mudah dibaca	3	4	3	4	2	4	4	4	3	2
Aspek Isi *E-Module*											
4	Uraian materi yang disajikan pada *e-module* sangat jelas	3	4	4	4	3	4	4	4	3	4
5	Contoh soal yang diberikan sesuai dengan materi pada pembahasan	4	3	4	3	4	4	4	3	4	4
6	Penggunaan kalimat pada *e-module* komunikatif dan mudah dipahami	4	3	3	4	4	4	4	4	3	4
7	Visualisasi yang ditampilkan pada *e-module* sesuai dengan materi	4	3	3	4	3	2	4	2	4	3
Aspek Penggunaan *E-Module*											
8	Pengguna dapat memahami materi Geometri Bangun Ruang Sisi Datar menggunakan *e-module* ini dengan lebih mudah	4	3	3	4	4	4	3	4	3	4
9	Pengguna merasa lebih mudah belajar menggunakan *e-module* ini	4	3	3	4	4	3	4	4	4	3
10	*E-module* mendorong pengguna untuk belajar secara mandiri	4	3	4	4	4	3	4	4	3	4
Jumlah		38	33	34	39	35	33	38	36	33	35
Persentase (%)		95	83	85	98	88	83	95	90	83	88
Rata-rata Persentase (%)		88,50									
Keterangan		**Sangat Baik**									

Based on the results of table 4.12 above, it shows that the average percentage assessment is 88.50%, with the highest percentage being 98% and the lowest percentage being 83%. The results of this assessment show that the e-module material on geometric shapes can be applied in learning because it is in a very practical qualification. **Effectiveness Data Analysis:** The effectiveness of the learning model developed is seen from the students' learning completeness. Based on the previous explanation, the e-module developed on spatial geometry material is said to be effective if individual completion reaches the KKM value and more than 80% of students obtain learning outcomes above the KKM. Learning completeness is measured by giving learning result test questions to students where the learning result test has been validated first by a validator.

Table 4.13: Learning Test Results

No	Subjek	Hasil Belajar Siswa
1	AM	84
2	AH	89
3	AK	89
4	CS	76
5	FK	77
6	FM	91
7	HS	89
8	JM	84
9	KM	89
10	LR	87
11	NS	96
12	PL	92
13	SM	73
14	VT	92
Skor Rata-rata		86
Skor Maksimum Ideal		100

From the data above, it was found that 2 out of 14 students got scores of 73 and 77, but these scores were already above the school's KKM, so it can be concluded that all students

were declared complete. This means that the e-module developed is effective to use.

4. Conclusions and Suggestions

Based on the results of the development and discussion, the following conclusions were obtained: (1) The electronic module or e-module Augmented Reality GeoGebra Geometry Building Spaces received an average final percentage score of 90.83% and was in the very valid category. This value was obtained based on expert/expert validation. From the results of the practical assessment of students, an average percentage of 88.50% was obtained and was in the very practical category. The results of the practical assessment of the teacher's response received a score of 89.29%. The results of the practicality of observing learning implementation obtained a score of 89.70%. Thus, the Augmented Reality e-module GeoGebra Geometry Builds Space has fulfilled the valid and practical category. (2) To determine the effectiveness of the e-module, a test instrument is given. From the final results, it was found that student learning outcomes increased after using the developed e-module. Based on descriptive data, an average score of 86% was obtained, which meets the standards above the school's KKM. Thus, the Augmented Realty GeoGebra Geometry Building Space e-module is declared effective.

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