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DEVELOPMENT OF PBL E-MODULES ON POLYHEDRON CONSTRUCTIONS FOR GEOMETRICAL THINKING ABILITY

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ABSTRACT

This research aimed to address the issue of low geometry proficiency among students and the lack of teaching materials and assess the validity and practicality of utilizing PBL e-modules as a teaching aid. The research employed the ADDIE model as a development method. To assess the e-module's validity, three media and three material experts were consulted. The material expert evaluation yielded a score of 3.60, while the media expert evaluation yielded a score of 3.29, indicating that the media and material of the e-module are valid for use as teaching materials. Furthermore, a small class trial involving ten students demonstrated a practicality score of 3.35, signifying highly practical results. The field test resulted in a score of 3.25, indicating that the PBL e-module is practical. The teacher's response yielded a score of 3.74, indicating that it is practical. Consequently, the PBL e-modules developed for the geometric material on polyhedron thinking skills are valid and practical, making them suitable as teaching materials in the learning process.

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INTRODUCTION

Technology is developing rapidly (Ningsih & Fuadiah, 2022; Pramana et al., 2020). It has become essential in various domains, including communication, information dissemination, trade, agriculture, health, and education (Setiabudi et al., 2022). The evolution of technology has significantly impacted the education sector in this era of revolution (Elvarita et al., 2020; Pramana et al., 2020; Setiabudi et al., 2022) as an effort to improve quality (Pramana et al., 2020) and students' understanding. As a result, it is imperative to have competent and innovative educators who can create engaging and comprehensible learning experiences to improve the quality of education. Additionally, Hasanah (2020) emphasizes the importance of educators developing teaching materials that aid in students' understanding of mathematics. This is reinforced by Government Regulation Number 19 of 2005, which expects educators to develop teaching materials. Law number 14 of 2005 article 10, paragraph 1 also mentioned that educators must have several components, one of which is professional, where teachers are required to have the ability to develop teaching materials. With the development of teaching materials, there will be more innovation in learning, and problems in learning can also be resolved. One example of a problem during the Covid-19 pandemic was that all teaching and learning activities had to change from face-to-face to distance learning (Asyura & Dewi, 2020; Ramadanti et al., 2021; Setiabudi et al., 2022). The lack of preparation and the need for numerous adjustments have resulted in suboptimal learning outcomes (Ramadanti et al., 2021), creating difficulties on several fronts. For instance, the unavailability of online teaching materials has made the learning process less effective (Etanastia et al., 2022). Consequently, there is a need to develop teaching materials that enable students to learn independently, anywhere, and anytime. Leveraging technology, we can develop various teaching materials that allow students to study independently without requiring teacher supervision. One such example is e-modules.

E-modules are electronic learning media that can be run or opened via computers, gadgets, or other software devices (Elvarita et al., 2020) which contain procedures, material with text, images, or both (Herawati & Muhtadi, 2018) and are equipped with video, audio, and animation to make it easier to deepen the material (Feriyanti, 2019) with a systematic and interesting arrangement with reference to competence (Ramadanti et al., 2021). Developing e-modules can increase student learning motivation and positively impact students (Pramana et al., 2020). The characteristics of learning modules are as follows: (a) Self-instructional (Herawati & Muhtadi,

2018), (b) stand-alone, (c) user-friendly, (d) consistency, (e) self-contained, (f) adaptive ((the Ministry of National Education: 2017 in Feriyanti, 2019).

In order to create e-modules that promote student understanding, the use of effective learning models is essential. Some popular learning models include project-based learning (PJBL) (Chen & Yang, 2019; Guo et al., 2020; Rozal et al., 2021), inquiry-based learning (Tohir, 2020; Sugianto et al., 2020), contextual learning (Perwitasari et al., 2018; Etanastia et al., 2022), cooperative learning and problem-based learning (PBL) (Ningsih & Fuadiah, 2022). PBL is a student-centered learning model that emphasizes the active involvement of students in the learning process. Using real-life problems as the starting point for learning, students can develop critical thinking skills and acquire knowledge effectively (Ramadanti et al., 2021; Setiabudi et al., 2022). Research conducted by Arumsari & Sesanti (2021); Ramadanti et al. (2021); Ningsih & Fuadiah (2022) on the development of PBL e-modules has shown that they are valid, effective, and practical as teaching materials. Therefore, PBL is a suitable and effective learning model that can support the development of practical, valid, and effective e-modules.

The results of observations and interviews with teachers and students at the school studied showed that teachers still need other teaching materials because the teaching materials used were limited, mainly only using textbooks from the government and the internet. In addition, it is also known that students' geometric thinking skills were low. The low ability of students' geometric thinking was obtained based on the VHGT test, showing that 41% were at the previsualization level, 53% at the visualization level, and 6% at the analysis level. In fact, in general, junior high school students' geometric thinking skills are at the level of informal deduction. Previous research (Naufal, 2021; Pujawan, 2020; Yuliana & Ratu, 2019) also showed that the geometric ability of students in Indonesia is lacking. It is not only in Indonesia but also in Turkey (Yılmaz & Koparan, 2015; Faruk Tutkun & Ozturk, 2013), the Czech Republic (Haviger & Vojkůvková, 2015), South Africa (Alex & Mammen, 2016), Ghana (Armah & Kissi, 2019) and Malaysia (Hassan et al., 2020).

The PBL model was chosen to develop e-modules because it is closely related to everyday life and promotes student engagement, facilitating learning. Moreover, students can learn independently, anytime and anywhere, without needing a teacher's presence. However, unlike previous studies, this research employed geometric material for polyhedrons, as geometric thinking skills among Indonesian students are still low. Therefore, this study aims to

offer innovative learning solutions, assess the practicality and validity of the developed PBL e-module on polyhedrons, and determine its effect on students' geometric thinking abilities. This research is novel, as no previous studies have developed e-modules utilizing a problem-based learning model for polyhedrons.

METHOD

The method used in this research is Research and Development, which is a product development method. In this study, the product to be produced is a PBL e-module on polyhedrons. The subject of this research was Year 9 students from one of the junior high schools in Purbalingga, Indonesia. This research and development use the ADDIE development model, which has five stages. (1) Analysis, at this stage, the researcher makes initial observations and analyzes the curriculum, materials, characteristics of students, and the problems faced in learning. (2) Design, this stage is carried out by designing materials, learning plans, and e-module prototypes. (3) Development, the development stage is carried out by conducting product validation to material experts about content feasibility, presentation feasibility, language, and learning models. The validation to media experts regarding aspects of graphic feasibility includes e-module size components, e-module cover designs, and e-module content designs, as well as conducting small class trials to find out e-modules that are acceptable and easily understood by students. (4) Implementation, carried out by conducting field tests to determine the feasibility and practicality of the e-module by giving questionnaires to students regarding aspects of appearance, material presentation, benefits, and PBL learning models, as well as teacher response questionnaires covering aspects of the feasibility of media presentation, material feasibility, readability, and PBL models. (5) Evaluation can be done by looking at the evaluation results by the validator, teacher, and students on the e-module (Hasanah, 2020). The feasibility of the e-module is reviewed in terms of validity and practicality. The validity of the e-module can be seen from the validation results of material experts and media experts with the following criteria in Table 1.

Table 1. Expert Validation Criteria

Quality score	Eligibility Criteria	Information
$3.26 < x \leq 4.00$	Valid	No revision required
$2.51 < x \leq 3.25$	Valid Enough	Minor Revision
$1.76 < x \leq 2.50$	Invalid	Minor revision and retesting of the material
$1.00 < x \leq 1.75$	Invalid	Major Revision

(Etanastia et al., 2022)

Meanwhile, to find out the practicality of the e-module, it can be seen from the results of the student and teacher response questionnaire calculations with the following criteria in Table 2.

Table 2. Practicality Test Criteria

Quality score	Eligibility Criteria
$3.26 < x \leq 4.00$	Highly Practical
$2.51 < x \leq 3.25$	Practical
$1.76 < x \leq 2.50$	Poorly Practical
$1.00 < x \leq 1.75$	Not Practical

(Etanastia et al., 2022)

The instruments in this study were: (1) van Hiele geometry test questions to determine the level of students' geometric thinking skills, (2) validation sheets for material experts and media experts, and (3) response questionnaire sheets addressed to Year 9 students and math teachers in the school studied.

The data analysis technique used in this study was qualitative analysis in the form of input, suggestions, and criticisms given by validators, teachers, and students, while quantitative analysis was in the form of data from questionnaires calculated by material experts, media experts, teacher responses, and student responses. These results are used by researchers to improve e-module products.

RESULTS AND DISCUSSION

The PBL e-Module on geometric material on polyhedron was developed using the Research and Development method, which aims to create a product in the form of an e-module with the ADDIE research model. In the ADDIE research model, there are five research stages, namely *analysis, design, development, implementation,* and *evaluation* (Arumsari & Sesanti, 2021; Ramadanti et al., 2021; Etanastia et al., 2022).

Before conducting the research, the researchers conducted preliminary observations and interviewed teachers and students at SMP N 1 Karangmoncol. After completing the observations and interviews, the researcher gave the van Hiele geometry test to class 9G students at SMP N 1 Karangmoncol for further analysis. The van Hiele geometry test results showed that students' geometric thinking skills were low. It is proven from the test results that 13 students are at the previsualization level, 17 are at the visual level, two are at the analysis level, and no students are at the level of informal deduction, deduction, or rigor. At this analysis stage, the researcher

analyzed the needs of schools, students, and teachers regarding the problems found. The analysis carried out includes the curriculum, syllabus, materials, media, and other supporting needs (Arumsari & Sesanti, 2021; Harahap et al., 2022).

The next stage is the design stage, where the researchers begin to design the e-module design according to needs, including material, curriculum, and PBL e-module design. At this stage, the researchers designed a rough design (Hasanah, 2020) on Word and then implemented the design on Canva. After the design on Canva is complete, the design is then exported in pdf and inserted into the corporate pdf flip. In addition to the graphic and written designs, the e-module is also equipped with an explanatory video regarding the material in the e-module. At the design stage, the e-module is also adapted to the PBL learning model and van Hiele's theory. This is done by compiling e-module material with the PBL model in it and adapting it to Van Hiele's theory and characteristics. In addition, the questions given to students are also in accordance with Van Hiele's theory.

At the development stage, making e-modules uses Flip pdf corporate. Then validation was carried out (Etanastia et al., 2022; Harahap et al., 2022) on three material experts consisting of 2 teachers and one lecturer, as well as three media experts. From the validation results, it was obtained a value of 3.60 for the material expert and 3.29 for the media expert, so from the two assessments, the result was that the PBL E-Module on geometry material on polyhedron is valid for use in learning. Table 3 presents the results of the assessment of material experts and media experts on PBL E-Module for polyhedrons.

Table 3. Results of Material Expert Assessment

Aspect	Validators			Average	Criteria
	1	**2**	**3**		
Content Eligibility	3.86	3.71	3.57	3.71	Valid
Eligibility of Presentation	3.67	4.00	3.00	3.56	Valid
language	4.00	3.67	3.00	3.56	Valid
Learning model	4.00	3.00	3.00	3.33	Valid
Final score	3.87	3.67	3,27	3.60	Valid

Based on the results of the material expert's assessment, the final score was 3.60, where 3.60 was between $3.26 < X \leq 4.00$, which means the material in the E-Module is valid.

Table 4. Results of Media Expert Assessment

Aspect	Validators			Average	Criteria
	1	2	3		
E-Module size	3.5	3	4	3.5	Valid
E-Module cover design	3.2	3	3.8	3.33	Valid
E-Module content design	3.13	3.63	2.88	3.21	Valid Enough
Final score	3.25	3.25	3.38	3.29	Valid

The media expert's assessment obtained a final result of 3.29, which is between $3.26 < X \leq 4.00$, meaning that the PBL E-Module media is valid. From the results of the assessment of material experts and media experts, it is known that the PBL E-Module for polyhedrons is valid so that it can be used during learning. At the development stage, small class trials were also carried out to determine the feasibility of the e-module before conducting field trials. Learning activities include an introduction, core, and closing using the PBL E-Module for polyhedron on the ability to think geometrically as teaching materials. Furthermore, students were given a response questionnaire to determine the level of practicality and all aspects of the e-module, starting from the appearance, presentation of material, benefits, and use of the PBL E-Module. The final result obtained by the average student response is 3.35, so it can be categorized as "highly practical" according to the practicality criteria. Table 5 presents the results of students' responses in small class trials.

Table 5. Student response results in small group tests

Aspect	Average	Criteria
Appearance	3.34	Highly Practical
Presentation of material	3.5	Highly Practical
Benefit	3.25	Practical
PBL learning models	3.12	Practical
Final score	3.3	Highly Practical

In the implementation phase, field tests were carried out on 33 students at the school studied. Learning in the field test was conducted face-to-face, starting from the preliminary, core, and closing activities. A student response questionnaire were administered to students to find out the practicality of the module, with an average result of 3.25, so that it could be categorized as "practical" according to the practicality criteria. Table 6 presents the result of calculating the field test student responses.

Table 6. Field test student response results

Aspect	Average	Criteria
Appearance	3.25	Practical
Presentation of material	3.32	Highly Practical
Benefit	3.21	Practical
PBL learning models	3.20	Practical
Final score	3.25	Practical

In addition to student responses, teachers were given a questionnaire to find out the level of practicality of the E-Module. The recapitulation of the teacher's response is presented in Table 7.

Table 7. Teacher response results

Aspect	Average	Criteria
Eligibility of Media Presentation	3.75	Highly Practical
Material Eligibility	3.95	Highly Practical
Legibility	3.75	Highly Practical
PBL learning models	3,5	Highly Practical
Final score	3.74	Highly Practical

Table 7 shows that from the teacher's assessment of the PBL e-module on polyhedron for geometric thinking skills, it is highly practical to use in learning. The final score of the teacher's response assessment is between $3.26 <$ and $3.74 \leq 4.00$, included in the highly practical criteria.

Finally, in the evaluation stage, the data was taken from criticism and suggestions received by researchers from the validation questionnaire of material experts, media experts, teacher responses, and student responses. To obtain a quality, valid and practical E-Module, it is necessary to improve and add to it according to the needs of suggestions and criticism from validators, students, and teachers (Pramana et al., 2020).

CONCLUSION

The present study aimed to develop an e-module using the PBL model for polyhedrons and evaluate its practicality and validity. The product of this research is a valid and practical e-module that can be used as teaching material in the learning process. The material expert validation resulted in a score of 3.60, and the media expert validation resulted in a score of 3.29, meeting the criteria for validity. Moreover, the student response questionnaire yielded a score of 3.25, while the teacher's response questionnaire yielded a score of 3.74, indicating that the PBL e-module is highly practical to use in learning.

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