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Open Problem Based Geometry Learning E-Module to Strengthen Creative Thinking Skills

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Abstrak

Salah satu ketrampilan yang perlu dikembangkan dalam revolusi industri 4.0 adalah berpikir kreatif. Kemampuan berpikir kreatif mahasiswa masih perlu dikembangkan. Tujuan penelitian ini adalah untuk menciptakan e-modul pembelajaran geometri berbasis masalah terbuka untuk penguatan kemampuan berpikir kreatif mahasiswa PGSD. Jenis penelitian ini adalah penelitian pengembangan dengan desain menggunakan tahapan Ploom. Subjek penelitian adalah mahasiswa PGSD. Subjek ujicoba kelompok kecil adalah 18 mahasiswa PGSD. Metode pengumpulan data berupa pemberian angket untuk mendapatkan data kuantitatif dan kualitatif, uji coba untuk melakukan pengujian kepraktisan e-modul yang dikembangkan, dan Focus Group Discussion *(FGD) untuk mengumpulkan pandangan dan masukan dari ahli materi dan media. Instrumen penelitian ini adalah angket dan uji kompetensi masalah terbuka. Hasil penelitian menunjukkan e-modul divalidasi oleh ahli media menunjukkan prosentase 87%. Sementara e-modul divalidasi oleh ahli materi menunjukkan prosentase 93%. Hasil analisis uji coba e-modul menunjukkan 55% mahasiswa memenuhi aspek orisinalitas, 28% mahasiswa memenuhi syarat kelancaran, 72% bersifat keluwesan, dan 83% bersifat elaborasi. Guru menganggap e-modul dapat membantu meningkatkan minat dan keterlibatan mahasiswa. Simpulan penelitian menunjukkan e-modul pembelajaran geometri berbasis pemecahan masalah terbuka yang dikembangkan memenuhi syarat kevalidan dan kepraktisan. Implikasi pengembangan e-modul pembelajaran geometri berbasis masalah terbuka terhadap pendidikan secara umum yaitu pedagogi, aksesibilitas, dan pengembangan profesional.*

Kata Kunci: *Berbasis Masalah Terbuka, Berpikir Kreatif, E-Modul Pembelajaran Geometri*

Abstract

Creative thinking is one of the skills that must be developed in the Industrial Revolution 4.0. Students' creative thinking skills still need to be developed. This study aims to create an e-module for learning geometry based on open problems to strengthen the creative thinking skills of PGSD students. This type of research is development research with a design using the Ploom stages. The subjects of the study were PGSD students. The subjects of the small group trial were 18 PGSD students. The data collection method was a questionnaire to obtain quantitative and qualitative data, a trial to test the practicality of the developed e-module, and a Focus Group Discussion (FGD) to collect views and input from material and media experts. The research instruments were a questionnaire and an open-problem competency test. The study results showed that the e-module was validated by media experts, with a percentage of 87%. Material experts validated the e-module, and it showed a rate of 93%. The results of the e-module trial analysis showed that 55% of students met the originality aspect, 28% met the fluency requirements, 72% were flexible, and 83% were elaborative. Teachers should consider e-modules to help increase student interest and engagement. The study's conclusion shows that the developed e-module for geometry learning based on open problem-solving meets the requirements of validity and practicality. The implications of creating an e-module for geometry learning based on open problems for education in general are pedagogy, accessibility, and professional development.

Keywords: Open Problem Based, Creative Thinking, Geometry Learning E-Module

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1. INTRODUCTION

The era of the industrial revolution 4.0 is marked by digitalization and automation (Munir, 2017; Siregar et al., 2020). The rapid development of technology and communication in this era has an impact on services to students. Facing challenges in the era of the industrial revolution 4.0, students also need to be prepared to have cognitive abilities and 4C skills (Critical Thinking and Problem Solving, Communication, Collaboration, Creating and Innovating) (Ramdhani et al., 2023; Sangsawang, 2020). One of the skills that need to be developed is creative thinking. Creative thinking skills are skills to think of something new and innovative (Nurdyani et al., 2018; Varlık et al., 2024). Classroom learning should encourage the development of creativity (Ferdiani et al., 2019). One type of problem that has the potential to develop students' creative thinking skills is open-ended problems (Thahir et al., 2021; Yuliastuti et al., 2019). This is because open-ended problems do not have a single answer or the ideas in determining the answer are also not single. Open-ended problems trigger students to creatively explore various ways or solutions to the problem. The Elementary School Teacher Education (PGSD) study program has five fields of science that must be taken by its students, one of which is mathematics. Mathematics teaches us to think logically, analytically, systematically, critically, and creatively (Hadar, 2017; Liu & Zhong, 2024). In mathematics, one of the compulsory courses is the Geometry Learning course. This course is very important for students who will later graduate to become teachers in elementary schools (SD) considering its content which contains concepts and how to teach geometry material in elementary schools. A good understanding of concepts by PGSD students will have implications for the instillation of geometry concepts later when they become teachers.

However, its application to geometry learning materials, the concepts presented are still in the form of memorizing area and volume formulas (Harris et al., 2023). Based on an initial study by providing open problems related to geometry material to PGSD students at Universitas PGRI Kanjuruhan Malang (Unikama) who are taking the Geometry Learning course. The students who became respondents in working on the open problems were 15 (fifteen) students. The open problems given to the respondents were "Given a rectangle with a length of 6 cm and a width of 4 cm. Make a square with a minimum area of 1 cm2so that it covers the rectangle. How many can you make?". Based on the answers given, there were 6 (six) students who gave one answer with the same pattern (with a side length of 1 cm), there were 7 (seven) students who gave two answers with the same pattern (the first pattern with a side length of 1 cm, and the second pattern with a side length of 2 cm, and only 2 (two) students gave answers with different patterns. This means that students' creative thinking skills still need to be developed. Students must be accustomed to technology in learning. Learning in this era requires educators to be able to master and utilize technology in the learning process (Demir, 2024; Fatmawati & Safitri, 2020). Students tend to prefer using electronic learning resources rather than printed learning resources, because they can display text, images, animations, and also interactive videos (Borokhovski et al., 2016; Denan et al., 2020).

The solution to overcome these problems is to use modules. Modules are a form of independent teaching materials that are packaged systematically and contextually (Imansari & Sunaryantiningsih, 2017; Sukarman et al., 2021). Modules contain a set of planned learning experiences and are design to help students master specific learning objectives. E modules are electronic modules with use of technology This e-module is one of the teaching materials that requires students' independence in understanding concepts (Istuningsih et al., 2018). The application of the module can condition learning activities to be more well-planned, independent, complete and with clear results (output (Melyastiti et al., 2023; Pramana et al., 2020; Serevin et al., 2018). There are textbooks used by lecturers in delivering geometry material, it's just that the presentation of the material in the textbook used by lecturers as a reference book has not provided students with the opportunity to find concepts independently, be it the concept of the

area of a flat shape or the concept of the volume of a solid shape. So far, lecturers have also rarely given open problem-solving assignments for the material studied in class, as a result, students are less challenged with their creative ideas in completing their assignments. Development of interactive e-modules based on Case (Creative, Active, Systematic, Effective) as an alternative learning media for transformation geometry to support student learning independence and competence (Wiratama & Margunyasa, 2021).

The findings related to the E-module state that the e-module based on the KPK and FPB material for grade IV Elementary School is feasible to use The e- module can improve students' critical thinking skills (Jannah, 2020). In contrast to the development of the e-module, the development of the e-module in this study emphasizes open problem solving as a reinforcement of students' creative thinking skills. In addition, the e-module is also equipped with animated videos (with the Geogebra application, Canva application, and video maker) in exploring concepts for the area and circumference of flat shapes as well as exploring the concept of surface area and volume of solid shapes. The provision of videos is intended to foster positive student responses so that they can stimulate thinking activities and strengthen understanding of material concepts. The development of e-modules with open problem solving in geometry learning is important. The purpose of this study is to create an e-module for learning geometry based on open problems that meet the validity and practicality to strengthen the creative thinking skills of PGSD students. Open problem-based development research has significant urgency in various fields, especially in education and technology. As science and technology continue to develop, research that focuses on open problems helps accelerate the accumulation of new knowledge.

2. METHOD

This type of research is development research with a design using Ploom stages. This research refers to the stages (Suastika & Wahyuningtyas, 2020). The stages are: 1. preliminary research,2. prototyping phase, and 3. assessment phase. At the stagepreliminary research, the researcher conducted an analysis related to the Learning Outcomes of Geometry Learning Courses (CPMK) in the PGSD Study Program, learning resources and ongoing learning conditions, and PGSD students' understanding of geometry material. Based on the results of the analysis at the stagepreliminary research, onprototyping phase The researcher designed an e-module for learning geometry, and research instruments, consisting of: e-module validation sheet, teacher response questionnaire, and presentation of material in the e-module based on open problem solving. Assessment phaseTwo activities were carried out, namely: validation of the e-module and conducting a trial of the e-module in real situations in the field. The trial was carried out on the e-module after being declared valid by the validator. The development procedure follows the flow in Figure 1.

The data collection method is in the form of providing a questionnaire to collect data from subjects regarding opinions and perceptions regarding the practicality of using e-modules in a systematic and structured manner, trials to ensure that the instruments used are effective, valid and relevant before being applied on a wider scale, and *Focus Group Discussion* (FGD) to collect views and input from material and media experts. The research instruments were questionnaires and open-ended problem competency tests. Validation was carried out to ensure that the product developed was in accordance with the research objectives. Validation consisted of material and media validation. The e-module trial aimed to see the practicality of the e-module. Trial steps. Field trials and recording of trial results, analysis of trial results, making decisions about trial results, revising the e-module based on trial results decisions. These four activities were carried out until a practical e-module was obtained. The subjects of the small group trial were 18 PGSD students at Universitas PGRI Kanjuruhan Malang. In this study, the

data analyzed were data on the validity and practicality of the e-module. Data analysis refers to (Argaswari, 2018). Validation and trial data were analyzed qualitatively. The analysis of validation data was intended so that the e-module met the validity requirements. Meanwhile, the analysis of trial data was classified according to the aspects of originality, fluency, flexibility, and elaboration. The e-module was validated using the E-module Validation Sheet. In this study, the e-module was validated by media experts and material experts. The components of the e-module validation sheet for media experts are shown in Table 1 and Table 2.

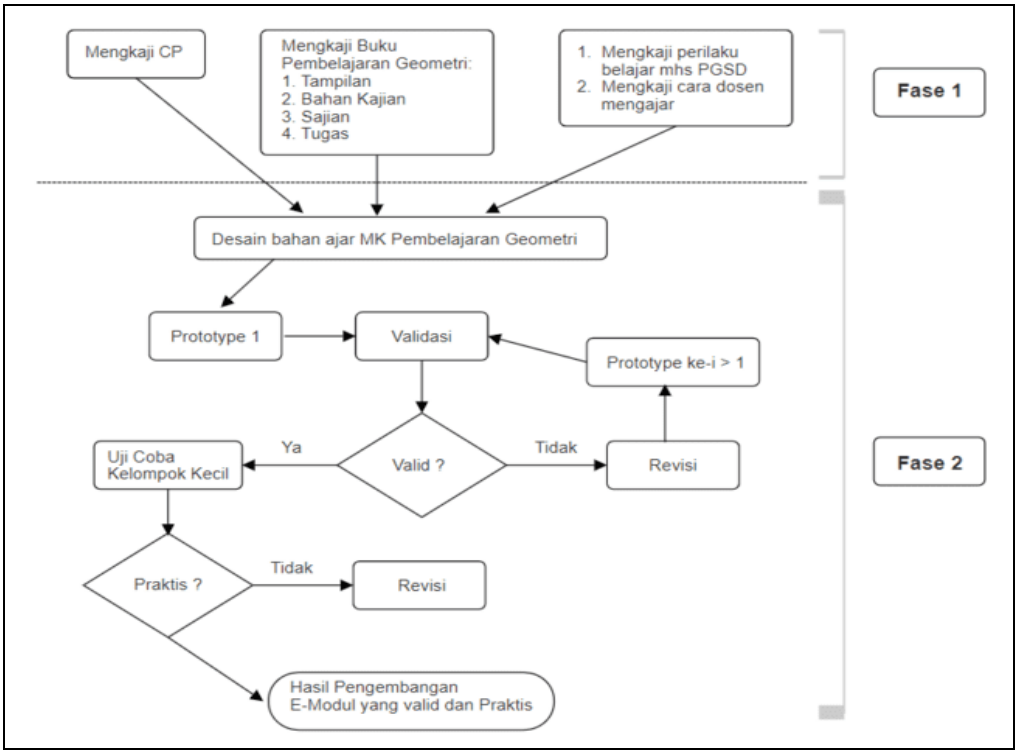

Figure 1. E-Module Development Flow

Table 1. The Components of the Media Expert E-module Validation Sheet

No	Components	Indicator
1	Language	Information, instructions, commands, questions and symbols are clear and easy to understand
		Communicative use of language
		Use of unambiguous terms (multiple meaning)
2	Engineering Product	Clarity of purpose
		Systematic presentation of material
		Giving motivation
		The presence of interactivity (stimulus and response)
3	Appearance	Use of fonts (type and size)
		Layout
		Illustrations, graphics, images, photos, according to the topic presented
		Attractive display design

(Ngangi et al., 2023)

Table 2. The Material Expert E-module Validation Sheet Components

No.	Components	Indicator
1	Content Eligibility	Suitability of material and achievement of Learning Outcomes (CP) for Geometry Learning and Final Competencies for the material on area and circumference of flat shapes and surface area and volume of solid shapes
		Suitability of material and achievement of material indicators
		Scope of presentation of material
		Presentation of questions that support the achievement of material indicators
2	Aspect Solution Problem open	Presentation of material in the form of open problem solving
		Providing students with the opportunity to find many different correct ways/methods for solving problems
		Problems in the form of open ended
		Giving students the opportunity to check their own answer
		Providing opportunities for students to interact with their friends

(Yuza et al., 2023)

The assessment is done by checking one of the options given on the validation sheet. In addition to providing an assessment, the researcher also gives the validator the opportunity to provide suggestions and comments. The validation sheet also provides a place for the validator to provide conclusions related to the e-module being developed. If the validation results do not meet the validity criteria, a revision is made. To collect data on the practicality of the e-module, a teacher response questionnaire was used. Before the questionnaire was given, the teacher response questionnaire was first validated by an expert. The validation components of the teacher response questionnaire are shown in Table 3.

Table 3. The Teacher Response Questionnaire Validation Components

No.	Components	Indicator
1	Instructions	Instructions for filling out the questionnaire are clearly stated.
2	Substance	Each statement in the "Teacher Response Questionnaire" is clear (does not have double meanings)
		The statements in the "Teacher Response Questionnaire" are not dependent on each other
		The statements in the "Teacher Response Questionnaire" have *cover* teacher responses for each aspect (learning management, geometry learning e-modules, and student learning experiences
3	Language	Use language according to correct Indonesian language
		The choice of words used is in accordance with scientific rules
		Using easy to understand sentences

(Nuranisa et al., 2024)

Practicality data was collected during a small group trial. Students were asked to study the e-module and complete a competency test. The competency test aims to measure the level of student mastery of the module. The competency test contains open-ended problems that are useful for measuring the level of students' creative thinking skills. The indicator of creative thinking skills uses the Moma (2015) creative thinking indicator which has been adapted.

3. RESULT AND DISCUSSION

Result

The designed e-module is one of the results of development with full dedication based on the Geometry Learning Outcomes (CPMK) in the Elementary School Teacher Education Study Program (PGSD) and the Graduate Learning Outcomes (CPL) of Class Teachers in the PGSD Study Program. The e-module contains 3 (three) main material concepts, namely: Understanding bases, axioms, definitions, and theorems; Perimeter and area of flat shapes; and Surface area and volume of solid shapes. The e-module can be accessed via the link: https://www.bisnismatpgsd.com/beranda . The website page contains: home menu, materials, open problems, competency tests, and the drafting team. The home page contains indicators for each material and instructions for using the e-module as shown in Figure 2. The material menu contains materials on plane and spatial shapes. Plane shape materials include: Squares and rectangles, Triangles and the Pythagorean theorem, Rhombuses and kites, Trapeziums and parallelograms, and Circles. Space shape materials consist of: Cubes and cuboids, Pyramids, Cylinders, Cones, and Spheres, shown in Figure 3.

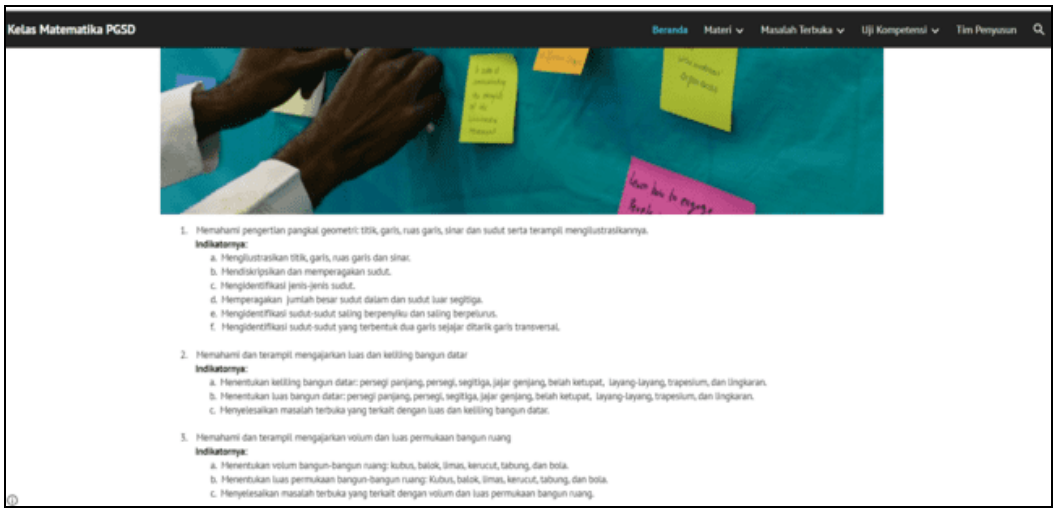

Figure 2. Description of Indicators for Each Material

Figure 3. Description of Planar and Spatial Building Materials

To strengthen students' understanding of the material, after the e-module description there are open-ended problem exercises that can be solved. The exercises are also a way to provide students with the opportunity to identify and correct misunderstandings. Students' mastery of the material is measured using competency tests 1 and 2 as in Figure 4.

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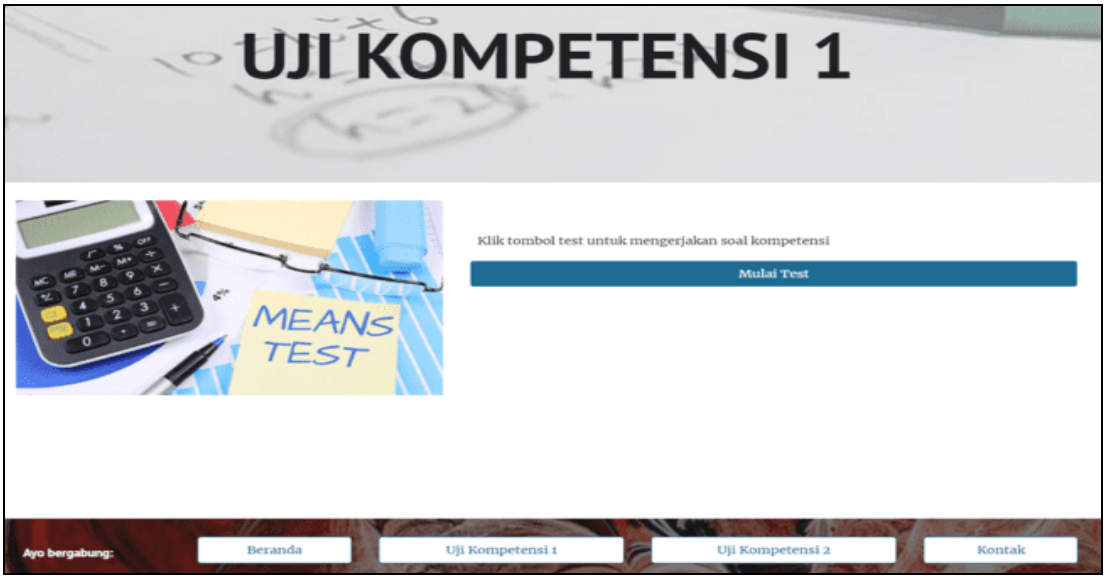

Figure 4. Competency Test 1 and Competency Test 2

Media expert validation of the e-module showed 87%. This means that the interface design is considered attractive and in accordance with the principles of learning design. The layout and navigation of the e-module are easy for students to understand and use. Interactive features such as videos, animations, and quizzes work well, are able to increase student engagement, and provide quick feedback to students. An attractive visual display can impact on student interest (Hartanti et al., 2020). The e-module is compatible with various devices (computers, tablets, and mobile phones) and no significant bugs or technical problems were found during testing. As for recommendations for improvement, the researcher added more interactive elements to further stimulate student interest and improved the quality of graphics and animations to be more visually appealing.

The validation of the material expert on the e-module showed 93%. The geometry material presented is in accordance with the applicable curriculum and learning standards. The delivery of concepts is clear and easy for students to understand. The practice questions are varied and challenging, but still in accordance with the level of student ability. The examples and illustrations in the e-module are relevant to everyday life and help understanding the concept. In addition, no conceptual errors or misleading information were found. Recommendations for improvement from the material expert, namely adding more examples of geometry applications in real life and expanding the variety of questions to cover more aspects of creative thinking skills. The trial was conducted on 18 students. After studying the e-module, students were asked to complete a competency test. The results of the analysis of the completion of the student competency test are shown in Figure 5.

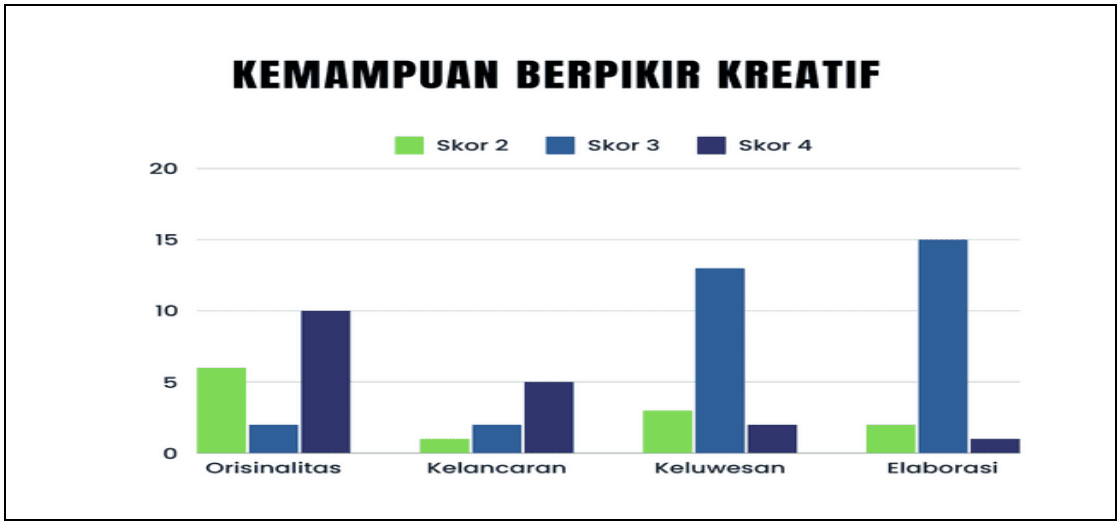

Figure 5. The level of students' creative thinking skills for E-module Competency Test

Based on the results of the e-module trial analysis, 55% of students met the originality aspect, 28% met the fluency requirements, 72% showed flexibility, and 83% were elaborative. Students were able to produce answers using their own methods, were able to provide more than one relevant idea, were able to solve correctly, and some of them were able to describe the answers systematically. By providing open- ended problems, students are given the opportunity to develop creative thinking, affection, and aesthetics in learning (Wilkie, 2024). The creativity of problem solving in students is influenced by the complexity of the questions and the open-ended nature of the questions (Wilkie, 2024). This means that simple and closed questions can cause student creativity to be low.

Discussion

The development of an e-module for geometry learning based on open problem solving aims to meet the demands of developing the competencies of PGSD students. Open problem solving uses a constructivist approach that combines cognitive and affective aspects simultaneously (Nurdianasari et al., 2023; Yu, 2024). This e-module is intended to prepare students to face the challenges of the 21st century by developing creative thinking, problem solving, and collaboration skills (Tang et al., 2020). These abilities are very important in an increasingly complex and dynamic world of work. This e-module is designed to stimulate divergent thinking, namely the ability of students to generate various ideas and creative solutions to given problems. Divergent thinking skills influence the formation of creative thinking (Norris et al., 2023). Through the use of open problems, students are encouraged to explore various approaches and perspectives, thereby increasing their creativity. Open-ended problem assignments allow students to develop multiple strategies and solutions, thus motivating students to explore different possible approaches and outcomes (Leikin & Elgrably, 2022; Sujanem & Putu Suwindra, 2023). Although creativity is often overlooked in higher education, the use of open-ended problems and supportive learning environments can enhance students' creativity and critical thinking (Fischer & Barabasch, 2023). In addition, students are trained in facing and solving complex problems that do not have a single solution. This helps students develop critical and creative thinking skills in unstructured situations

The e-module is also designed to guide students through a systematic problem-solving process. This includes problem identification, information gathering, solution exploration, and outcome evaluation. This systematic approach helps students to be more engaged in the learning process and develop higher- order thinking skills needed in problem solving (Cho & Kim, 2020;

Pratiwi & Hapsari, 2020). Structured learning with complex problem solving allows students to work more effectively in teams and produce better solutions (Brandl et al., 2024; Wardhani, 2022). Some activities in the e-module involve group work, which aims to improve students' communication and collaboration skills. Through discussion and teamwork, students can exchange ideas and gain different perspectives to enrich the problem-solving process. The e-module is designed to attract students' interest by presenting learning materials in an interactive and engaging form. Features such as learning videos, interactive quizzes, and problem-based activities are designed to make learning more fun and challenging. The use of interactive elements can make learning more interesting and challenging for students (Zhao et al., 2021). Learning that emphasizes student involvement through the presentation of material in a more dynamic and attractive package enables more effective learning and increases student interest (Baskara & Yudiana, 2023; Sujanem & Putu Suwindra, 2023).

E-modules utilize web-based digital technology to provide easy access to learning materials and activities. This is intended to facilitate self-paced learning, so that students can learn at their own pace and access resources anytime and anywhere. The use of web-based technology to support self-paced learning is an alternative strategy for students to access learning materials as needed (Chiou et al., 2010; Ebrahimi, 2023). The readiness and use of technology in e-learning are closely related to the effectiveness of self-paced learning (Meduri et al., 2022; Sharma et al., 2023). E-modules are equipped with evaluation tools that allow for continuous measurement of student progress Continuous monitoring of student progress helps improve student learning through more frequent and process-focused evaluations (Castillo-Manzano et al., 2023). Continuous evaluation is useful for regularly measuring student understanding and obtaining constructive feedback throughout the learning process (Fynn & Mashile, 2022). Through integrated quizzes, assignments, and feedback, students can monitor their progress independently and teachers can evaluate the effectiveness of learning. The evaluation system in the e-module is designed to provide constructive and useful feedback to students. Feedback is intended to help students improve their performance gradually (Yang et al., 2023). This helps students understand their strengths and areas for improvement in creative thinking and problem-solving skills.

Based on the validation results, this module is suitable for use in terms of interface design aspects, it is considered attractive and in accordance with the principles of learning design. An attractive visual appearance can have an impact on student interest (Hartanti et al., 2020). In addition, the geometry material presented is in accordance with the applicable curriculum and learning standards. The delivery of concepts is clear and easy for students to understand. Practice questions are varied and challenging, but still in accordance with the level of student ability. Examples and illustrations in the e-module are relevant to everyday life and help understanding concepts. By providing open-ended problems, students are given the opportunity to develop creative thinking, affection, and aesthetics in learning (Wilkie, 2024). Students' problem-solving creativity is influenced by the complexity of the questions and the open-ended nature of the questions (Abdullateef, 2024; Raz et al., 2024). The results of the analysis show that students have sufficient originality skills. Practical application and reflective evaluation greatly influence the uniqueness of the solutions produced (Li & Tu, 2024). Students also demonstrated good flexibility and elaboration skills. Flexibility in students is shown by the ability to see various possible solutions to open problems from different perspectives. Different perspectives are part of a person's talent (Runco & Alabbasi, 2024). In addition, students' high elaboration ability shows that students can analyze the context of the problem and create effective solutions, so that students are able to create creative narratives for solving open problems (Sierra et al., 2024). Even so, the aspect of fluency in students shows a low value. Students are very limited in generating creative ideas for solving open problems. This is because

the solution is done independently. Neurocognitive factors greatly influence creativity performance in a collaborative atmosphere than independent performance (Wu, 2024).

Teachers feel that e-modules help increase student interest and engagement in geometry learning. The use of e-modules before class can maximize interactions between teachers and students and between students (Lo & Hew, 2021). E-modules are one of the interactive and participatory strategies to motivate student engagement (Jansen et al., 2023). E-modules are considered effective in strengthening students' creative thinking skills. E-modules are easy to use and integrate into the learning process. This finding is reinforced by previous research findings stating that e-modules equipped with the latest technology make learning more relevant to real conditions in the field (Ahshan, 2021). This e-module not only teaches academic material but also develops critical thinking skills, creativity, collaboration, and communication which are very important in the 21st century. Intensive collaborative activities in the classroom encourage students to be more proactive in solving problems faced during learning (Venton & Pompano, 2021). The advantages of this study can be seen in the facilitation of more authentic evaluations, namely through an open problem-based approach, lecturers can assess students' understanding more authentically, observing students thinking, analyzing, and solving problems. One of the challenges in developing this e-module is the limited access to technology for some students, so infrastructure support and training are needed for teachers to maximize the use of this e-module. The development of e-modules is limited to certain topics in geometry and does not yet cover the entire curriculum as a whole. The development of this open-ended problem-based learning e-module has contributed to strengthening creative thinking skills and learning flexibility in problem-solving skills that have more than one correct answer.

4. CONCLUSION

The developed open-ended problem-solving-based geometry learning e-module meets the validity and practicality requirements. This e-module requires further adjustment to suit the various levels of student ability. In addition, some recommendations for further research are the development of e-modules with more complex interactive features: It is recommended to develop e-modules that include further interactive features, such as simulations or educational games that can increase motivation and learning experience. The impact of learning by combining open-ended problem-based e-modules and other approaches, such as project-based learning or case-based learning on student learning outcomes.

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