Electronic Module of Geometry Based on Open Problems

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Abstract **– The aim of this study is to develop teaching material products in the form of open problem-based e-modules in geometry learning courses. Plomp's development stages are used in this study, namely preliminary research, prototype stage, and assessment stage. This paper focuses on the assessment stage, the e-module field test. The field test is conducted at the Elementary School Teacher Education Study Program of PGRI Kanjuruhan University Malang, Nusantara PGRI University Kediri, and STKIP PGRI Trenggalek involving 277 students as subjects. In the field test, the practicality and effectiveness of the E-Module were measured using the Lecturer and Student Response Questionnaire and the Creative Thinking Ability Test. Based on the analysis results, lecturers and students responded positively to the designed e-module. More than 75% of the students' creative thinking ability level was at least in the "High" category. The form of open problems presented in this e-module makes students able to provide more than one solution and were also able to provide alternative solutions to open problems. However, in general, students are still unable to come up with new and unique solutions. The results of this study show that e-module meet the criteria of practicality and effectiveness.**

Keywords **– Development, E-modules, geometry, open problems, creative thinking ability.**

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1. Introduction

The rapid development of information and communication technology in the globalization era has an impact on education [1]. This has resulted in the digitization of learning organizations, which includes the application of digital technologies into various parts of educational institutions, such as teaching, learning, and administration [2]. Digital platforms allow educators to provide real-time assessment through online quizzes, automated assignments, or analysis of student learning performance. In this manner, students can immediately know their potential and the aspects that need improvement in their learning process [3], [4]. According to [5], online learning is considered a good choice, especially for adult learners. This is because online learning applications are easy to use on personal computers (PCs) or laptops, allowing students to follow the learning anytime and anywhere [6].

The current technological developments make it easier for educators to create various learning media that support education. One of the media that can be used is an interactive e-module. Unlike conventional modules that are given to students in printed form, this e-module is designed in electronic format and can be used on various devices, such as computers, laptops, and smartphones [7]. E-modules are designed to support learners in mastering the learning experience in accordance with the learning objectives that have been set [8]**.** E-modules are very effective because of helping students visualize, build, and associate in the thinking process [7], [9]. E-modules can engage students' attention because of having sound and moving images in the form of videos [10]. The use of e-modules in learning makes students interested in the learning process, because it can be accessed anytime and anywhere supported by adequate tools, and does not make it difficult for students [11], it is also easy for teachers to carry out teaching activities even though they are in different places with students [12]. Another advantage of learning with e-modules is that students can relearn what they don't understand [13].

This makes the use of e-modules in classroom learning have an impact on student learning outcomes [14], [15].

Creative thinking is a thought that seeks to create new ideas [16]. Creative thinking skills are the skills to think of something new and innovative [17]. Furthermore, [18] stated that the ability to think creatively in mathematics includes the ability to solve problems or construct thoughts in structure, state different statements with ordinary deductive logic, and put forward general concepts to unite important things in mathematics. Creative thinking skills are one of the competencies included in 21st century education [19]**.** According to [20] students' mathematical creative thinking ability has an important role, so it needs to be developed through habituation in mathematics learning. Creative thinking skills need to be developed from an early age, especially in mathematics learning [21]. As [22] added that classroom learning should encourage the development of students' creativity. However, the results of several studies state that students' creative thinking skills are still weak [23], [24].

Mathematical creative thinking skills can not grow by themselves. Students' success in learning or in their abilities is greatly influenced by what kind of learning is received [25]. One effective way to develop creative thinking skills is through open-ended problems [26], [27]. A similar opinion was also conveyed by [28], the type of problem that has the potential to develop students' creative thinking skills as an open problem. Open problems are problems that do not have one correct solution or clear approach, thus allowing students to think more flexibly, originally, and exploratively. Open problems allow students to explore ideas and strategies. Open problems are used to assess how students think, not just the end result. However, the facts in the field show that there are still many teachers who tend to give mathematical problem solving tasks in the form of closed or convergent problems that give strict restrictions to students [29]. On the other hand, geometry textbooks circulating in Indonesia still do not provide opportunities for students to strengthen creative thinking skills, because the presentation of problems still does not provide opportunities for students to solve open problems, as shown in Figure 1.

EXERCISE:
1. The perimeter of a kite is 100 cm, if the ratio of the short side to the long side is 2:3. Find the length of the short side and long side of the kite!
2. The perimeter of a rhombus is 40 cm. If the length of one diagonal is 12 cm, find the area of the rhombus!
3. If the lengths of the two diagonals of the rhombus are 8 cm and 6 cm, determine the perimeter of the rhombus!

Figure 1. Exercise problems that are not yet open problems

According to [30], [31] the indicators of creative thinking ability are fluency, flexibility, and novelty. Fluency refers to being able to solve problems with a variety of solutions and answers, flexibility refers to being able to solve problems in one way, then using other ways, and novelty refers to checking answers with several methods of solving or answers, then making other different ones. Development of e-modules learning geometry has been widely done, such as e-module development research with inquiry approach [13] and geometry learning module based on Van Hiele Theory [32]. After exploring, the two studies did not emphasize the provision of open problems. Based on the above considerations, therefore, this study aims to develop an e-module geometry learning based on open problems to strengthen students' creative thinking skills that focus on the assessment stage. The e-module developed is also equipped with animated videos in exploring the concept for the area of shapes and exploring the concept of the space volume. Providing videos is intended to foster a positive response from students so that it can stimulate thinking activities and strengthen understanding of the concept of the material. This paper focused on the assessment stage, the e-module field test. The field test was to assess the practicality and effectiveness of the geometry E-modules.

2. Methodology

The research method used in this study is research and development (R&D). This method is intended to produce teaching materials that are applicable and effective.

2.1. Development Procedure

The focus of this study is to develop teaching material products in the form of open problem-based e-modules in Geometry Learning courses. This research is a development research that adapts three stages [33] which include (1) preliminary research; (2) prototyping stage; and (3) assessment stage, as illustrated in Figure 2.

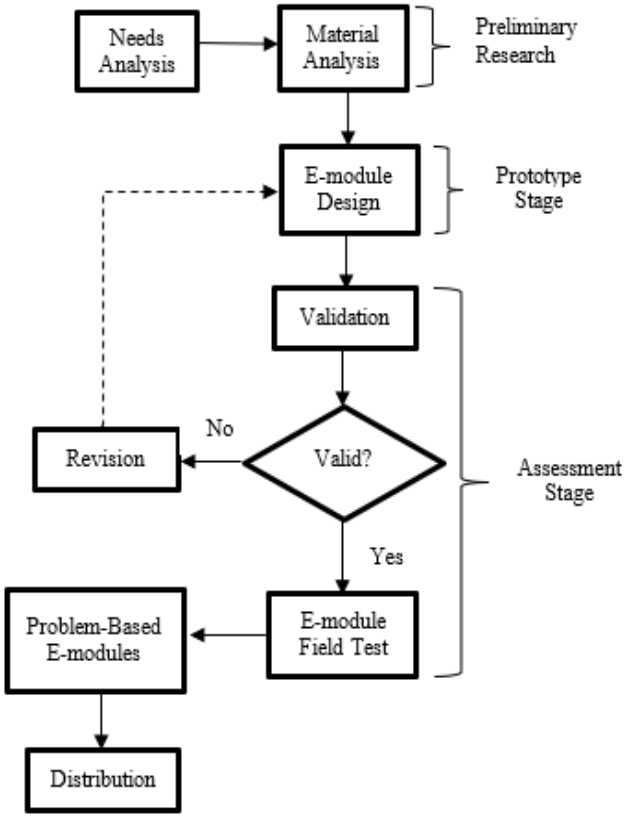

Figure. 2 Development procedure

In this paper, the focus is on the assessment stage where the results of the e-module field test are carried out after the designed e-module is declared valid by the validator. In this study, the product trial will be tested for practicality and effectiveness with an experimental approach as part of the development research process as in the study conducted by [34].

To assess the practicality of the e-module, a lecturer response questionnaire was used. There are 4 (four) aspects that are assessed, namely: (1) material, (2) language, (3) open problems, and (4) practicality. The assessment is done by ticking one of the options that have been given, namely: Strongly Agree (SS), Agree (S), Disagree (TS), and Strongly Disagree (STS). SS criteria for score 4, S for score 3, TS for score 2, and STS for score 1. In addition to the assessment by ticking the options that have been given, researchers also provide opportunities for respondents (lecturers) to provide suggestions and comments in the space provided.

Researchers also conducted unstructured interviews with lecturers to find additional information about the results of the e-module field test. Related aspects of the lecturer response questionnaire and its statement items are presented in Table 1. The aspects of the questionnaire are adapted from [8].

Table 1. Aspects of lecturer response questionnaire

Aspects	Questionnaire statement items
Material	1. Learning indicators are in accordance with learning outcomes. 2. The material is in line with the learning indicators. 3. In-depth material presentation. 4. Examples in the E-Module are in accordance with the material. 5. Images are in line with the material. 6. The video on the E-Module supports the understanding of the material.
Language	1. Systematic presentation of material. 2. Coherent presentation of material. 3. The sentences used do not cause double meanings.
Attractiveness	1. The open-ended problems given as exercises can encourage the growth of students' creative thinking skills. 2. The open-ended problems given in the Competency Test can be used to measure students' creative thinking skills. 3. The presentation of material based on open problems. 4. Examples in the E-Module in the form of open problems.
Practicality	1. E-Module instructions are clear. 2. Placement of button usage is in accordance with the E-Module display.

To assess the effectiveness of e-modules, student response questionnaires and creative thinking ability tests were used. In the student response questionnaire there are 4 (four) aspects that are assessed, namely: (1) material, (2) language, (3) attractiveness, and (4) practicality. The assessment is done by ticking one of the options that have been given, namely: Strongly Agree (SS), Agree (S), Disagree (KS), and Disagree (TS). The criteria of SS for score 4, S for score 3, KS for score 2, and TS for score 1. Related aspects of the student response questionnaire and its statement items are presented in Table 2. The aspects of the questionnaire are adapted from [8].

Table 2. Aspects of student response questionnaire

Aspects	Questionnaire statement items
Material	1. The material in the E-Module is systematic in accordance with the learning outcomes. 2. Images on the E-Module are in accordance with the material. 3. This E-Module uses video illustrations to understand the material. 4. The examples used in the E-module are in accordance with the material. 5. The open problems given as exercises can encourage the growth of students' creative thinking skills.
Language	1. E-modules use language that is easy to understand. 2. The text on the E-Module is interesting and easy to read. 3. The E-Module does not use sentences that cause double meanings.
Attractiveness	1. The images on the E-Module are interesting. 2. The appearance of the E-Module is interesting. 3. I am very interested in using this E-module
Practicality	1. This e-module is easy to use 2. This E-Module makes it easy for me to learn independently. 3. The instructions on the E-Module are clearly outlined. 4. The placement of button usage is in accordance with the E-Module.

For the creative thinking ability test, there are 3 (three) indicators that are assessed, namely fluency, flexibility, and originality. The related indicators of creative thinking ability and their descriptions are presented in Table 3. The indicators of creative thinking ability are adapted from [35].

Table 3. Indicators of creative thinking ability

Indicators	Description
Fluency	Fluency emphasizes the ability to produce several ideas and multiple answers or questions, investigate a problem from different points of view, find alternatives or different directions, and successfully apply various approaches or ways of thinking.
Flexibility	The flexibility in thinking was reflected from the likely different ideas and ability to change the way or approach of problem-solving quickly.
Originality	The originality was usually reflected in the unusual answers or solutions and the tendency to have different answers from other students. A student with creativity and the ability to think in high divergence did not have much difficulty in solving the problems.

Research Subject

The research subjects for this field test were students of the Elementary School Teacher Education Study Program at Universitas PGRI Kanjuruhan Malang, Universitas Nusantara PGRI Kediri, and STKIP PGRI Trenggalek. The number of students involved as subjects was 277 people.

Data Analysis

The data analyzed during the field test were the practicality and effectiveness data of the e-module. Practicality data analysis was carried out on the results of the lecturer response questionnaire, while effectiveness data analysis was carried out on the results of student response questionnaires and the results of student creative thinking ability tests. The lecturer's response is said to be positive if the lecturer gives an average score of at least 3 (three) for each aspect in the response questionnaire [36]. The percentage of practicality is measured using the formula in equation (1), while the determination of e-Module practicality criteria can be seen in Table 4. The Criteria for e-module practicality are adapted from [37].

$$Pr = \frac{Ts}{S\,max} \text{ x } 100\% \quad (1)$$

Pr : Practicality percentage.
Ts : Total score.
S Max : Maximum score.

Table 4. Criteria for e-module practicality

Practicality Percentage (*Pr*)	Criteria
$80\% < Pr \leqslant 100\%$	Very practical
$60\% < Pr \leqslant 80\%$	Practical
$40\% < Pr \leqslant 60\%$	Practical enough
$20\% < Pr \leqslant 40\%$	Less practical
$0\% \leq Pr \leqslant 20\%$	Not practical

Furthermore, student responses are said to be positive if students give an average score of at least 3 (three) for each aspect in the response questionnaire. Determination of the level of students' creative thinking ability uses the provisions in Table 5. The criteria for creative thinking ability are adapted from [36].

Table 5. Criteria for creative thinking ability level

Interval	Creative Thinking Ability Level
$Kr \geq 3.25$	Very High
$2.25 \leq Kr < 3.25$	High
$1.25 \leq Kr < 2.25$	Low
$Kr < 1.25$	Very Low

Data on student responses and creative thinking skills were analyzed using descriptive statistics as done in the research of [38] to determine the level of effectiveness of the product developed. E-modules are said to be effective if the responses given by students are positive, and at least 75% of the level of students' creative thinking skills are in the category of at least High [36].

3. Results

The results and discussion in this paper are focused on the results of the field test. This field test was conducted after the e-module was declared valid by the validator. This field test was used to see the practicality and effectiveness of the e-module.

3.1. E-Module Practicality

The practicality of the e-module is seen from the results of the lecturer response questionnaire. The lecturers involved in filling out this questionnaire were 3 (three) people, i.e. a lecturer who teaches Geometry Learning courses from the Elementary School Teacher Education Study Program at Universitas PGRI Kanjuruhan Malang, a lecturer who teaches Geometry Learning courses from Universitas Nusantara PGRI Kediri, and a lecturer who teaches Geometry Learning courses from STKIP PGRI Trenggalek.

The results of the lecturers' response questionnaire are presented in Table 6.

Table 6. Results of lecturer response questionnaire

Aspect	Score
Material	3.72
Language	3.55
Open Problems	3.16
Practicality	3.66
Average score	**3.58**

Based on the information provided in Table 6, it can be seen that each aspect on the lecturer response questionnaire has an average score of at least 3 (three). This shows that students give a positive response to the designed e-module. Next, the percentage of e-module practicality will be calculated.

Table 7. Lecturer response questionnaire score

Aspect	Number of statement items	Maximum score	Score acquisition
Material	6	72	67
Language	3	36	32
Open Problems	4	48	38
Practicality	2	24	22
Total	15	180	159

Based on the data in Table 7, the percentage of e-module practicality is obtained as follows.

$$Pr = \frac{159}{180} \text{ x } 100\%$$
$$Pr = 0{,}883\text{x } 100\%$$
$$Pr = 88{,}3\%$$

The results of this calculation indicate that the e-module is categorized as “Very Practical”.

3.2. E-Module Effectiveness

The effectiveness of the e-module is seen from the results of the student response questionnaire and the results of the student creative thinking ability test. The results of the student response questionnaire and the results of the student creative thinking skills test are presented in Table 8, and Table 9.

Table 8. Results of student response questionnaire

Aspect	Score
Material	3.309
Language	3.307
Attractiveness	3.302
Practicality	3.306
Average score	**3.306**

Based on the information provided in Table 8, it can be seen that each aspect on the student response questionnaire has an average score of at least 3 (three). This shows that students give a positive response to the designed e-module. Next, the results of the student creative thinking ability test will be calculated. The calculation results are presented in Table 9.

Table 9. Students' creative thinking ability level

Interval	Creative Thinking Ability Level	Total	Percentage of Creative Thinking Ability Level
Kr ≥ 3.25	Very High	5	2%
$2.25 \leq Kr < 3.25$	High	232	84%
$1.25 \leq Kr < 2.25$	Low	23	8%
Kr < 1.25	Very Low	17	6%
Total		**277**	**100%**

Based on the data in Table 9, it is obtained that 86% of students have creative thinking skills at the minimum level of "High". This can be seen from the subject's work on one of the test questions which can be seen in Figure 3 below.

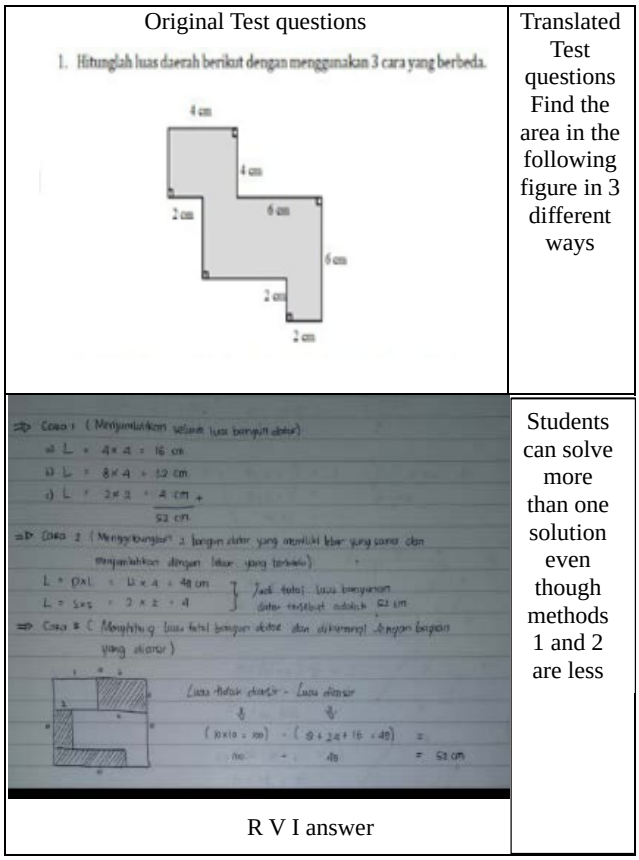

Figure 3. Student's test results

In Figure 3, students are given a test of creative thinking skills andasked to calculate the area using three different methods.

Students can solve it using three different methods: first, students divide the flat shape into three parts and add the areas of the three shapes; second, students divide the flat shape into two parts and add the areas of the two parts; and third, students draw a complete square and calculate its area, then subtract the area of the unnecessary shape.

Based on the analysis of the results of the student response questionnaire in Table 8 and also the results of the student creative thinking ability test in Table 9, the designed e-module is categorized as effective. Based on the analysis of the field test data, the designed e-module meets the criteria of practicality and effectiveness.

4. Discussion

Based on the analysis of the results of the response questionnaire related to the e-module that has been designed, it turns out that lecturers and students give a positive response. The calculation of the percentage of practicality shows that the e-module is categorized as "Very Practical". Based on the results of the interview, the lecturer said that this e-module facilitates the learning process. Lecturers also said this e-module can increase students' interest and engagement in learning geometry. It can happen because this e-module is designed with an attractive appearance, communicative language, and equipped with images and videos that support the material presentation. This developed e-module is also equipped with a learning video that makes an attractive appearance, of course, someone will be happy to learn with e-modules. This is in accordance with [39]. This is in accordance with [39] stating that students tend to prefer using electronic learning resources over print learning resources, since electronic modules can display text, images, animations, and also interactive videos. The use of interactive elements can make learning more interesting and challenging for students [40]. The application of e-modules in learning can attract students' interest because e-modules are equipped with moving images (animated videos) and also material summary videos so that students are eager to learn [41]. By utilizing e-modules, students can understand the material more quickly. Electronic modules provide images and text that are easy to understand, so students remember them easier [42]. In addition to the attractive appearance, e-modules are practical, for example, the apps can be accessed easily, the apps are easy to install on laptops, and the instructions for using the e-modules are clearly outlined. This kind of accessibility encourages users to keep learning the material on the e-module [43]. With the ease of accessing the app, one will be re-energized to learn the material in the e-module.

The choice of language is the spearhead for e-module teaching materials. With language that is easy to understand, communicative, and has no double meaning, it will attract someone to always want to read e-modules. Communicative, unambiguous, and easy-to-understand language makes students interested in reading the module [44]. Students' interest in learning using e-modules is due to the fact that e-modules are made with communicative, unambiguous, and easy-to-understand language [45], [46].

The developed Geometry Learning E-module is based on open problems. Open problems trigger students to creatively explore various ways or solutions to the problem. Through the use of open problems, students are encouraged to explore various ways and strategies, thus increasing their creative thinking skills. This is in accordance with what [47] stated that tasks with open problems allow students to develop various strategies and solutions, so that students can explore various possible approaches and results.

Open problems in this e-module are given in the example section, the main activity of the module, and in the competency test. Open problems are emphasized here because of triggering creative thinking skills. Activities carried out in the electronic module can guide students in finding concepts when studying geometry materials [48]. The use of open problems and a supportive learning environment can enhance students' creativity and critical thinking [49].

Based on the results of the field test analysis of the e-module, 84% of the students' creative thinking ability level is in the high category, even 2% of students' creative thinking ability is in the very high category. This means that the open problems emphasized in the e-module can provide reinforcement for the development of students' creative thinking skills. Through the provision of open problems, students are given the opportunity to develop their creative thinking in learning [50].

The analysis of the test results of students' creative thinking skills is related to the indicators of creative thinking skills shown in Figure 4.

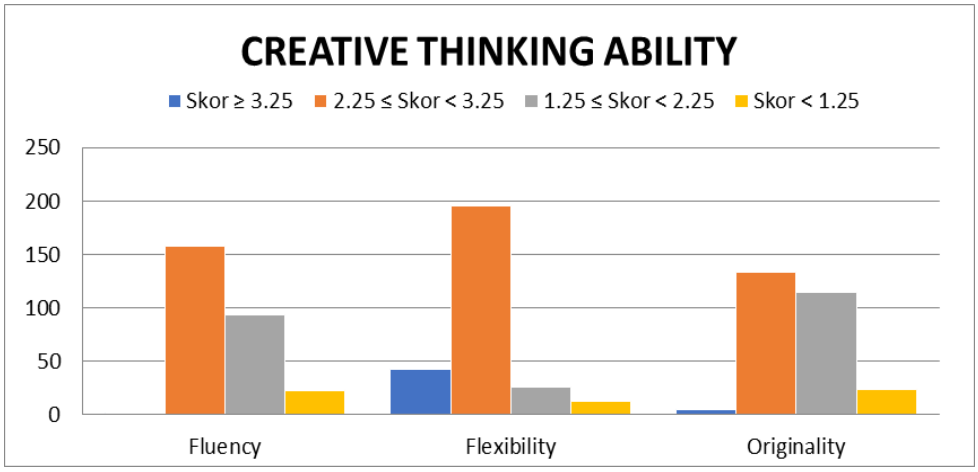

Figure 4. Analysis of students' creative thinking ability test results

The analysis results showed that 57.8% of students met the fluency indicator, 85.9% met the flexibility indicator, and 49.8% met the originality indicator. In general, students have been able to provide more than one solution to the open problems that are given. Students are also able to provide alternative solutions to open problems. However, in general, students are still unable to come up with new and unique solutions. Based on these results, students still need to frequently practice solving open problems so that new ideas emerge from the exercises carried out. The results section describes the obtained findings gathered from the research. Providing appropriate figures and tables to effectively illustrate the results. Figures are used to present data trends or other visual information while tables are particularly useful when the exact values are important.

5. Conclusion

This open problem regarding based geometry e-module has advantages in the form of easy access, systematically organized material, and equipped with learning videos to understand the material. This is reflected in the results of the e-module field test which shows that the e-module meets the criteria of practical and effective. The module is said to be practical because all aspects of the lecturer's response questionnaire get a score above 3 (three). The module is effective because each aspect of the student response questionnaire has an average score above 3 (three), and more than 75% of students scored above 2.25 on their creative thinking skills, which means that students' creative thinking skills are in the high category.

Since the product of the development that is "e-module based on open problems in geometry learning courses" has met the criteria of valid, practical, and effective", then the e-module can be used as an alternative for lecturers when lecturers want to provide reinforcement of creative thinking skills to the students being guided. The limitation of this research is on the scope of material coverage on the e-module. The geometry material developed in this e-module is only the area and perimeter of flat shapes as well as the volume and surface area of spatial shapes. Another limitation is on data analysis, precisely related to the analysis of the effectiveness of e-modules. In this study, the analysis related to the effectiveness of e-modules was only carried out using descriptive statistics. In this study, no comparison of results with the control class has been done. In future research, it is recommended to more accurately test the effectiveness of e-modules using quantitative research involving experimental classes and control classes analyzed by inferential statistics.

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