



Critical Thinking on the Determinants Matrix: The Development of A Teaching Module

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Abstract: This research is motivated by the unavailability of determinant matrix teaching materials that meet students' needs and curriculum standards and students' low critical thinking skills, so a determinant matrix teaching module is needed that complies with curriculum standards and facilitates critical thinking skills. Teaching modules are developed using the Project-Based Learning model. This mixed-methods research aims to determine teaching modules' validity, practicality, and effectiveness. This article is a design research report using the Plomp model. The data sources in this research are material expert validators, media experts, educational practitioners, and respondents. The instruments used are validity sheets for material experts, media experts, description tests, observation of the learning process, and critical thinking ability tests. The results of data analysis in this research concluded that the teaching module that had been developed was very valid, practical, and effective. The developed instructional materials are believed to support learning that emphasizes critical thinking. In conclusion, the teaching materials incorporate exercises that enhance critical thinking skills using case presentations. Furthermore, it is suggested that the module be used as an alternative teaching tool and that further research be done with different data, materials, or other mathematical abilities.

INTRODUCTION

Covid-19 hit the world in all sectors, including the education sector. During a pandemic, educators the pandemic, educators started using other methods in schools and were starting to use other methods for continuous learning for their students (Batubara & Batubara, 2015). One of them was the distance learning method. However, this method has resulted in learning loss or reduced knowledge and skills academically (Donnelly & Patrinos, 2022).

To anticipate learning loss, education units were given the freedom by the Government of Indonesia to implement

three curriculum options: national, emergency, and alternative.

To implement the curriculum, the Government of Indonesia has issued regulations for a new paradigm learning program. In this program, educators need to make teaching modules with differentiated learning principles so that each student learns according to their needs and stages of mental development.

Among the several teaching tools, there were teaching modules. Teaching modules were described as learning plans prepared according to the phases or stages of student development, considering the themes and teaching topics, and based on

long-term development. Based on the diagnostic test of the determinant of matrix material related to critical thinking skills carried out on the second-semester student at Islam Nusantara University, the result showed that the student's critical thinking ability was 68%. According to Arikunto, this result belongs to the medium category (Arikunto, 2010). Based on the assessment system at Islam Nusantara University, this result was categorized as sufficient or equivalent to a C value with a scale of 0 to 100 but still below the requirement of a learning objective of 70.

The results of interviews with lecturers who teach determinants of matrix material also showed students' critical thinking skills were low due to the absence of adequate teaching modules. Even more, learning activities were only done through WhatsApp groups, so the learning was not optimal. Meanwhile, when students use a differentiated teaching module, learning will be focused on student learning styles and improve their learning outcomes (Helma & Edizon, 2017).

Critical thinking skills are the fourth to sixth level of the cognitive domain type in Bloom's Taxonomy, which requires higher-order thinking skills. It was also a skill to think rationally and reflectively based on what was believed and done. The advantages of critical thinking skills are that they can help students manage their learning abilities in the long term (Aizikovitsh-Udi & Cheng, 2015; Setyowati et al., 2018) and solve problems that will be faced in the future (Peter, 2012).

Critical thinking involves assessing and appraising available data to ascertain trustworthy information, which can then be employed to arrive at sound conclusions (Akib & Muhsin, 2020; Verawati et al., 2019; Yasir & Alnoori, 2020). Another point of view coming from (Franco et al., 2018; Karakoç, 2016; Lorencová et al., 2019; Qablan, 2019; Santos, 2017; Yuli & Siswono, 2016) That idea that critical thinking prowess varies among individuals

highlights the importance of fostering it from a young age. Critical thinking is a structured process that empowers learners to formulate and articulate their viewpoints and perspectives (Araya, 2020; Costa et al., 2021; Costa et al., 2021; Rositawati, 2018; Putu & Suhardiana, 2019).

Students must be able to use their critical thinking in a way that offers creative thought and demonstrates it. The teacher must accommodate this process with learning media (Changwong et al., 2018;Ediyani et al., 2020). However, the learning media that the teacher used was limited to contextual, authentic, and open-ended problems and did not provide independent learning.

Based on the results of the research As'ari (2019) conducted, it can be concluded that: 1) Description of the mathematical problem-solving strategy module according to student needs in Mathematics Education, 2) There is a module design that fits the needs of Mathematics Education students, 3) The mathematics problem-solving strategy module is feasible to use and declared valid and 4) Based on the post-test, the mathematics problem-solving strategy module is effective for improving the mathematical problem-solving abilities of Mathematics Education students.

A teaching module was developed before with the same design research, learning model, and students (Fadlurrochman et al., 2022). Similar efforts have been undertaken to enhance critical thinking skills by developing teaching materials like flipbooks for elementary school students in science subjects (Landina & Agustiana, 2022). Other researchers are also attempting to enhance critical thinking skills using Google Sites. In line with the efforts of previous researchers, the development of case-based teaching materials is necessary to improve student's critical thinking abilities (Gesly et al., 2023). Nevertheless, the development of a teaching module addressing the determinant of matrices to

students' thinking skills, particularly one that employs project-based learning as the instructional model, has yet to be discovered. Therefore, creating such instructional material is crucial to enhance the effectiveness of the learning process.

Based on the explanation above, it was necessary to develop a teaching module about the determinant of the matrix related to students' thinking skills that use project-based learning for the learning models. The purpose of this study was to describe quantitatively the

development of teaching modules using validity, practicality, and effectiveness.

METHOD

The research approach used in this study was mixed methods, analyzing the data quantitatively and using a qualitative approach to describe the developing process of the teaching module. The method and model used were design research and the Plomp Model. The research process flow is presented in Figure 1.

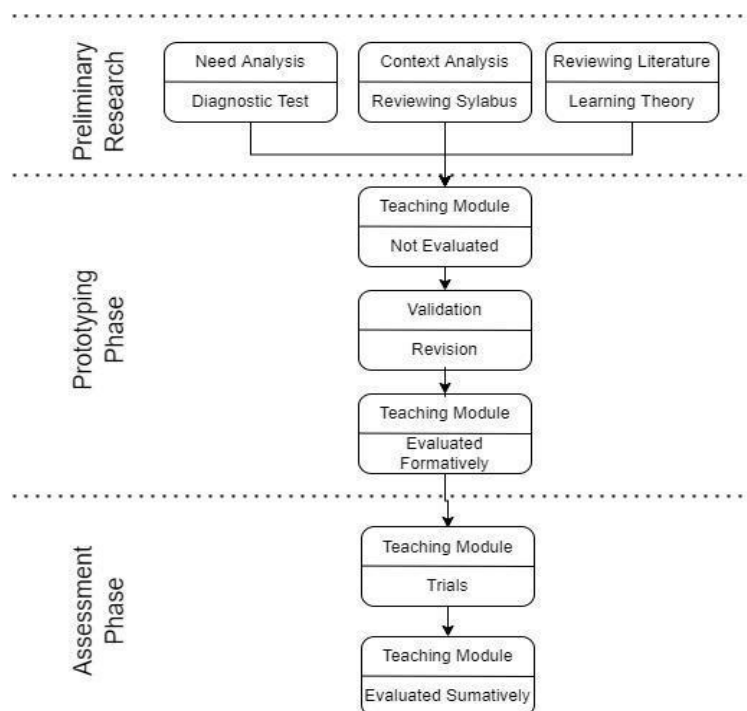


Figure 1. Plomp Model Development Procedure.

The research steps refer to Bannan-Ritland's (Plomp & Nieveen, 2010) design research. These steps were: 1) Preliminary research that consists of need and context analysis, review of literature, and development of a conceptual or theoretical framework for the study; 2) The prototyping phase consists of an iterative design phase with a formative evaluation that is aimed at improving and refining the intervention; 3) The assessment phase consists of summative evaluation to conclude whether the module meets the pre-determined specifications.

The study encompassed participants, including validators, mathematics teachers, mathematics lecturers, and mathematics students. The data was taken from the results of the validity and practicality test. The validity score guide utilized a four-point Likert scale for assessment.

Analysis of Validity

The validation process involves a comprehensive evaluation of the obtained scores related to validity measures. The interpretation of the validation results is presented in the following Table 1.

Table 1. Validity Criteria.

No	Score (%)	Validity Criteria
1	85.01 - 100.00	Very Valid
2	70.01 - 85.00	Quite Valid
3	50.01 - 70.00	Not Valid
4	01.00 - 50.00	Invalid

Analysis of Practicality

The practicality score of the product is derived from the measured scores divided by the overall score. A product is

considered practical when it achieves a high score. The interpretation of the product's practicality is presented in the following Table 2.

Table 2. Practicality Criteria.

No	Score (%)	Practicality Criteria
1	85.01 – 100.00	Very Practical
2	70.01 – 85.00	Quite Practical
3	50.01 – 70.00	Not Practical
4	01.00 – 50.00	Impractical

Analysis of Effectiveness

The effectiveness value of the development product is obtained by dividing the measured scores by the overall score. A product is considered

effective when it achieves a high score. The interpretation of the product's effectiveness is presented in the following Table 3.

Table 3. Effectiveness Criteria.

No	Percentage (%)	Criteria
1	$p > 80$	Excellent
2	$60 < p \leq 80$	High
3	$40 < p \leq 60$	Moderate
4	$20 < p \leq 40$	Low
5	$p \leq 20$	Poor

RESULT AND DISCUSSION

The result of this study was a teaching module related to student's critical thinking skills with project-based learning. It was generated from design research steps with the Plomp Model, as shown in Figure 1.

Preliminary Research

Need analysis was carried out in the form of a diagnostic test for mathematics students at Islam Nusantara University to aim at students' need for learning and in the form of an interview with the lecturer. Context analysis was done by reviewing the syllabus of the material. The step then reviewed relevant learning theory, conformity with course achievement, and critical thinking theory.

Needs analysis is an essential process in the context of education and instructional programs(Husna, 2018). This process involves identifying and prioritizing needs, which indicate a gap between the actual state and the desired conditions at the individual, group, or institutional levels. Therefore, needs analysis plays a crucial role in program evaluation, as this activity clearly depicts the disparity between the current state and the desired conditions.

Prototyping Phase

The module was created based on the result of preliminary research and has three major sections. The section was: 1) General Information comprising course achievement, learning tools, and student targets. 2) The main component consists of

the description of the module, elements of local culture, learning objectives, triggering questions, learning activity flow, assessment, and reflection. 3) Attachment consists of reading material, evaluation test, and student worksheet.

The local culture was integrated into the learning activity and the achievement of the course and assessed in effective skill. The critical thinking skill was integrated into the example of the material and assessed in cognitive skill.

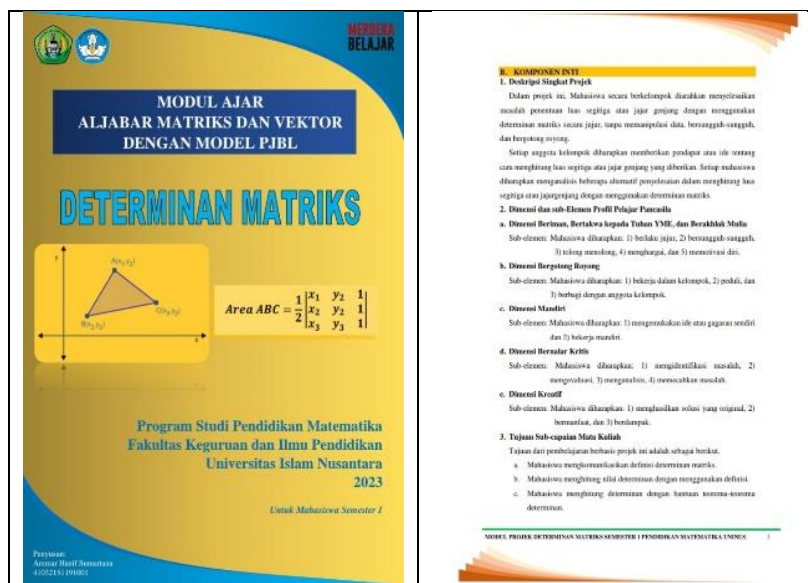


Figure 2. Cover and Component's Module.

In Figure 2, the cover of the module displayed the title, a drawing of the triangle in Cartesian, a formula of triangle area using determinant, and the module's author. The component's module displayed a short description of the module and sub-element of local culture in Indonesia. The presentation of local wisdom content is advocated as it can enhance students' critical thinking abilities (Suryanatha, 2013). The instructional materials present local wisdom content as an initiation for students' thinking.

After designing the initial product, the teaching module was evaluated on the validity of the material expert, media expert, and practitioner so that the

product could be revised and ready for the next step.

Validity of the Module

The validity of the module was divided into material expert validity and media expert validity. Material expert validity comprises three key aspects: content feasibility, presentation feasibility, and language eligibility. The validity data was obtained through a questionnaire. The result is shown in Table 4.

Media expert validity encompasses module size, cover design, and content design. The validity data was obtained through a questionnaire. The result is shown in Table 5.

Table 4. Material Expert Validity Results.

No	Aspect	Mean Score (%)	Criteria
1	Content Feasibility	79.91	Quite Valid
2	Presentation Feasibility	79.44	Quite Valid
3	Language Eligibility	80.76	Quite Valid
Mean Value		79.37	Quite Valid

Table 5. Media Expert Validity Results.

No	Aspect	Mean Score (%)	Criteria
1	Module Size	87.50	Very Valid
2	Cover Design	83.04	Quite Valid
3	Content Design	81.94	Quite Valid
Mean Value		84.16	Quite Valid

The result from material expert validity and media expert validity, respectively, was 79.37% and 84.16%, with criteria "quite valid". According to validity criteria, that means the developed teaching module was declared eligible as teaching materials and learning resources.

Assessment Phase

The assessment stages are conducted to evaluate the content of the module and ensure its relevance, accuracy, and completeness. Assessments are carried out through trials via surveys, tests, and observations. The outcomes of these assessments are utilized to refine and enhance the module,

creating a version that is more effective and relevant for the users.

Practicality of the Module

The practicality test was used to determine the practicality of the developed module. The purpose was to show if the module was realistically usable for which it has been designed and developed. The learning material applies to the intended settings in which it has been designed and developed (Plomp & Nieveen, 2010).

The practicality test, as a questionnaire, was carried out by high school mathematics teachers and mathematics education lecturers at Islam Nusantara University. The result of the practicality test is shown in Table 6.

Table 6. The Result of the Practicality Test.

No	Indicator	Mean Score (%)	Criteria
1	Cover Page	85.00	Quite Practical
2	Clarity of Tables/Illustrations/Pictures	85.42	Very Practical
3	Language and Sentences	81.25	Quite Practical
4	Writing Clarity	87.50	Very Practical
5	Colour Composition	78.13	Quite Practical
6	Module Content	83.33	Quite Practical
7	Motivate to respond to the learning	81.25	Quite Practical
Total		83.13	Quite Practical

The result from the practicality test was 83.13%, with quite practical criteria. According to the criteria, that means the developed teaching module was declared practical as teaching materials and learning resources.

Effectiveness of the Module

Utilizing the learning material results in attaining the desired outcomes (Plomp & Nieveen, 2010). The effectiveness test was determined to measure the effectiveness of the developed teaching modules. The aspects

assessed were based on formative assessments linked to students' critical thinking skills and integrated with learning completeness.

Table 7. Formative Assessment Recapitulation.

No	Aspect	Effectiveness	Criteria
1	Cognitive	70 %	Effective
2	Affective	90 %	Effective
3	Psychomotor	90 %	Effective

According to Table 7, the result from effectiveness was 70 %, 90 %, and 90 % with criteria effective. According to the criteria, that means the developed

teaching module was declared effective as a teaching material and learning resource.

Critical Thinking Skills

This module was developed about students' critical thinking skills. So, it was hoped that students could practice their critical thinking skills when using learning modules in the learning process.

This ability collaborated with teaching modules in the form of question grids, evaluation tests, learning processes, and sample questions.

According to Facione (2015), six indicators of ability were integrated into this teaching module. These abilities were interpretation, analysis, evaluation, inference, explanation, and self-regulation.

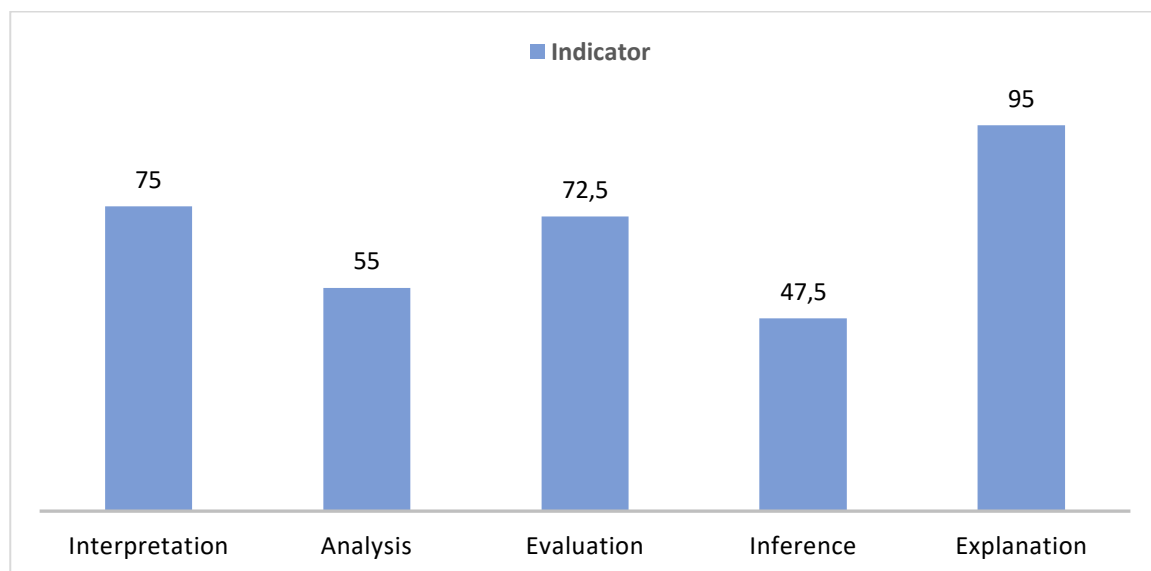


Figure 3. Average of Student's Critical Thinking Skills.

Figure 3 shows students' critical thinking skills based on a formative evaluation test attended by ten students who took the Matrix and Vector Algebra

course. Each indicator result was taken from a problem measuring students' critical thinking skills.

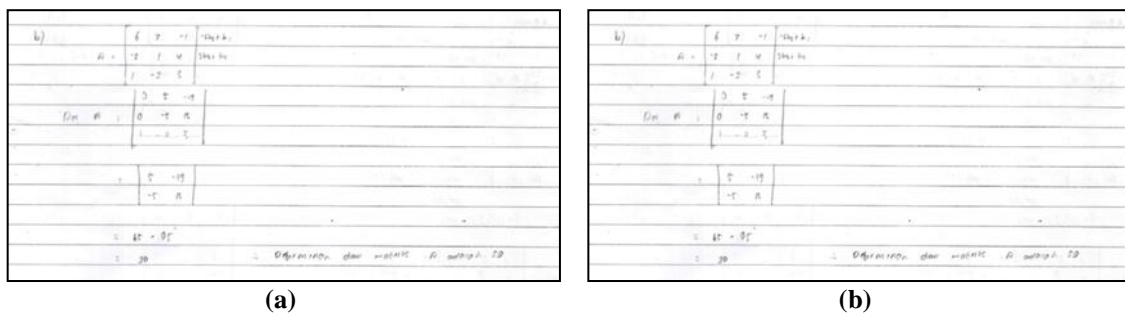


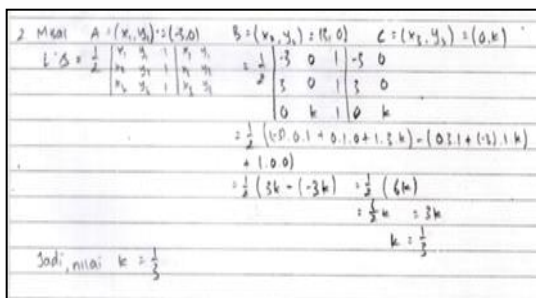
Figure 4. The Student's Answer Sheet: (a) Interpretation; (b) Analysis.

Figure 4 (a) shows students made several mistakes in interpreting the minor of a matrix entry. The student can show the interpretation process and write down the information needed to answer the

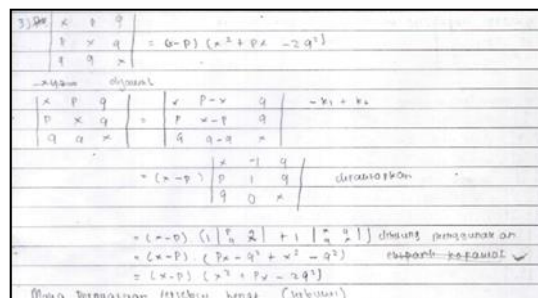
question. However, some students miss out on the interpretation process by directly answering the results without writing down the process.

Figure 4 (b) shows a student solving the determinants of the matrix using another method that was not instructed. Nevertheless, the student uses

the analysis skill by connecting the process with the concept given and giving an argument at every step.



(a)



(b)

Figure 5. The Student's Answer Sheet: (a) Evaluation; (b) Inference.

Figure 5 (a) shows the student performing an evaluation skill by solving the problem with a mathematical formula. However, there was a mistake in

the substitution process. Figure 5 (b) shows the student's inference skill by solving the problem and coming to the right answer to what was asked.

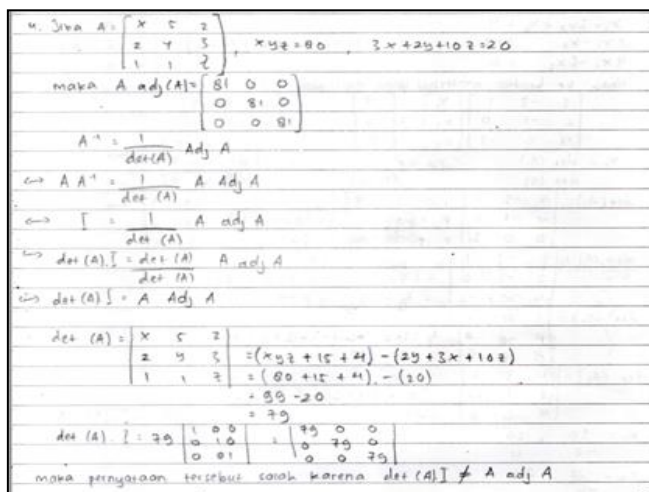


Figure 6. Answer Sheet of Student for Explanation.

Figure 6 shows the student using an explanation skill by explaining the concept given in every procedure for solving the problem correctly. Although the student solved the problem, he did not answer what was asked. This means the student could not show self-regulation skills. The critical thinking skill shown by students above can be explained by the fact that some students cannot use it to its full potential. This occurred because students cannot analyze and need help

understanding the problem (Arini et al., 2023).

Although the popular method to improve student critical thinking in the mathematical learning process was teaching methods that used PBL or STEM, this study uses the Project-Based Learning model because the students who used PJBL had a higher level of creative and critical thinking skills (Guo et al., 2020; Diana et al., 2021) and were more efficient at improving them (Wahdah et

al., 2023). As support for the findings of this research, other researchers have also discovered that the presentation of case-based teaching materials can enhance students' critical thinking abilities (Gesly et al., 2023). The instructional materials presented in this study also include local wisdom content, reinforcing students' critical thinking skills (Suryanatha, 2013). Similarly, the presentation of case-based teaching materials is closely related to the critical thinking pattern (Wahdah et al., 2023). While numerous studies have explored the development of teaching modules and other supporting media, there is still a gap in the literature concerning the creation of instructional materials specifically targeting the determinant of matrices about students' thinking skills, especially using project-based learning as the instructional model. Consequently, it is imperative to develop such instructional materials to augment the effectiveness of the learning process.

The current body of research has thoroughly investigated the development of teaching modules and supporting media. Nevertheless, a significant gap persists in addressing the determinant of matrices concerning students' thinking skills through project-based learning. This emphasizes the urgent necessity for the creation of instructional materials specifically designed for this context, focusing on the Determinants of the Matrix. The instructional materials also include facilities for efforts to understand matrix concepts through case investigations. This is highly relevant to a learning style that supports the practice of critical thinking. Through case investigation exercises, students can become accustomed to critical thinking. This becomes an innovation and advantage of the developed instructional materials.

CONCLUSION

Based on the study's results, it was found that the determinant matrix module related to the student's critical thinking skill was declared eligible to be used as teaching materials and learning resources by an overall average score of 79.37% from material experts and 84.16% from media experts. The module was deemed practical for use as both teaching materials and learning resources, achieving an average score of 83.13%, indicating it met the 'quite practical' criteria. And the module's effectiveness was effective, with scores of 70%, 90%, and 90%. It is believed that the developed module can be utilized as teaching material and learning resources, improving learning activities and enhancing students' critical thinking skills in the future.

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