Effectiveness of STEM-PBL Based E-Modules on Critical Thinking Skills of Junior High School Students

Feri Tiona Pasaribu[*1]; Tria Gustiningsi[2]; Hana Ariefah[3]
[1,2,3]Prodi Pendidikan Matematika, FKIP, Universitas Jambi, Indonesia
feri.tiona@unja.ac.id[*1], hanaariefah@gmail.com[3]

Abstract

Critical thinking is a crucial skill that must be developed in junior high school students to help them face complex problems and make decisions based on facts and data. This study aims to describe the improvement of students' critical thinking skills through the implementation of a STEM-PBL-based e-module. This research used a descriptive method with a qualitative approach. The subjects consisted of 26 seventh-grade students at MTs N 3 Batang Hari. Data were collected using an essay test comprising five questions, and the results were analyzed using the N-Gain formula. The findings showed a moderate improvement in all indicators of critical thinking: formulating problems (N-Gain = 0.66), managing facts (0.60), constructing logical arguments (0.66), drawing conclusions (0.62), and evaluating (0.63). These results indicate that the STEM-PBL-based e-module had a positive impact on enhancing students' critical thinking skills. The integration of real-world problem-solving and interdisciplinary concepts through STEM-PBL helped students engage more actively, develop logical reasoning, and improve overall learning outcomes. Therefore, STEM-PBL-based e-modules are recommended as effective instructional tools to support critical thinking development in junior high school students.

Keywords: *Critical Thinking Skills; E-Modules; STEM-PBL.*

Abstrak

Berpikir kritis merupakan keterampilan penting yang harus dikembangkan oleh siswa SMP untuk membantu mereka menghadapi permasalahan yang kompleks dan membuat keputusan berdasarkan fakta dan data. Penelitian ini bertujuan untuk mendeskripsikan peningkatan kemampuan berpikir kritis siswa melalui penerapan e-modul berbasis STEM-PBL. Penelitian ini menggunakan metode deskriptif dengan pendekatan kualitatif. Subjek penelitian terdiri dari 26 siswa kelas VII di MTs N 3 Batang Hari. Data dikumpulkan melalui tes uraian yang terdiri dari lima soal, dan dianalisis menggunakan rumus N-Gain. Hasil penelitian menunjukkan adanya peningkatan dalam semua indikator kemampuan berpikir kritis dengan kategori sedang, yaitu: merumuskan masalah (N-Gain = 0,66), mengelola fakta (0,60), menyusun argumen logis (0,66), membuat kesimpulan (0,62), dan mengevaluasi (0,63). Temuan ini menunjukkan bahwa e-modul berbasis STEM-PBL memberikan dampak positif dalam meningkatkan kemampuan berpikir kritis siswa. Integrasi pemecahan masalah nyata dan konsep lintas disiplin dalam pendekatan STEM-PBL mendorong siswa lebih aktif, berpikir logis, dan meningkatkan hasil belajar secara keseluruhan. Oleh karena itu, e-modul berbasis STEM-PBL direkomendasikan sebagai alat pembelajaran yang efektif untuk mendukung pengembangan berpikir kritis pada siswa SMP.

Kata Kunci: Kemampuan Berpikir Kritis; E-Modul; STEM-PBL.

*Correspondence:
Email: feri.tiona@unja.ac.id

INTRODUCTION

Education is a crucial element in developing the potentian and quality of human resource in country. (Hairunnisa et al., 2023). In general, education is understood as a lifelong process of self-development and improving one's thinking skills (Yayan et al., 2019). This is because education plays a significant role in enhancing the quality of human resources, particularly in developing thinking processes. One of the key thinking skills that contributes to quality of life is critical thinking. Therefore, critical thinking skills are among the essential aspects that need to be fostered through education so that students are prepared to face challenges and find solutions to problems.

Critical thinking is a vital skill in the global era, where individuals are required to tackle complex issues and make decisions based on facts and data. According to (Ennis, 2011), critical thinking involves reasonable refelctive thinking focused on deciding what to believe or do. In (Lestari et al., 2017) reveals that critical thinking is the process of formulating orderly reasoning actively and skillfully from drafting concepts, applying (synthesis), or evaluating information collected through the process of observation, experience, reflection, reasoning or communication as the basis for determining actions. And according to (Facione, 2015) Critical thinking is a complex thinking process consisting of interpretation, analysis, inference, evaluation, explanatory and self-regulation. Critical thinking is not an ability that is directly inherent in humans. This skill must be practiced in the learning process so that students are always used to thinking critically in solving problems Critical thinking is a complex thinking process consisting of interpretation, analysis, inference, evaluation, explanatory and self-regulation. Critical thinking is not an ability that is directly inherent in humans. This skill must be practiced in the learning process so that students are always used to thinking critically in solving problems (Haviz, 2009). Supporting this, (Paul & Elder, 2014) emphasize that critical thinking must be intentionally cultivated through guided pratice and explisit instruction. In this study, critical thinking indicators will be used by (Khasanah & Ayu, 2018) which includes 5 indicators, namely; (1) students can formulate the main problems; (2) disclose and

manage facts; (3) make arguments logical, relevant and accurate; (4) be able to draw conclusions and; (5) Evaluate.

In mathematics learning, studenr are often faced with various problem that require analysis, comparison, and logical reasoning. One topic that is particulary relevant for developing students' critical thinking skills is that concept of congruence. This topic involves understanding the peroportional relationship between two geometric figures and applying these concept in real word contexs. Therefore, congruence material offers a valuable opportunity for teacher to train students in critical thinking through matematical reasoning. However, based on observation and interview with grade VII.2 mathematics teacher at MTsN 3 Batang Hari, it was found that students struggle to develop critical thinking skillsdue to low concertration and lack of interest in the learning process. Futhermore, the instructional media used in still limites to conventional printes books, wich fail to actively engage students in problem solving processes.

This highlight a gap between the potential of congruence topic as a medium for critical thinking development and the current instructional practices that lack interactive, student-centered strategies. To address this gap, it is necessary to develop innovative learning media. This study proposes the development of a STEM-PBL-based e-module as a novel approach. Unlike conventional methods, the integration of STEM and Problem-Based Learning within a digital module format offers an engaging platform that encourages exploration, reasoning, and application of concepts. To make the learning experience more meaningful and relevant, the e-module is designed using real-life contexts from Jambi, such as local culture, environment, and daily situations familiar to students. Incorporating local context helps increase students' motivation and makes abstract mathematical concepts easier to understand. Research on this specific combination STEM-PBL-based e-modules applied to the topic of congruence in junior high school, particularly using local Jambi contexts is still limited, making this study a novel contribution to mathematics education research.

According to (Deviana & Mahendra Sakti, 2014) If the concentration of students is low, it will cause low-quality activities that will affect the comprehension of the material. From the results of student interviews, students stated that the lack of contestation in class was due to learning that became boring because they only used rigid and uninteresting books. This is an obstacle for teachers in improving students' critical thinking skills. Therefore, an innovation is needed that can increase students' concentration and interest in learning. According to (Vidianti et al., 2024) digital modules can improve learning engagement and high-order thinking skills.

Students' low critical thinking skills are shown in research that has been conducted by (Nuryanti et al., 2018) showed that the critical thinking ability of SMP 1 Delanggu students in Klaten Regency was relatively low, with an average percentage of 40.46%. This is in line with research conducted by (Hidayanti et al., 2016) which shows that the critical thinking ability of junior high school students in the Congruent material is still relatively low because students who meet each indicator of critical thinking ability are still at 50%. Therefore, one of the efforts that can be made to improve students' concentration so that they can improve students' critical thinking skills is to use a problem-based learning model that is integrated with the STEM (science, technology, engineering, and mathematics) approach.

E-Modules as an innovative learning medium in supporting teachers to foster critical thinking skills among students. E-Modules offer interactive and engaging content, enabling students to learn indenpendently and at their own pace, which can incrase their motivation and focus (Hutauruk et al., 2025). E-modules offer interactive and engaging content, enabling students to learn independently and at their own pace, which can increase their motivation and focus. In particular, STEM-PBL-based e-modules can integrate real-life problem-solving and critical thinking processes, making them highly relevant for mathematics topics such as similarity in geometry. Research by (Luh et al., 2024) Shows that STEM-integrated E-Modules significantly improve students' critical thinking and conceptual understanding. Therefore, this study aims to describe and

evaluate junior high school students' critical thinking skills after the use of STEM-PBL-based e-modules, highlighting their potential contribution as a modern educational tool that can enhance critical thinking in the learning process.

RESEARCH METHODS

This type of research is descriptive with a qualitative approach with the research subjects being 26 students of class VII.1 MTs N 3 Batang Hari which will be implemented in the 2024/2025 academic year. The instrument in this study is a critical thinking skills test consisting of 2 descriptive questions. The data collection procedures carried out are: 1) providing a critical thinking skills test after using the e-module. 2) correcting students' answers based on critical thinking indicators. 3) analyzing students' answers using the n-gain test. 4) concluding the results of the study.

The data analysis used in this study uses qualitative data analysis that refers to the opinions of Miles and Huberman (Sugiyono, 2018) which includes 1) the data reduction stage. The data reduction carried out started from the results of the critical thinking ability test and the results of interviews. 2) The data presentation stage is carried out by presenting data in the form of tables describing the results of the research. 3) The data collection stage is carried out by concluding the results of the analysis of the effectiveness of STEM-PBL-based e-modules on improving students' critical thinking skills. Data analysis uses the n-gain test using the following formula:

$$N_{gain} = \frac{Skor\ Posttest - Skor\ Pretest}{Ideal\ score - Skor\ Pretest}$$

(Sukarelawan et al., 2024)

Table 1. N-Gain Category

Grade	Critical Thinking Level
$0{,}70 \leq g \leq 100$	High
$0{,}30 \leq g < 0{,}70$	Medium
$0{,}00 \leq g < 0{,}30$	Low
$g = 0{,}00$	No Increase
$-1{,}00 \leq g < 0{,}0$	Reduction

(Sukarelawan et al., 2024)

RESULTS AND DISCUSSION

In this study conducted using a qualitative descriptive approach model with the material of Congruent, it aims to describe the effectiveness of STEM-PBL-based e-modules in improving the critical thinking skills of junior high school students. The subjects of this study were 26 grade VII students. Before conducting the study, the researcher had created a STEM-PBL-based E-module so that students could practice their critical thinking skills.

E-Module used in this study is an E-Module based on the STEM approach (science, technology, engineering, and mathematics) combined with the Problem-Based Learning (PBL) learning model. This E-Module was developed specifically for the Congruent material in grade VII of junior high school. The purpose of this E-Module is to help students develop their critical thinking skills through solving conceptual problems. The main components in this E-Module include the stages of PBL learning, namely: 1) student orientation to the problem, 2) organizing students to learn, 3) guiding individuals and groups, 4) developing and presenting work results, 5) analyzing and understanding. As well as STEM integration, namely; every activity in the module meets mathematical concepts with science and technology, such as through shadow measurement, scale comparison, and the use of simple applications. And this E-Module uses interactive features such as video links, QR Codes and interactive quizzes with questions that can improve critical thinking skills. Here are some displays of the E-Module used in this study:

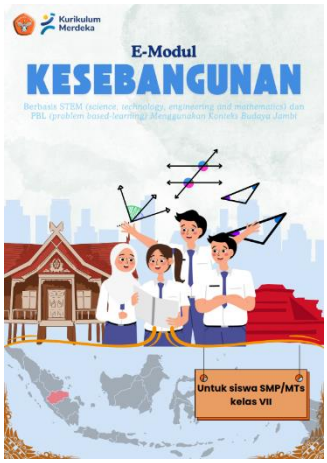

Figure 1. Initial view of E-Module

Figure 2. Example of PBL activities integrate STEM elements

Figure 3. Contexrual questions used to train students critical thinking

Figure 4. Interactive features

In the initial stage before using the e-module, the researcher conducted a pretest by giving 2 essay questions containing critical thinking indicators. This stage was carried out with the aim of knowing the comparison of scores before and after students learned to use the e-module.

After conducting the pretest, students were given an e-module as a learning medium to improve critical thinking skills for 4 meetings. Each meeting will use the STEM approach stages with the PBL (Problem based learning)

learning model. At the end of learning using the e-module, the researcher conducted a posttest as a comparison of values to determine the effectiveness of using the STEM-PBL based e-module in improving students' critical thinking skills.

In the next stage, namely the n-gain test with 26 students in class VII by giving 5 essay questions. The following is a table of the effectiveness of STEM-PBL-based e-modules in improving the critical thinking skills of junior high school students using critical thinking indicators, namely: (1) students can formulate the main problems; (2) disclose and manage facts; (3) make arguments logical, relevant and accurate; (4) be able to draw conclusions and; (5) Evaluate. The following are the results of students' answers based on critical thinking indicators:

Table 3. Results of Students' Critical Thinking Skills Based on Indicators

Indicators	Pretest	Posttest	N-Gain	Categhory
1	69,23	92,30	0,66	Medium
2	62,50	87,50	0,60	Medium
3	43,27	83,65	0,66	Medium
4	48,07	82,69	0,62	Medium
5	27,88	75,96	0,63	Medium
Total :			**0.63**	**Medium**

In the table, it can be seen that in indicator (1) students can formulate the main problems; in the pretest, students scored 69.23. This shows that only about half of the students were able to identify the main problems presented in the questions. After using the STEM-PBL-based E-Module, the posttest score increased to 92.30, indicating that almost all students were able to formulate the main problems. This shows an improvement in students' ability to identify key issues, with an N-Gain score of 0.66, which falls into the “Medium” category.

In indicator (2) disclose and manage facts, the pretest score was 62.50, while the posttest score increased to 87.50. The N-Gain score was 0.60, which falls into the “Medium” category. This improvement shows that the STEM-PBL-

based E-Module used in the learning process helped students express and manage the facts presented in the questions.

In indicator (3) make arguments logical, relevant, and accurate, students scored 43.27 in the pretest, which increased to 83.65 in the posttest. The N-Gain score was 0.66, also in the "Medium" category. This indicates a significant improvement in students' ability to construct logical arguments after using the STEM-PBL-based E-Module to enhance their critical thinking skills.

In indicator (4) be able to draw conclusions, the pretest score was 48.07, which increased to 82.69 in the posttest. The N-Gain score was 0.62, falling into the "Medium" category. This demonstrates that the use of the STEM-PBL-based E-Module in learning was quite effective in improving students' ability to draw conclusions during problem-solving.

In indicator (5) evaluate, the pretest score was 27.88, while the posttest score increased to 75.96. The N-Gain score was 0.63, which falls into the "Medium" category. This increase shows that learning using the STEM-PBL-based E-Module can enhance students' critical thinking skills in this category. Although the initial pretest score was very low, the substantial increase in the posttest proves that using the E-Module in learning is very effective.

Based on the calculation results, the overall average N-Gain score was 0.63, which falls into the "Medium" category. This shows that using the STEM-PBL-based E-Module to enhance junior high school students' critical thinking skills was quite effective. This finding consistent with reaserch by (Luh et al., 2024) which shows that STEM-integrated E-Modules significantly improve students' critical thinking and conceptual understanding. The "Medium" category indicates an increase in students' understanding and skills after participating in the learning process. This average N-Gain score reflects that the learning implementation was effective, but there is still room for improvement for example, by strengthening the learning methods, utilizing more interactive media, or increasing student engagement. Therefore, these results encourage the development of more innovative learning models to achieve optimal improvements in students' abilities in the future.

CONCLUSION

Based on the analysis, this study that the implementation of the STEM-PBL based e-module contributed meaningfully to the enhacement of studensts critical thinking skills. The improvement was evident across all measured indicators, comfirming that the integration of STEM principkes with problem-based learning strategies in a digital format is an effective way to support thinking development among junior high school stidents. This study succesfully addressed its objective of evaluating students' critical thinking abilities after using the e-module, and the findings demonstrate the value of using stuctured, interactive, and context rich digita tools in mathematics education. Futhermore, the novely of this study lies in its use of STEM-PBL based e-module tailored the topic of congruence and contextualized within local content from jambi, which adds relevamce and engagement for students. This localized and intergrated approach remains underexplored in previous literature, making a significant contribution to the field. While the results are promising, they also indicate opportunities for further development. Future efforts can focus on enhancing interactivity, expanding contextual elements, and applying the model to other mathematical topics to maximize student engagement and learning outcomes.

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