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Mathematical Critical Thinking Skills Through Case-Based Learning with Scaffolding in Cross-Study Program Classes

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Abstrak

Pembelajaran dengan kurikulum merdeka membuat mahasiswa memiliki hak belajar di luar program studinya sehingga pemikiran kritis sangat diperlukan. Guna meningkatkan kemampuan berpikir kritis matematis mahasiswa maka diterapkan *Scaffolding* pada *Case-Based Learning* (CBL). Peningkatan kemampuan berpikir kritis matematis mahasiswa di kelas lintas program studi melalui CBL dengan *scaffolding* merupakan tujuan penelitian ini. Metode penelitian adalah kuasi eksperimen. Instrumen penelitian adalah soal tes uraian kemampuan berpikir kritis matematis. Populasi penelitian adalah mahasiswa tingkat 3 Program Studi Pendidikan Matematika dan Pendidikan Biologi salah satu Universitas di Ciamis. Sampelnya yaitu 31 mahasiswa pendidikan matematika dan 10 mahasiswa pendidikan biologi, dipilih dengan *cluster random sampling*. Analisis data menggunakan uji gain ternormalisasi. Hasil penelitian menunjukkan kelompok mahasiswa secara keseluruhan, internal, dan eksternal pada kelas eksperimen mempunyai kemampuan berpikir kritis matematis lebih baik dari kelas kontrol. Persentase jumlah mahasiswa yang memperoleh n-gain ketegori tinggi juga lebih besar. *Scaffolding* pada CBL efektif untuk meningkatkan kemampuan berpikir kritis mahasiswa.
Kata Kunci: *Case-Based Learning;* Kemampuan Berpikir Kritis Matematis; *Scaffolding*

Abstract

Learning with an independent curriculum gives students the right to learn outside their study program so that critical thinking is very necessary. In order to improve students' mathematical critical thinking skills, Scaffolding is applied to Case-Based Learning (CBL). Improving students' mathematical critical thinking skills in cross-study program classes through CBL with scaffolding is the purpose of this study. The research method is quasi-experimental. The research instrument is a descriptive test of mathematical critical thinking skills. The research population was 3rd year students of the Mathematics Education and Biology Education Study Programs at one of the Universities in Ciamis. The sample was 31 mathematics education students and 10 biology education students, selected by cluster random sampling. Data analysis used the normalized gain test. The results showed that the student group as a whole, internally, and externally in the experimental class had better mathematical critical thinking skills than the control class. The percentage of students who obtained a high n-gain category was also greater. Scaffolding in CBL is effective in improving students' critical thinking skills.
Keywords: Case-Based Learning; Mathematical Critical Thinking Skills; Scaffolding

I. INTRODUCTION

Significant changes are currently happening across various sectors worldwide, often referred to as the "crisis period" (Sayyidi & Sidiq, 2020). One of these changes in Indonesia’s education sector is the shift to the Merdeka Curriculum, or Independent Curriculum. Independent learning is a new policy initiated by the Ministry of Education and Culture (Maghfiroh & Sholeh, 2022). The goal of this policy is to develop high-quality human resources capable of competing in the global job market, equipped with strong competencies to help reduce unemployment in Indonesia. Universities, seen as hubs of innovation, are expected to strengthen these competencies through the Independent Learning, Independent Campus program (Merdeka Belajar, Kampus Merdeka or MBKM).

According to the Director General of Higher Education or Dirjen Dikti Kemendikbud (2020), one of the primary policies of MBKM is the provision that allows students to study for three semesters outside their primary study program. This mandate from higher education regulations aims to produce graduates who are adaptive, competent, and competitive in the job market while enhancing the quality of learning in relevant fields.

The MBKM policy grants students the right to study outside their main study program for up to three semesters, focusing on subjects that are still relevant to their primary field and can be credited toward their degree. Engaging in this type of learning requires strong critical thinking skills, which help students comprehend the new material and reflect on their cognitive processes (Sumarna et al., 2017). Critical thinking also enables students to solve problems effectively, as it involves logical reasoning, interpretation, analysis, and evaluation of information, all of which contribute to making reliable and valid decisions in a rapidly evolving scientific landscape (Luritawaty et al., 2022).

The solid foundation of students' hard and soft skills can be strengthened if the Independent Curriculum is designed and implemented properly (Dirjen Dikti Kemendikbud, 2020). One key soft skill that can be nurtured through this curriculum is critical thinking. In 21st-century mathematics education, developing mathematical critical thinking skills is one of the "4C" abilities essential for students to master (Rahayu et al., 2022). Critical thinking enables individuals to make more informed decisions by engaging in mental processes such as gathering, classifying, analyzing, and evaluating information or evidence to solve problems (Amir, 2015; Prajono et al., 2022).

Critical thinking follows several stages: understanding and reasoning, gathering and analyzing relevant and reliable information, formulating assumptions and hypotheses, logically testing hypotheses, drawing conclusions, making evaluations, deciding what to believe or do, and predicting outcomes (Khairani & Abdullah, 2018). Additional indicators of critical thinking include interpretation, analysis, evaluation, and inference (Rani et al., 2018).

Several studies have shown that students' mathematical critical thinking skills remain low (Nurdwiandari, 2018; Rani et al., 2018), with less than 25% of students mastering all the indicators of mathematical critical thinking (Jiwandono, 2019). These findings indicate that students' critical thinking abilities in mathematics are not meeting expected standards.

Critical thinking can be developed through a well-structured learning process in lectures. Student-centered learning plays a significant role in the Merdeka Belajar, Kampus Merdeka (MBKM) program (Dirjen Dikti Kemendikbud, 2020). To enhance students' mathematical critical thinking skills, particularly in the context of independent learning, it is crucial to design learning models that not only align with regulatory requirements but also enable students to explore and improve their mathematical reasoning.

In this study, Scaffolding will be integrated into Case-Based Learning (CBL) as an innovative approach to enhance students' critical thinking. Scaffolding refers to providing targeted support to students based on the specific difficulties or challenges they face (Chairani, 2015). This method helps students better comprehend the material. Additionally, CBL offers numerous advantages when implemented effectively, as it focuses on real-world cases relevant to the subject matter (Syarafina et al., 2017; Trianto, 2011).

Research has demonstrated that innovative combinations of instructional methods, such as project-based learning paired with scaffolding, positively impact students' mathematical communication skills (Paruntu et al., 2018). Similarly, CBL combined with feedback enhances students' conceptual understanding (Asfar et al., 2019) and improves learning outcomes (Simbolon, 2022)

Based on this background, this study aims to examine: (1) whether the improvement in students' mathematical critical thinking skills is greater in classes receiving instruction through Scaffolding in the CBL model compared to those receiving conventional learning, across student groups: (a) Overall, (b) Within the study program, and (c) Outside the study program; and (2) the percentage of students categorized into high, medium, and low normalized gain groups in mathematical critical thinking between the experimental group (Scaffolding in CBL) and the control group (conventional learning).

II. Method

This type of research is a quasi-experiment involving two research groups. The experimental class is the first group that receives treatment and the control group is the second group that does not receive treatment. The research design used is pretest and posttest non-equivalent group design (Sugiyono, 2017). The population in this study were 62 students of Mathematics Education and Biology Education at Galuh University. Sampling used cluster random sampling (Fajrin & Leonardi, 2019). The technique is to take a random sample of 1 class from level 3 in the Mathematics Education and Biology Education Study Programs to be combined into an experimental class, namely a class that uses the application of scaffolding in CBL with details of 15 Mathematics Education students and 5 Biology Education students. Furthermore, taking 1 class randomly from level 3 in the Mathematics Education and Biology Education Study Programs to be combined into a control class that learns with conventional learning which in this case uses CBL learning because the learning that is usually carried out by lecturers in the Mathematics Education Study Program at Galuh University is currently this model. The details of the control class are 16 Mathematics Education students and 5 Biology Education students. The study was conducted in the even semester of the 2022-2023 academic year.

The research instrument is a mathematical critical thinking ability test. The mathematical critical thinking ability test questions are in the form of essays with questions given referring to the mathematical critical thinking indicators (Rani et al., 2018). Before being used, the instrument was first validated by experts and tested first to then test its validity and reliability in order to obtain a suitable test instrument (Febrianawati, 2018). The scoring of students' answers to the mathematical critical thinking ability test questions is based on the scoring guidelines. The research procedure includes four stages, namely: preparation; implementation; data analysis; and drawing conclusions.

The pretest was conducted before the experimental class and control class carried out learning, while the posttest was conducted after the experimental class received learning. Furthermore, the pretest and posttest data were processed to obtain the n-gain value. The n-gain formula according to Hake (Retnani & Zuhdi, 2019) is used as follows:

$$Gain\ ternormalisasi = \frac{skor\ postes - skor\ pretes}{skor\ maksimum\ ideal - skor\ pretes}$$

The analysis of the n-gain data was conducted using SPSS software. The categorization of n-gain values followed the guidelines outlined in Table 1 (Sundayana, 2014).

Tabel 1.
Categorization of N-gain Value

N-gain Value	Interpretation
-1,00 ≤ g <0,00	Decrease
g = 0,00	No Improvement
0,00 < g <0,30	Low
0,30 ≤ g <0,70	Moderate
0,70 ≤ g <1	High

III. RESULT AND DISCUSSION

The research commenced with administering a post-test to assess the initial mathematical thinking abilities of both the experimental and control classes. Following this, learning activities were conducted in the experimental class using Scaffolding within a Case-Based Learning (CBL) framework, while the control class engaged in Conventional Learning Based on CBL. The learning sessions spanned four meetings in the Linear Programming course of the Mathematics Education program. After the learning activities concluded, a post-test was administered to evaluate the students' final mathematical critical thinking abilities.

The data collected from the pre-test and post-test were processed to calculate the n-gain values. Data analysis for the n-gain values was performed using SPSS software and involved three stages: the normality test, the homogeneity test, and the t-test. Additionally, the analysis results were supplemented by comparing the percentage of students classified according to their n-gain categories.

The normality test, following the method of Lestari & Yudhanegara (2015), was

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conducted to ascertain whether the data from both groups were drawn from normally distributed populations. The hypotheses for this test were as follows:

H0: The data is normally distributed.

H1: The data is not normally distributed.

The testing criteria were:

1. If the significance value ≥ 0.05, then H0 is accepted.
2. If the significance value < 0.05, then H1 is rejected.

Subsequent to the normality test, a homogeneity test was performed, as both classes were determined to be normally distributed. This test aimed to evaluate whether the sample data came from homogeneous populations. The homogeneity test, according to Lestari & Yudhanegara (2015), utilized the Levene Test, with the following hypotheses:

H0: $\sigma_1^2 = \sigma_2^2$ (homogeneous variances).

H1: $\sigma_1^2 \neq \sigma_2^2$ (non-homogeneous variances).

The testing criteria for the homogeneity test were:

1. If the significance value ≥ 0.05, then H0 is accepted.
2. If the significance value < 0.05, then H1 is rejected.

The next stage involved hypothesis testing using the t-test, given that the data were normally distributed and the variances were homogeneous. The hypothesis tested was whether the improvement in students' mathematical critical thinking skills in classes receiving instruction with Scaffolding in the CBL model was superior to that of students undergoing conventional learning. The specific comparisons were: (a) Overall; (b) Within the study program (internal); (c) Outside the study program (external).

The statistical hypotheses for this study were as follows:

H0: $\mu_1 \leq \mu_2$, indicating that the increase in students' mathematical critical thinking skills in classes utilizing Scaffolding in the CBL model is the same as or not better than that of students receiving conventional learning.

H1: $\mu_1 > \mu_2$, indicating that the increase in students' mathematical critical thinking skills in classes utilizing Scaffolding in the CBL model is better than that of students receiving conventional learning.

The criteria for the t-test were:

1. If the significance value ≥ 0.05, then H0 is accepted.
2. If the significance value < 0.05, then H1 is rejected.

A. Results of N-Gain Analysis for the Entire Student Group

The Shapiro-Wilk test was employed to assess the normality of the data. Based on the results of the analysis, the experimental class had a significance value of 0.143, which is greater than 0.05 (H_0 is accepted, meaning the data is normally distributed), while the control class had a significance value of 0.548, also greater than 0.05 (H_0 is accepted, indicating normal distribution).

Levene's test was used to evaluate the homogeneity of variance. According to the results presented in Table 3, the significance value was 0.676, which is greater than 0.05 (H_0 is accepted, meaning the data variances are homogeneous).

Hypothesis testing was conducted using the t-test, with the results summarized in Table 2.

Table 2.
t-test of N-Gain Value

Independent Samples Test				
		t-test for Equality of Means		
		t	df	Sig. (2-tailed)
N-Gain Value	Equal variances assumed	.692	39	.0493

Based on the t-test results in Table 4, the significance value was found to be 0.0493, which is less than 0.05 (H_0 is rejected). This indicates that the increase in students' critical mathematical thinking skills in the experimental class, which received Scaffolding within the CBL model, is significantly better than that of the control class, which received conventional learning, across the entire student group.

B. Results of N-Gain Analysis for the Internal Student Group of the Mathematics Education Study Program

The Shapiro-Wilk test was used to assess the normality of the data. According to the results, the experimental class had a significance value of 0.188, which is greater than 0.05 (H_0 is accepted, indicating the data is normally distributed), while the control class had a significance value of 0.454, also greater than 0.05 (H_0 is accepted, confirming normal distribution).

Levene's test was employed to check the homogeneity of variances. Based on the analysis results presented in Table 3, the significance value was 0.066, which is greater than 0.05 (H_0 is accepted, indicating homogeneous variance across groups).

Hypothesis testing was conducted using the t-test. The results are shown in Table 3.

Table 3.
t-test of N-Gain Value

Independent Samples Test				
		t-test for Equality of Means		
		t	df	Sig. (2-tailed)
N-Gain Value	Equal variances assumed	.756	29	.0457

Based on the results of the data analysis in Table 3, the significance value was found to be 0.0457, which is less than 0.05 (H_0 is rejected). This indicates that the increase in students' critical mathematical thinking skills in the experimental class, which received learning with Scaffolding in the CBL model, is significantly better than that of students in the control class, who received conventional learning, within the internal student group of the Mathematics Education study program.

C. Results of N-Gain Analysis for the External Student Group of the Mathematics Education Study Program

The Shapiro-Wilk test was used to assess normality. The analysis results indicated that the experimental class had a significance value of 0.956, which is greater than 0.05 (H_0 is accepted, meaning the data is normally distributed), and the control class had a significance value of 0.967, also greater than 0.05 (H_0 is accepted, indicating normal distribution).

Levene's test was applied to assess the homogeneity of variances. According to the data processing results, the significance value was 1.486, which is greater than 0.05 (H_0 is accepted, indicating that the data variances are homogeneous).

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Hypothesis testing was performed using the t-test, with the results presented in Table 4.

Table 4.
t-Test of N-Gain Value

Independent Samples Test				
		t-test for Equality of Means		
		t	Df	Sig. (2-tailed)
N-Gain Value	Equal variances assumed	.201	8	.0445

Based on the data analysis results in Table 4, the significance value was found to be 0.201, which is greater than 0.05 (H_0 is accepted). This indicates that the increase in students' mathematical critical thinking skills in the experimental class, which received Scaffolding in the CBL model, is not significantly better than that of students in the control class, who received conventional learning, within the external student group of the Mathematics Education study program.

D. Comparison of Percentage of Students by N-Gain Categories

To further support the SPSS data processing results, a comparison of the percentage of students falling into the high, medium, and low n-gain categories in mathematical critical thinking skills is presented between the experimental class, which received Scaffolding in the CBL model, and the control class, which received conventional learning. The comparison of percentages is provided in Table 5.

Table 5.
Comparison of Percentage of Students by N-Gain Categories

N-GAIN CLASSIFICATION	EKSPERIMENTAL CLASS (%)	CONTROL CLASS (%)
0,70 ≤ g < 1 (High)	50	43
0,30 ≤ g < 0,70 (Moderate)	50	57
Total	**100**	**100**

As shown in Table 5, the percentage of students in the high n-gain category is 50% for the experimental class, compared to 43% for the control class, indicating a higher proportion of students in the experimental class. In the medium n-gain category, 50% of students in the experimental class and 57% in the control class are classified, showing a higher percentage for the control class.

These results reflect the differing impacts of the treatments given to the two groups. The experimental class received Scaffolding within the CBL model, whereas the control class was taught using only the CBL model. Research supports that CBL, when properly implemented, has several advantages in learning (Trianto, 2011; Dewi & Hamid, 2015). These advantages include: (1) students can propose cases and apply them to new situations, (2) students collaborate and develop analytical skills while improving communication, (3) students are more actively involved in learning, and (4) case-based learning enhances cooperative learning, speaking, and critical thinking skills.

The stages or syntax of the CBL learning model (Trianto, 2011) applied in this study are as follows. First, the teacher divides the students into groups of five. Then, the teacher provides each group with a case derived from an article or news related to the material being studied. After that, each group is given time to discuss the case provided, with the teacher offering written questions to guide and direct the discussion process. Finally, question-and-answer sessions and discussions are held to observe the responses of each group. Throughout this learning process, students are actively engaged and participate fully. CBL is designed to stimulate and train students' critical thinking skills by presenting cases that require the use of critical thinking (Bahrullah, 2021).

The effectiveness of CBL is further enhanced by integrating scaffolding within the learning syntax. Scaffolding provides learning support through appropriate conceptual frameworks and tools, guiding students in performing each activity independently (Waiyakoon et al., 2015). As noted by Wood et al., scaffolding enables a child or adolescent to solve problems, complete tasks, or achieve goals that would not otherwise be attainable without assistance (Bakker et al., 2015).

This assistance is adapted according to the difficulties experienced by students (Chairani, 2015), and gradually reduced so that they can eventually master the concepts independently or solve problems without additional help. Instructors can use various forms of scaffolding to enhance students' critical thinking skills by exploring, practicing, and building these skills consistently.

Common scaffolding techniques used in learning include modeling desired behaviors, offering explanations, encouraging student participation, verifying and clarifying student understanding, and prompting students to provide clues or solutions (Hasan, 2015; Kusmaryono et al., 2020; Susilowati & Ratu, 2018; Hogan & Pressley (Murdiyani, 2013)).

In this study, scaffolding was implemented during the discussion phase, where each group was given time to discuss cases provided by the lecturer. To foster understanding, the lecturer explained key concepts and offered relevant written questions to guide the discussion. These questions were presented in the form of worksheets that each group member completed, ensuring that the discussion remained focused and students' thought processes were systematically guided.

Developing conceptual thinking is achieved through the use of guiding questions that encourage students to reason. During question-and-answer sessions and discussions, aimed at evaluating the responses of each group, the process can be directed to facilitate a deeper understanding of the material. This approach motivates students to actively participate in the learning process. Additionally, reviewing and reflecting activities, which serve as a form of feedback, are conducted when students present the results of their case-based assignments. Through these presentations, the extent of the students' understanding of the material is assessed, and any conceptual errors can be corrected by the lecturer.

The findings of this study are consistent with previous research. Scaffolding has been shown to assist students in mastering the subject matter (Susilowati & Ratu, 2018). Moreover, the Case-Based Learning (CBL) model has proven to be effective in enhancing students' cognitive skills and abilities (Dewi & Hamid, 2015; Dewi et al., 2022).

IV. CONCLUSION

The findings of this study demonstrate that across the student groups—(a) overall, (b) internal, and (c) external—the mathematical critical thinking ability in the experimental class was superior to that of the control class. The percentage of students achieving a high n-gain category was significantly higher in the experimental class compared to the control class, indicating that the application of scaffolding in Case-Based Learning (CBL) is effective in enhancing students' critical thinking skills.

In the overall student group, consisting of students from both the Mathematics Education and Biology Education study programs, it was concluded that the improvement in mathematical critical thinking skills was greater in the class that received instruction using scaffolding within the CBL model than in the class that received conventional instruction. Similarly, in the internal student group, which comprised only students from the Mathematics Education study program, the results revealed that the experimental class exhibited a higher improvement in mathematical critical thinking skills compared to the control class.

For the external student group, consisting of students from the Biology Education study program, the results also indicated that the increase in mathematical critical thinking skills was more pronounced in the class receiving scaffolding within the CBL model than in the class receiving conventional instruction. These findings underscore the effectiveness of scaffolding within the CBL framework in enhancing mathematical critical thinking abilities.

This study contributes to the development of learning model syntax, particularly in classes implementing the independent curriculum. The integration of scaffolding supports differentiated learning by accommodating the diverse academic backgrounds of students across various study programs. The scaffolding strategies employed in this study included modeling desired behaviors, presenting explanations, encouraging student participation, verifying and clarifying students' understanding, and prompting students to provide critical insights or keys to problem-solving.

Further research could deepen these findings by investigating the specific forms of scaffolding tailored to students' cognitive abilities. Such exploration would ensure that the scaffolding provided is better aligned with the students' needs, adapting to their initial levels of understanding of the material.

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