

Outside-In Blended Learning: A Transformative Approach to Developing Mathematical Critical Thinking Skills

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Abstract. *Developing students' mathematical critical thinking skills is essential for addressing complex problems in contemporary mathematics education. This study examines the effects, differences, and improvement levels of students' mathematical critical thinking skills through the implementation of Outside-In Blended Learning and conventional instruction. A quasi-experimental method with a nonequivalent control group design was employed. The population consisted of eighth-grade students at State Junior High School 1 South Halmahera, Indonesia, with a total sample of 78 students. Data were collected using a mathematical critical thinking skills test and analyzed through inferential statistics. The findings indicate that both Outside-In Blended Learning and conventional instruction positively influenced students' mathematical critical thinking skills. Through the Outside-In Blended Learning model, students engaged with contextual problems by observing, interpreting, and constructing solutions based on conceptual understanding reinforced during classroom discussion and reflection. In contrast, teacher-centered instruction provided fewer opportunities for exploration and reasoning. A clear gap emerged between the two groups, suggesting that conventional instruction does not fully optimize students' potential for critical thinking, whereas Outside-In Blended Learning more effectively promotes analytical and reflective thinking. The improvement in students' mathematical critical thinking after the implementation of Outside-In Blended Learning was categorized as moderate, with an N-gain score of 54.93. Overall, the Outside-In Blended Learning model offered a more comprehensive and contextual influence on students' mathematical critical thinking development.*

Keywords: *Instructional approaches, mathematical critical thinking, outside-in blended learning*

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Introduction

Mathematical critical thinking skills are an essential competency for junior high school students to face 21st-century challenges, as they require both conceptual understanding and the ability to analyze, evaluate, and solve problems logically and reflectively (A'yun et al., 2021; Angraini & Wahyuni, 2021). However, mathematics instruction in schools still largely relies on conventional teacher-centered approaches, which emphasize final outcomes and provide limited opportunities for students to explore ideas or engage in deep thinking. This situation leads students to become passive, struggle to connect concepts with real-world contexts, and lack practice in critically evaluating mathematical problems (Setiana et al., 2021; Sachdeva & Eggen, 2021; Rais & Xuezhi, 2024; Hidayat et al., 2022).

Innovation in learning models is essential to improve the quality of mathematics education (Rohmah et al., 2022). One promising approach is Outside-In Blended Learning, which integrates experience-based learning outside the classroom with face-to-face and online instruction (Pollarolo et al., 2023). By initiating learning from real-world phenomena close to students' experiences and connecting them with formal concepts through digital media and classroom discussions, students are expected to develop a more meaningful understanding while simultaneously enhancing their mathematical critical thinking skills (Ridwan et al., 2022; Ismail et al., 2022; Matitaputty et al., 2024).

Although Outside-In Blended Learning shows promise, its implementation in mathematics education at junior high schools remains limited. Most blended learning research has focused on the effectiveness of digital media or online learning, while the exploration of out-of-class experiences as the starting point of learning is still minimal. Furthermore, empirical studies measuring the impact of this model on junior high school students' mathematical critical thinking skills are still scarce, both in terms of research design, measurement instruments, and systematic implementation results. This indicates a need for further research to address these gaps (Fitriati et al., 2025; Monteleone et al., 2023; Scheiner, 2023; Dewi et al., 2024).

According to Appelbaum (in Samaras et al., 2022), students can be taught to conduct activities involving comparison, induction, generalization, contradiction, proving, relating, analyzing, evaluating, and graphing impartially. According to Glazer (in Alharbi, 2022), three indicators can be used to improve a person's critical thinking capacity: (1) Increased capacity, the ability to develop statements carefully (using previously learned theories); (2) Generalization, the ability to conclude data entered into narrower categories; (3) Problem-solving, the ability to recognize unknowns, ask questions, and draw conclusions about unknowns that are needed in certain situations, arithmetic models and their descriptions, and draw conclusions about results or outcomes.

The post-COVID-19 shift in educational paradigms has accelerated the transition to digital and hybrid learning (Bringula & Atienza, 2023); however, a new challenge has emerged: ensuring that technology-based learning remains contextual, interactive, and meaningful. The Merdeka Curriculum emphasizes the development of higher-order thinking skills, including critical thinking. In this context, Outside-In Blended Learning is relevant because it combines technology with authentic learning experiences to promote active student engagement. Another important issue is the digital divide between schools and teachers' readiness to design context-based learning activities integrated with digital platforms (Samura & Darhim, 2023; Kadirbayeva et al., 2022; Brandt & Columba, 2022).

Previous research has shown that blended learning enhances students' motivation, independence, and learning outcomes, whereas context- or environment-based learning develops critical thinking and mathematical problem-solving skills. However, few studies have comprehensively integrated these two approaches. Research on the implementation of Outside-In Blended Learning offers the opportunity to reinforce these findings and provide new insights into the integration of contextual experiences and technology to enhance students' mathematical critical thinking.

Hasanah and Malik (2020) demonstrated that the implementation of blended learning significantly enhances students' critical thinking abilities and communication skills. The combination of online and face-to-face learning enables students to explore knowledge, engage in discussions, and reflect on their understanding. Through collaborative interactions on digital platforms and direct guidance in the classroom, students become more open in expressing ideas and more skilled in analyzing and solving problems logically. These findings confirm that blended learning is effective in improving learning outcomes while simultaneously developing higher-order thinking skills and essential academic communication skills in the digital era.

To strengthen the analysis, the researcher conducted a preliminary study at another school as initial data. The results indicated that students still experienced difficulties in learning linear equations because teachers focused primarily on government textbooks, which introduce variables in an abstract manner. Variables should ideally be presented through examples of their application in various contexts. Students' learning experiences with linear equations remain suboptimal, as teachers need to employ a greater variety of instructional approaches or models. Additionally, the independent curriculum content is overly dense, resulting in insufficient learning time, and many students still require assistance in mastering the material.

The novelty of this study lies in the development and implementation of the Outside-In Blended Learning model, designed to enhance junior high school students' mathematical critical thinking skills. This research evaluates the model's effectiveness on learning outcomes while also examining students' thinking processes in solving contextual mathematical problems. In addition, outside-in-based learning tools were developed, such as contextual worksheets, field activities, and interactive digital media. This approach introduces a new innovation in mathematics instructional design by connecting real-world experiences with abstract concepts.

The main variables of this study are students' mathematical critical thinking skills and the implementation of Outside-In Blended Learning. Based on these variables, the research questions are as follows: Does Outside-In Blended Learning influence junior high school students' mathematical critical thinking skills compared to conventional learning? Is there a difference in the development of mathematical critical thinking skills between students participating in Outside-In Blended Learning and those in conventional learning? Which specific domains show improvement in mathematical critical thinking skills in both groups of students?

This study is expected to provide both theoretical and practical contributions to education, particularly in the development of learning models relevant to 21st-century needs. Theoretically, the findings can expand understanding of the effectiveness and characteristics of Outside-In Blended Learning in enhancing mathematical critical thinking. Practically, the results can serve as a reference for teachers in designing mathematics instruction that is more contextual, adaptive, and technology-based, thereby offering a novel approach as well as a practical solution to improve the quality of mathematics learning at the junior high school level.

Method

This study employed a quasi-experimental method with a nonequivalent control-group design and implemented the Outside-In Blended Learning approach. Table 1 presents a summary of the research procedures, highlighting the differences in treatment between the experimental and control classes as well as the systematically organized stages of the learning activities.

Table 1. Experimental design and learning procedures

Research Stage	Main Activities	Experimental Class	Control Class
Planning	Developing learning materials, instruments, and research schedule	Lesson Plan based on Outside-in Blended Learning	Lesson Plan based on conventional learning
Implementation	Administering the pretest and conducting learning activities according to the design	Combined online–offline learning (outdoor activities and LMS integration)	Full face-to-face classroom learning
Evaluation	Conducting posttest, observation, and analysis of learning outcomes	Assessing the improvement of critical thinking skills	Assessing the improvement of skills through conventional methods

The Outside-In Blended Learning approach is implemented through the systematic integration of learning activities outside and inside the classroom. Out-of-class activities emphasize exploration and contextual tasks to observe, collect data, and solve real-world problems, whereas in-class activities focus on elaboration and reflection through discussions, data analysis, and the construction of mathematical concepts under teacher guidance. The synergy between these two learning environments helps students connect concrete experiences with theoretical understanding, enhancing critical thinking and meaningful problem-solving skills.

The selection of the population and the use of a non-random sampling technique were based on practical considerations and the contextual characteristics of the study. The population was chosen for its relevant attributes, such as academic ability, the implemented curriculum, and learning facilities that support the Outside-In Blended Learning model. A purposive sampling technique was employed to select classes with specific conditions suitable for the experimental treatment, including teacher readiness, class size, and balanced learning schedules. This selection enabled the study to be conducted effectively and in accordance with the field context without disrupting ongoing learning activities (Creswell, 2015; Samura et al., 2022).

The population in this study was taken from students of State Junior High School 1, South Halmahera Regency, Indonesia. The research sample was 78 grade VIII students. The sample was grouped into two classes: experimental and control classes. For the experimental class, the number of students was 39, and the number of students in the control class was 39.

Prior to the implementation of the study, the researcher obtained official approval from the relevant authorities as well as consent from the school, teachers, and students. Each participant was informed about the purpose, procedures, and benefits of the research, while their identities and personal data were kept confidential. Participation was voluntary, and participants were allowed to withdraw at any time without consequence. Accordingly, all stages of the research were conducted responsibly, with full respect for participants' rights, and in compliance with established research ethics.

The mathematical critical thinking test was used as a research instrument and was constructed in alignment with the instructional content, consisting of four open-ended questions based on critical thinking indicators. Validity and reliability testing were first conducted by mathematics teachers with at least a master's degree to evaluate the readability and content appropriateness of the items. The Q-Cochran test was employed to examine the consistency of the validation results.

A readability test was then conducted with several junior high school students in Ternate City to ensure that the items were easily understood as intended. Inter-rater correlations were examined using the Pearson Product Moment, while reliability was assessed using Cronbach's Alpha due to the open-ended format of the test items.

The critical thinking test used in this study covered the topic of linear equations. Prior to conducting the empirical validity test, the items were first examined for face and content validity. The results of the validators' assessments regarding these two forms of validity are presented in Table 2.

Table 2. Summary of the results of the face validity and content validity tests of the mathematical critical thinking ability test

Validity Test	**Statistics**			
	N	***Cochran's Q***	***df***	***Asymp.Sig.***
Face validity	4	2.000[a]	2	0,368
Validity of content	4	1.000[a]	2	0,607

The following are the results of the empirical validity test. Four questions were given to 50 students who were not research samples, as shown in Table 3.

Table 3. Results of the validity test of the critical thinking ability instrument

Question Number	**R Count**	**R Table**	**Sig. (2-tailed)**	**Information**
1	0.954	0.273	0.000	Valid
2	0.941	0.273	0.000	Valid
3	0.940	0.273	0.000	Valid
4	0.923	0.273	0.000	Valid

Considering Table 3, the results of the validity test of the mathematical critical thinking ability test items can be valid. Meanwhile, the consistency of the test items (reliability test) can be shown in Table 4. The Table shows that the Cronbach's Alpha value for the four tested items is 0.955. Based on Guilford's reliability coefficient categories, this value falls within the 'very high' category. This indicates that the mathematical critical thinking test items are highly reliable and possess very strong consistency even when administered repeatedly to students.

Table 4. Reliability test results

Cronbach's Alpha	**N of Items**
.955	4

The data were collected using written open-ended tests, consisting of a pretest and posttest of mathematical critical thinking skills administered to both the experimental and control groups. These tests were used to examine students' improvement in critical thinking as well as the effectiveness of the implementation of the Outside-In Blended Learning approach.

The steps in data processing are data enumeration (complete data collection) and data quality assessment (data if it meets the desired standards). If data loss occurs, data extraction is carried out. This procedure is carried out to anticipate errors in the analysis (Samura & Darhim, 2023). Data enumeration is complete. First, a preliminary analysis is carried out, namely the data normality and variance homogeneity tests. Next;

a. Descriptive statistical measures such as mean, variance, average, and standard error are applied for pretest, posttest, and gain values. Descriptive statistical analysis only provides general information about sample data without performing specific sample calculations for the population.

b. Using inferential statistical analysis, calculating the effect of implementing Outside-In Blended Learning and Conventional Learning on critical mathematical thinking skills.
c. Calculating the increase in students' critical mathematical thinking skills using the Normalized Gain developed by Hake. The N-Gain index criteria are shown in Table 5.

Table 5. Normalized gain score criteria

Normalized Gain Score (g)	Interpretation
$g \geq 0{,}70$	Height
$0{,}30 \leq g < 0{,}70$	Currently
$g < 0{,}30$	Low

d. Calculate the learning effectiveness using the N-gain score (percentage) with the criteria shown in Table 6.

Table 6. Categories of interpretation of N-gain effectiveness

Percent (%)	Interpretation
< 40	Ineffective
40 - 55	Less Effective
56 - 75	Quite Effective
> 76	Effective

e. Calculating the effect sizes of Outside-In Blended Learning on improving students' critical mathematical thinking skills. Cohen's(d) classification of effect sizes is shown in Table 7.

Table 7. Classification of Cohen's(d) effect size

Effect Size	Criteria
$0{,}00 \leq ES < 0{,}20$	Very small
$0{,}20 \leq ES < 0{,}50$	Small
$0{,}50 \leq ES < 0{,}80$	Currently
$0{,}80 \leq ES < 1{,}30$	Height
$1{,}30 \leq ES$	Very large

Results and Discussion

The collected data were analyzed using descriptive and inferential statistics with the assistance of Microsoft Excel and SPSS 21. Descriptive statistics were employed to describe students' mathematical critical thinking abilities before and after the treatment, as well as the degree of improvement. Subsequently, inferential statistics were used to draw conclusions regarding the differences and improvements in abilities between the two classes. The research findings are presented as follows:

How Junior High School Pupils' Mathematics Critical Thinking Abilities are Affected by Traditional and Outside-In Blended Learning

Testing how outside-in blended learning and traditional learning affect students' mathematical critical thinking abilities is the next stage. Prior to the inferential statistical test, two preparatory tests were performed: the variance equality test (homogeneous) and the data normalcy test. The information about normality test results for the Outside-In Blended Learning and traditional learning classes is displayed in Table 8.

Table 8. An overview of the data from the mathematical critical thinking ability normality test

Learning	Test	Shapiro Wilk			Conclusion
		Statistics	df	Sig.	
Outside-In Blended Learning	Pretest	0.945	39	0.058	Normal
	Posttest	0.953	39	0.104	Normal
Conventional	Pretest	0.95	39	0.084	Normal
	Posttest	0.974	39	0.501	Normal

Referring to Table 8, the pretest and posttest results indicate that the Shapiro–Wilk test for both the Outside-In Blended Learning group and the conventional learning group produced normally distributed data, with significance values for both groups exceeding the alpha level of 0.05. Thus, parametric statistical tests such as the paired-sample t-test can be applied. Since the data are normally distributed, a homogeneity test can also be conducted. The results of the homogeneity test are presented in Table 9.

Table 9. An overview of the mathematical critical thinking skill data homogeneity test

	Levene Statistics	df1	df2	Sig.
Pretest	1.867	1	76	0.176
Posttest	5	1	76	0.028

The results of the equality test in Table 9 show differences between the pretest and posttest. In the pretest, the data from the Outside-In Blended Learning group and the traditional learning group were homogeneous. However, in the posttest, the data from the two groups were not homogeneous. Thus, overall, there is no equality (non-homogeneity) between the data from the Outside-In Blended Learning and traditional learning groups.

The research hypotheses have been formulated as follows for students who learn through traditional and outside-in blended learning:

H_0: Mathematical critical thinking abilities are unaffected by the use of outside-in blended learning and traditional learning methods.

H_1: The application of both traditional and outside-in blended learning has an impact on students' critical thinking abilities in mathematics.

The results of the parametric statistical test (paired-sample t-test) used to compare traditional learning and Outside-In Blended Learning are summarized in Table 10.

Table 10. An overview of the mathematical critical thinking skill t-test for paired samples

Learning		Mean	N	Std. Deviation
Outside-In Blended Learning	Posttest	69.31	39	17.977
	Pretest	36.33	39	12.468
Conventional	Posttest	52.31	39	12.759
	Pretest	29.67	39	10.413

The output in Table 10 shows that the mean pretest and posttest scores in the Outside-In Blended Learning group were 36.33 and 69.31, respectively, while in the traditional learning group the corresponding means were 29.67 and 52.31. Descriptively, there is a difference in the mean scores between the pretest and posttest in both groups. To determine whether these differences are significant, the results of the paired-sample t-test in Table 11 must be interpreted.

Table 11. T-test correlations of mathematical critical thinking skills for paired samples

Learning		N	Correlation	Sig.
Outside-In Blended Learning	Posttest & Pretest	39	0.916	0
Conventional	Posttest & Pretest	39	0.723	0

Table 11 presents the results of the correlation test between the pretest and posttest scores. In the Outside-In Blended Learning group, the correlation coefficient is 0.916 with a significance value of 0.000, indicating that the two variables are related. A similar pattern is observed in the traditional learning group, which shows a correlation coefficient of 0.723 with a significance value of 0.000. A summary of the paired-samples test is presented in Table 12.

Table 12. An overview of the mathematical critical thinking skill t-test for paired samples

Learning		Paired Differences			Sig. (2-tailed)
		Mean	95% Confidence Interval of the Difference		
			Lower	Upper	
Outside-In Blended Learning	Posttest - Pretest	32.974	30.305	35.644	0.000
Conventional	Posttest - Pretest	22.641	19.759	25.523	0.000

Based on Table 12, the Sig. (2-tailed) value for the Outside-In Blended Learning group is $0.000 < 0.05$, indicating that H_0 is rejected and H_1 is accepted. This demonstrates a mean difference between the pretest and posttest scores, suggesting that the Outside-In Blended Learning approach affects students' mathematical critical thinking skills. The same applies to the conventional learning group, with a Sig. (2-tailed) value of $0.000 < 0.05$, indicating a mean difference that shows traditional instruction also influences mathematical critical thinking skills.

In the Outside-In Blended Learning group, the Mean Paired Difference was 32.974, indicating the average difference between the posttest and pretest scores, with a 95% confidence interval ranging from 30.305 to 35.644. In the traditional learning group, the Mean Paired Difference was 22.641, with a 95% confidence interval ranging from 19.759 to 25.523, reflecting the average difference between the posttest and pretest scores. This test measures the extent to which students' mathematical critical thinking skills are influenced by the Outside-In Blended Learning approach and traditional instruction. The effect size was calculated using Cohen's d, and the results of the calculation are summarized in Table 13.

Table 13. Cohen's(d) Effect Sizes Calculation Results

Learning	Effect Size	Category
Outside-In Blended Learning	2.131909	Very large
Conventional	1.944144	Very large

The calculations presented in Table 13 indicate that the implementation of the Outside-In Blended Learning approach yields a significant impact on students' mathematical critical thinking skills. Traditional instruction also demonstrates a significant effect. Thus, each instructional session has the potential to enhance students' abilities.

Disparities in Students' Development of Mathematical Critical Thinking Skills in Conventional and Outside-In Blended Learning

This section evaluates the differences in the improvement of mathematical critical thinking skills between the two instructional treatments. Prior to the analysis, a hypothesis was formulated stating that students who participate in the Outside-In Blended Learning approach will experience greater improvement in their mathematical critical thinking abilities compared to those who learn through traditional instruction.

The results of the normality test indicate that the data on students' mathematical critical thinking skills in both the Outside-In Blended Learning and traditional learning groups are normally distributed (see Table 8). Meanwhile, the homogeneity test shows that the data from the two instructional approaches are not homogeneous (see Table 9). Before conducting the parametric statistical test (independent sample t-test), the statistical hypothesis was established to assess the differences in the improvement of students' mathematical critical thinking skills.

H_0: $\mu_1 = \mu_2$

H_1: $\mu_1 > \mu_2$

Information:

μ_1: The mean score of students who took part in Outside-In Blended Learning in terms of mathematical critical thinking abilities.

$\boldsymbol{\mu_2}$: The mean score of pupils who engaged in traditional instruction in mathematical critical thinking.

The statistical hypothesis test was conducted using an Independent Samples T-test on the data from students who participated in Outside-In Blended Learning and traditional instruction, which exhibited different means but non-homogeneous variances. The 'Equal variances not assumed' table was used as a guide for interpretation. This test compares the mean improvement in critical thinking skills under unequal variances, where H_1 is rejected and H_0 is accepted if Sig. (2-tailed) > 0.05. The summary of the test results is presented in Table 14.

Table 14. An overview of the t-test of variations in the development of mathematical critical thinking skills

Group		t-test for Equality of Means t	df	Sig. (2-tailed)	Conclusion
Posttest	Equal variances not assumed				Reject H_0
Gain Score Value	Equal variances not assumed	5,764	66,394	0,000	Reject H_o

Based on Table 14, the Sig. (2-tailed) values for the N-Gain score and posttest are 0.00 < 0.05, indicating that H_1 is accepted and H_0 is rejected. This demonstrates that students who participated in the Outside-In Blended Learning approach achieved higher average scores compared to those in traditional instruction, suggesting that this method is more effective in enhancing mathematical critical thinking skills at SMP Negeri 1 Halmahera Selatan.

Students that Engage in Outside-In Blended Learning and Traditional Learning Experience an Improvement in Their Mathematical Critical Thinking Abilities

The results of the prerequisite tests indicate that the data are normally distributed. The Normalized Gain values can be used to assess the improvement in students' mathematical critical thinking skills using parametric statistics, specifically the paired-samples t-test. The results of the Gain Value test are presented in Table 15.

Table 15. An overview of the results of the gain score calculation

Value	Learning	Statistical Test	
Gain Value Score	Outside-In Blended Learning	Minimum	0.2
		Maximum	0.94
		Mean	0.5493
		Std. Deviation	0.20023
	Conventional	Minimum	0
		Maximum	0.58
		Mean	0.3269
		Std. Deviation	0.13415

Based on Table 15, students who participated in the Outside-In Blended Learning approach had an average Gain Value of 0.5493 (SD = 0.20023), with the lowest and highest scores being 0.20 and 0.94, respectively. In contrast, students in the traditional learning group had an average Gain Value of 0.3269 (SD = 0.13415), with scores ranging from 0.00 to 0.58. The improvement in mathematical critical thinking skills is classified as moderate for both methods, but it is higher in the Outside-In Blended Learning group.

The Gain Score percentage was used to compare the effectiveness of the Outside-In Blended Learning approach and traditional instruction in enhancing students' mathematical critical thinking skills, with the calculation results presented in Table 16.

Table 16. Summary of gain score calculation results

Value	Learning	Statistical Test	
Gain Score Value (%)	Outside-In Blended Learning	Minimum	19.54
		Maximum	94
		Mean	54.9342
	Conventional	Minimum	0
		Maximum	58.49
		Mean	32.6899

Based on Table 16, the average N-gain for students in the Outside-In Blended Learning group was 54.93% (categorized as less successful), with scores ranging from 19.54% to 94%, while the traditional learning group had an average N-gain of 32.69% (categorized as unsuccessful), with scores ranging from 0.00% to 58.49%. Thus, although the Outside-In Blended Learning approach is more effective than traditional instruction, both methods remain suboptimal in enhancing students' mathematical critical thinking skills.

This study discussion highlights the improvement of students' mathematical critical thinking skills through both traditional instruction and the Outside-In Blended Learning approach. The traditional class was used as a comparison to evaluate the effectiveness of Outside-In Blended Learning, with relevant analyses connected to theory and findings from other studies at SMP Negeri 1 Halmahera Selatan.

Based on the analysis results, there is a significant difference between the mean pretest and posttest scores in both the Outside-In Blended Learning and traditional instruction groups, with greater improvement observed in the posttest. This indicates that students' mathematical critical thinking skills are influenced by the instructional method. According to Slavin et al. (2003) and Creswell (2015), comparing pretest and posttest means is an important tool for assessing the effectiveness of a teaching method or intervention, provided that the tests are valid and reliable.

The Outside-In Blended Learning strategy in the experimental class integrates learning resources and instructional strategies in accordance with the pedagogical framework. This approach combines real-world experiences and external perspectives with both in-class and out-of-class learning, such as field studies, case studies, and real-world problem solving, to create a holistic and practical learning experience and develop students into critical thinkers who can easily adapt to real-world knowledge (Baidoo & Luneta, 2024; Canbulat & Uzun, 2024). The instructional material was delivered through various individual, group, pair, and whole-class activities, providing students with opportunities to develop concepts, procedures, and principles in solving mathematical problems. Each exercise began with the presentation of a problem to stimulate students' thinking activities (Qassim et al., 2023; Cannon et al., 2023).

According to the learning theory underpinning this approach (Shurygin et al., 2024), stimulus factors are crucial for triggering a sequence of mental activities consisting of action-process-object-scheme. Linear equation instruction was conducted outside the classroom to allow students to observe the environment, relate objects to the concepts of line equations and slope, and engage in activities such as surveying or analyzing using linear equations. Through the Outside-In Blended Learning approach, the material was presented as mathematical problems that challenge the thinking process and the formation of new mental objects (Nizaruddin & Kusmaryono, 2023; Dahiana et al., 2024). Vygotsky's learning theory (Seon-Mi & Kellogg, 2022) emphasizes that social and cultural environments greatly influence learning and development. Learning occurs through active interaction with others, and interaction patterns are structured so that each student can express their mental activities and facilitate peer-to-peer communication (Smolucha & Smolucha, 2021). This type of activity supports the learning process, allowing students to reflect on their achievements, gain inspiration for further mental exercises, and express their mental activities both orally and in writing (Aisyah et al., 2023; Fleer, 2024).

Quantitative analysis indicates that students' abilities vary, influenced by the way the teacher delivers the material. In the Outside-In Blended Learning approach, students first engage in out-of-class learning, then continue in-class instruction using modules or learning platforms, participate in small group discussions, and solve problems through discussion, Q&A sessions, and argumentation. In contrast, in conventional instruction, the teacher serves as the focal point of learning activities through lectures and demonstrations. According to Bruner's theory of cognitive development (Cory & Ray, 2023), learning is more effective when students discover information independently, an approach adapted in the discovery learning model to promote self-directed learning (Tanjung et al., 2024; Siregar, 2023).

The results of the Paired Samples T-Test indicate that both the Outside-In Blended Learning approach and conventional instruction have a significant effect on students' mathematical critical thinking skills. Samura and Darhim (2023) demonstrated that GeoGebra-assisted blended learning enhances mathematical critical thinking abilities. Blended learning connects traditional teaching with the demands of modern education (Özdemir, 2023) and, through the Outside-In approach, is particularly relevant for secondary education by preparing students for the workforce and integrating practical skills in accordance with industry and technological requirements (Baidoo & Luneta, 2024; Tsui & Mok, 2024).

The N-Gain analysis results indicate that students' mathematical critical thinking abilities moderately increased through both conventional learning and Outside-In Blended Learning. However, the effectiveness of Outside-In Blended Learning compared to traditional learning is considered limited, as traditional learning often fails to cultivate perseverance, diligence, and reflective motivation that support mathematical critical thinking. This aligns with Hutauruk & Priatna (2017), who argue that critical thinking requires persistence, enthusiasm, and resilience, not merely completing mathematical content tasks. Meanwhile, Hasanah and Malik (2020) found that blended learning is effective in enhancing critical thinking and communication skills. The results of the independent-samples t-test also confirm a significant difference in critical thinking and communication abilities between the experimental and control classes.

The Outside-In Blended Learning approach significantly enhances students' critical thinking skills through authentic experiences and structured academic reflection. This model initiates learning from contextual experiences, presenting authentic problems that reflect real-world situations. Through initial exploration outside the classroom, students are encouraged to observe, inquire, and interpret phenomena independently. When these experiences are brought into the classroom, learning focuses on critical analysis and reflection, where students evaluate findings, compare them with theoretical frameworks, and construct logical arguments. This process promotes the development of deep understanding by synthesizing empirical experiences and conceptual knowledge (Rahmi & Azrul, 2022).

The implementation of Outside-In Blended Learning creates a collaborative and reflective learning environment that supports the development of higher-order critical thinking skills. Activities such as online group discussions, project-based problem solving, and interactive feedback help students enhance their analytical, reasoning, and decision-making abilities. This approach also fosters metacognitive awareness, whereby students evaluate the validity of their own arguments and consider multiple perspectives. Consequently, Outside-In Blended Learning not only strengthens the cognitive dimension of critical thinking but also cultivates critical dispositions, including curiosity, openness to new ideas, and intellectual responsibility (Rizki et al., 2023; Stone, 1985).

The Outside-In Blended Learning approach has a significant impact on students' critical thinking abilities compared to conventional methods or technology-based blended learning that are not connected to real-world experiences. Theoretically, this approach aligns with Vygotsky’s social constructivist theory and Kolb’s experiential learning theory, which emphasize knowledge construction through social interaction and reflection on authentic experiences. Learning begins with real-world situations outside the classroom, which are then critically analyzed within the classroom, resulting in a synthesis of empirical experiences and conceptual reasoning. These findings highlight the need for educators to design learning experiences that integrate both physical and digital spaces while remaining relevant to students’ life contexts. Consequently, Outside-In Blended Learning expands the concept of blended learning and offers a more reflective, contextual, and critical-thinking-oriented pedagogical direction (Setiawan et al., 2022).

Conclusion

The implementation of Outside-In Blended Learning at SMP Negeri 1 Halmahera Selatan significantly enhances students' mathematical critical thinking skills compared to conventional learning. This model connects mathematical concepts with real-world situations outside the classroom, making students' thinking processes more analytical and reflective. Students are encouraged to observe, interpret, and develop solutions based on conceptual understanding, which is further reinforced through in-class discussions and reflection. In contrast, traditional teacher-centered learning limits opportunities for exploration and critical reasoning, whereas the Outside-In approach promotes conceptual understanding, logical reasoning, evaluation of mathematical arguments, and creative, context-based problem-solving strategies.

There is a clear gap in the development of students' mathematical critical thinking skills between conventional learning and Outside-In Blended Learning. Conventional learning is often limited to the application of technology in the classroom without connection to real-world contexts, causing students to merely follow procedures and formulas without deep analysis. In contrast, Outside-In Blended Learning provides authentic experiences through contextual problems outside the classroom, which stimulate logical, evaluative, and creative thinking, subsequently analyzed and reflected upon in class. Thus, conventional learning does not fully optimize students' critical thinking potential, whereas Outside-In Blended Learning is more effective in fostering analytical and reflective thinking patterns.

Students participating in both Outside-In Blended Learning and conventional learning demonstrate improvements in mathematical critical thinking skills, although the degree of development differs. Both approaches provide opportunities to deepen conceptual understanding, practice logical reasoning, and enhance problem-solving skills. However, the improvement among students in the Outside-In Blended Learning model is more significant, as it integrates real-world experiences outside the classroom with conceptual analysis in class, promoting reflective, evaluative, and creative thinking. Meanwhile, conventional learning reinforces foundational knowledge and procedural skills but is less effective in developing deeper dimensions of critical thinking. Thus, while both approaches contribute to mathematical critical thinking abilities, Outside-In Blended Learning exerts a more comprehensive and contextually meaningful impact.

This study has several limitations, including a small sample size and being conducted at a single junior high school, which limits the generalizability of the findings. The relatively short duration of the intervention may also not reflect the long-term impact of implementing Outside-In Blended Learning on students' mathematical critical thinking skills. In addition, the study focused solely on the cognitive aspect without exploring affective dimensions or motivation, which may influence learning outcomes. Therefore, future research is recommended to use larger and more diverse samples, extend the duration of implementation, and include additional variables such as creativity, learning motivation, and student collaboration to gain a more comprehensive understanding of the effectiveness of the Outside-In approach.

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