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Investigating The Impact of the 3cm Model on Enhancing Students' Critical Thinking Skills

Nur Janah[a,1], Ifa Fauziah[b,2], Deny Hadi Siswanto[c,3]
[a] Master of Mathematics Education, Ahmad Dahlan University, Yogyakarta, Indonesia
[b] Indonesian Language and Literature, Gadjah Mada University, Sleman, Indonesia
[c] Muhammadiyah Mlati Senior High School, Sleman, Indonesia
[1] 2207050009@webmail.uad.ac.id; [2] ifafauziah@mail.ugm.ac.id; [3] denysiswanto11@guru.sma.belajar.id

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ABSTRACT
This research aims to assess the effect of the Cool, Critical, Creative, and Meaningful (3CM) learning model in improving students' critical thinking skills on the topic of matrices. A quantitative approach was used, employing a pre-experimental design with a one-group pretest-posttest format. The study involved 30 11th-grade science students from SMA Muhammadiyah Mlati. The instruments for this research included a critical thinking skills test based on the indicators of Focus, Reason, Inference, Situation, Clarity, and Overview, as well as a student perception questionnaire regarding the 3CM learning model. The validity and reliability tests showed that all instruments were valid and reliable. Tests for normality and linearity confirmed that the data were normally distributed and exhibited a significant linear relationship. Regression analysis demonstrated a positive and significant correlation between the 3CM model and students' critical thinking skills (sig. = 0.003 < 0.05), with the model explaining 27.7% of the variance. The average pretest score of 61.56 increased to 85.80 in the posttest, with the greatest improvement observed in the Situation indicator. These findings indicate that the 3CM model is effective in enhancing students' critical thinking skills and contributes to the development of innovative teaching strategies in mathematics education.

Keywords: 3CM Model, Critical Thinking Skills, Matrix

Corresponding Author:
Nur Janah, Ahmad Dahlan University
2207050009@webmail.uad.ac.id

INTRODUCTION
Critical thinking skills are essential competencies that students must possess to face the challenges of the 21st century [1]. These skills enable students to analyze information, evaluate arguments, and solve problems logically and systematically. In the context of mathematics education, critical thinking is crucial not only for memorizing formulas but also for understanding concepts, identifying relationships among them, and applying them in more complex situations [2]. Unfortunately, students' critical thinking abilities remain relatively low, particularly when dealing with abstract mathematical content such as matrices, which require deep reasoning and analytical thinking for proper understanding and application.

Matrices are a fundamental topic in the high school mathematics curriculum, particularly for Grade XI, due to their connection to other concepts such as systems of linear equations, geometric transformations, and applications in various fields of science and technology [3],[4]. However, many students find matrices difficult to understand because of their symbolic and abstract nature, leading to low motivation and difficulties in organizing steps to solve problems [5]. This issue is further exacerbated by conventional teaching methods that are still dominant in classrooms, which offer little space for students to explore and reflect critically, resulting in teacher-centered learning with minimal student interaction [6].

Therefore, a learning model is needed that not only delivers content in a one-way manner but also encourages students' active participation in each stage of learning. Active participation is key to fostering critical thinking habits, where students are encouraged to observe, question, and evaluate information more deeply [7]. When actively involved, students are not merely passive recipients of knowledge but become constructors of their own understanding based on experience and reflection. In 21st-century education, critical thinking is a vital competence that must be developed to prepare students for the complexities of life and the rapid, diverse flow of information [8].

One promising model for enhancing critical thinking skills is the Cool, Critical, Creative, and Meaningful (3CM) learning model. This model is designed to create an enjoyable learning atmosphere (cool), encourage analysis and evaluation (critical), stimulate original thinking (creative), and emphasize meaningfulness in the learning process (meaningful) [9]. By combining these four aspects, the 3CM model provides a broad space for students to explore ideas, question assumptions, and develop higher-order thinking skills [10]. Teachers act as facilitators who guide the learning process flexibly, fostering dialogical, collaborative interactions that empower students' thinking abilities [11].

The 3CM model emphasizes meaning-making through an approach that links students' prior knowledge to new concepts being learned [12]. Students are encouraged to construct new understanding through exploration and discussion, and to verify information critically through reflection and testing. This process positions students as active learners who are given opportunities to develop independent and responsible thinking. The stages of this model guide students to ask questions, express ideas, and reflect on their thinking more systematically and deeply, making the learning experience more enjoyable, personally meaningful, and impactful on learning outcomes.

Previous studies Abidah et al. [13] have shown that the 3CM model can have a positive impact on conceptual understanding and higher-order thinking skills. Students engaged in learning with this model tend to be more active, reflective, and capable of constructing logical arguments. However, studies specifically examining the impact of the 3CM model on students' critical thinking skills in the topic of matrices remain scarce [14]. This presents an opportunity for further research to determine the effectiveness of the 3CM model in the context of mathematics learning, especially in abstract and challenging topics like matrices. The 3CM model is also in line with the Merdeka Curriculum approach, which emphasizes learner autonomy and the development of higher-order thinking competencies. In this approach, students are positioned as active agents in constructing knowledge through structured and meaningful processes, while teachers act as facilitators who help students explore and develop their understanding independently [15], [16].

Therefore, the implementation of the 3CM model in mathematics education is expected to create a fun, challenging learning environment that encourages students to think critically and improves the quality of instruction [17]. This study aims to investigate the impact of applying the 3CM model on improving students' critical thinking skills in the matrix topic and to describe how the learning process through this model can support students in developing a

deeper understanding. The results of this study are expected to contribute to the development of innovative instructional models that can improve the quality of mathematics learning at the secondary school level.

METHOD

This study employs a quantitative approach with a one-group pretest-posttest pre-experimental design to examine the effect of the 3CM model on improving students' critical thinking skills in matrix material. The research subjects were 30 eleventh-grade science students at SMA Muhammadiyah Mlati, selected using a non-probability sampling technique. The research instruments included a questionnaire (5-point Likert scale) consisting of 10 items to measure students' perceptions of the 3CM-based learning model and a critical thinking skills test consisting of 5 questions, developed based on Ennis [18] indicators: Focus, Reason, Inference, Situation, Clarity, and Overview. The research procedure consisted of three stages: preparation (instrument validation), implementation (pretest administration, 3CM model-based learning, and posttest administration), and data analysis. The data were analyzed using SPSS-25 through validity, reliability, normality, regression, and gain tests to determine the contribution and improvement of students' numeracy skills following the intervention.

The implementation of the 3CM learning model in this study was conducted through several structured learning stages adapted to the characteristics of matrix material. In the *Cool* stage, the teacher created an engaging and supportive learning atmosphere by presenting contextual problems related to matrices to stimulate students' interest and motivation. In the *Critical* stage, students were encouraged to analyze problems, identify relevant concepts, and discuss possible solution strategies collaboratively. During the *Creative* stage, students developed alternative methods and explored various ways to solve matrix problems independently or in groups. Finally, in the *Meaningful* stage, students reflected on the learning process and connected the concepts learned with real-life applications to strengthen conceptual understanding and long-term retention.

To analyze the improvement in students' critical thinking skills, descriptive and inferential statistical analyses were employed. Descriptive statistics were used to determine the mean scores of the pretest and posttest results for each critical thinking indicator, while inferential statistics were conducted through simple linear regression analysis to examine the effect of the 3CM learning model on students' critical thinking skills. In addition, gain score analysis was used to identify the extent of students' improvement after the intervention. The interpretation of the results was carried out by comparing the statistical findings with relevant theories and previous studies concerning critical thinking and innovative mathematics learning models.

RESULTS AND DISCUSSION

Results

The validity test was conducted prior to the implementation of the research or before the collection of pretest and posttest data. This process aimed to ensure that the instruments used accurately measured the intended variables. In this study, validity and reliability tests were carried out using SPSS-25 software. The instruments were tested on twelfth-grade science students at SMA Muhammadiyah Mlati who had previously studied the relevant material. An item was considered valid if the Pearson correlation coefficient (r_{count}) was greater than the r_{table} value, and deemed reliable if the significance value of Cronbach's Alpha was greater than 0.05. Table 1 presents the results of the validity and reliability tests for the questionnaire and test instruments using SPSS-25.

Table 1. Hasil Uji Validitas danReliabilitas

Test			Questionnaire		
Items	**r_{count}**	**Sig.**	**Items**	**r_{count}**	**Sig.**
1	0,433	0,312	1	0,523	0,423
2	0,456		2	0,498	
3	0,543		3	0,642	
4	0,395		4	0,543	
5	0,443		5	0,502	
			6	0,621	
			7	0,588	
			8	0,654	
			9	0,559	
			10	0,546	

Based on Table 1, it can be seen that all items in both the questionnaire and the test are declared valid, as the r_{count} values for all items exceed the r_{table} value (0.361). Furthermore, the reliability test results show that the significance value for the questionnaire instrument is 0.423 > 0.05, and for the test instrument is 0.312 > 0.05. Therefore, both instruments are considered valid and reliable, and thus suitable for use in this study. Before the learning implementation, students first completed a pretest, then participated in classroom instruction using the 3CM model, followed by completing the provided questionnaire, and finally taking the posttest. After the data were collected, a normality test was conducted, with the results presented in table 2.

Table 2. Normalitas Test Result

		Unstandardized Residual
N		30
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	5.33015245
Most Extreme Differences	Absolute	.103
	Positive	.078
	Negative	-.103
Test Statistic		.103
Asymp. Sig. (2-tailed)		.200[c,d]

Based on table 2, it can be observed that the Asymp. Sig. (2-tailed) value is 0.200 > 0.05, indicating that the data are normally distributed. Subsequently, a linearity test will be conducted to determine whether the sample data come from a population with the same level of variability. The results of the test are presented in table 3.

Table 3. Linearity Test Results

		Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	(Combined)	521.871	7	74.553	2.659	.037
	Linearity	314.895	1	314.895	11.229	.003
	Deviation from Linearity	206.977	6	34.496	1.230	.329
Within Groups		616.929	22	28.042		
Total		1138.800	29			

Based on table 3, it can be seen that the significance value for Deviation from Linearity is 0.329 > 0.05, indicating that there is a significant linear relationship between the

implementation of the 3CM model and students' critical thinking skills. The next step is to determine the regression coefficient, as shown in table 4.

Table 4. Regression coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	22.135	18.998		1.165	.254
	3CM Model	.008	.003	.526	3.271	.003

Based on Table 4 above, the significance value is 0.003, which is less than 0.05. This indicates that there is a positive and statistically significant relationship between the implementation of the 3CM model and students' critical thinking skills. The magnitude of the effect of the 3CM model implementation on students' critical thinking ability can be further examined in Table 5.

Table 5. Magnitude of influence

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.526[a]	.277	.251	5.42450

Based on Table 5, the R Square value is 0.277, indicating that pocket money contributes 27.7% to students' motivation to learn mathematics, while the remaining 72.3% is influenced by other factors not examined in this study. Meanwhile, the improvement in students' critical thinking skills can be observed from their pretest and posttest scores as shown in the following figure.

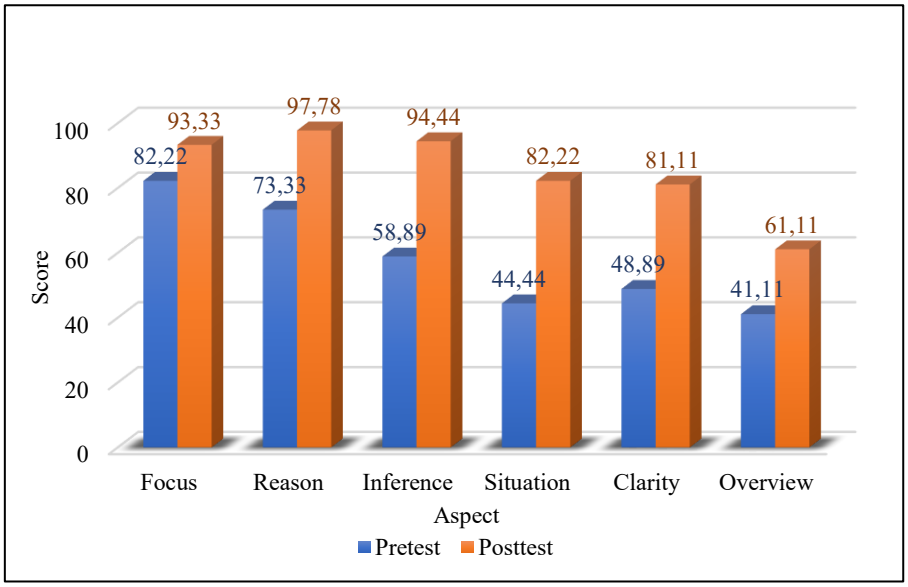

Figure 1. Improving Critical Thinking Skills

Based on the figure above, the pretest and posttest results across six aspects of critical thinking skills show that the highest posttest score was in the Inference aspect, reaching 94.44, while the lowest pretest score was in the Overview aspect, with a score of 41.11. The average pretest score was approximately 61.56, which increased to around 85.80 in the posttest. The greatest improvement occurred in the Situation aspect, rising from 44.44 (pretest) to 82.22

(posttest), representing a 37.78-point increase. Meanwhile, the smallest improvement was in the Focus aspect, which increased by only 11.11 points from 82.22 to 93.33. Overall, these results indicate a significant enhancement in students' critical thinking skills following the instructional intervention.

Discussion

The results of this study indicate that the instruments used have met the criteria for validity and reliability based on tests conducted using SPSS-25. All items in both the test and questionnaire instruments had r_{count} values greater than the r_{table} (0.361), and the Cronbach's Alpha significance values exceeded 0.05. This signifies that the measuring instruments consistently and accurately assess the variable under study, namely students' critical thinking skills. Validity and reliability testing is a crucial step in quantitative research to ensure that the data collected genuinely reflects actual conditions in the field. These aspects are essential as a foundation for proceeding to statistical data analysis; if the instruments are invalid, then the conclusions drawn may also be misleading.

Further data analysis showed that the data were normally distributed, as indicated by the Asymp. Sig. value of 0.200 > 0.05. The linearity test also confirmed a significant linear relationship between the independent and dependent variables, with the deviation from linearity significance value of 0.329 > 0.05. Therefore, the statistical approach used in this study is valid, and the linear regression model is appropriate to examine the effect of the 3CM learning model on critical thinking skills. The regression test results revealed a positive and significant relationship between the implementation of the 3CM model and the improvement of students' critical thinking skills, with a significance value of 0.003 < 0.05. This is further supported by an R Square value of 0.277, which means that the model accounts for 27.7% of the improvement in critical thinking skills, while the remaining 72.3% is influenced by other external factors not examined in this study.

The pretest and posttest data covering six aspects of critical thinking (Focus, Reason, Inference, Situation, Clarity, and Overview) demonstrated a significant increase. The greatest improvement was observed in the Situation aspect (an increase of 37.78 points), while the smallest improvement occurred in the Focus aspect (an increase of 11.11 points). This reflects that the 3CM learning model is capable of enhancing various aspects of critical thinking in a balanced manner, although its effect is more pronounced on those initially scoring lower. The increase in the average score from 61.56 to 85.80 reflects the model's effectiveness in stimulating students to think more deeply, structurally, and analytically. These findings are in line with the study by Ariza et al. [19] and Adhelacahya et al. [20], which suggests that learning strategies emphasizing exploration and active student engagement significantly enhance dimensions of critical thinking.

The Caring, Critical, Creative and Meaningful model (3CM) is highly aligned with the principles of the Merdeka Curriculum, which emphasizes differentiated instruction, project-based learning, and the development of students' character and competencies. In this context, the 3CM model does not only address cognitive aspects but also integrates affective and conative domains, supporting the implementation of the Pancasila Student Profile. Learning becomes more meaningful as students are encouraged to understand problems in real-life contexts, think critically to solve them, and demonstrate social awareness toward their environment. This study supports the findings of Kintoko [21] and Wahyudi et al. [22], who stated that holistic approaches like 3CM foster 21st-century skills, including critical thinking, collaboration, and creativity.

Moreover, the improvement in the Situation and Inference aspects of critical thinking shows that the 3CM model effectively hones students' abilities to understand the context of

problems and draw logical conclusions from available information. This is especially important in the digital age, where students are exposed to a wide range of complex information and need critical thinking skills to filter, evaluate, and use it wisely [23], [24]. These skills are also integral to the literacy- and numeracy-based national assessments introduced by the Ministry of Education and Culture through the Merdeka Curriculum, which focuses not only on content mastery but also on essential competency development [25], [26].

Therefore, this study makes a tangible contribution to the field of education, particularly in efforts to improve students' critical thinking skills through the application of an innovative learning model that aligns with the direction of the Merdeka Curriculum. The findings may serve as a reference for teachers and education practitioners in designing learning experiences that not only deliver content but also train students to think, feel, and act critically and creatively. Further research is strongly recommended to explore other factors that may influence the enhancement of critical thinking skills, such as students' backgrounds, teacher approaches, and the use of educational technology.

Furthermore, the effectiveness of the 3CM model can also be explained through the constructivist learning perspective, where students actively build knowledge through interaction, exploration, and reflection. In the learning process, students were encouraged to analyze matrix-related problems collaboratively, communicate their reasoning, and evaluate alternative solutions critically. Such learning conditions provide opportunities for students to develop metacognitive awareness, particularly in monitoring and evaluating their own thinking processes. This finding aligns with previous studies indicating that student-centered learning environments significantly contribute to the development of higher-order thinking skills, especially when learners are actively involved in inquiry-based and reflective activities. The enjoyable and meaningful learning atmosphere promoted by the 3CM model also increases students' motivation and confidence in expressing ideas, which ultimately supports the improvement of critical thinking performance.

In addition, the findings of this study imply that mathematics instruction should no longer focus solely on procedural mastery but should also facilitate students in developing analytical and evaluative thinking skills. The implementation of the 3CM model demonstrates that innovative instructional approaches can transform abstract mathematical concepts, such as matrices, into more contextual and understandable learning experiences. Through meaningful engagement and creative problem-solving activities, students become more capable of connecting mathematical concepts with real-life situations. Therefore, teachers are encouraged to integrate learning models that emphasize critical, creative, and meaningful learning experiences into classroom practice. Such efforts are expected not only to improve academic achievement but also to prepare students with essential competencies needed to face future educational and societal challenges.

CONCLUSION

Based on the research findings, it can be concluded that the instruments used to measure students' critical thinking skills have met the requirements for validity and reliability, making them suitable for data collection. The data obtained were also normally distributed and demonstrated a significant linear relationship between the independent and dependent variables, thereby allowing the use of a linear regression model. The regression results indicated that the implementation of the 3CM learning model had a positive and significant effect on the improvement of students' critical thinking skills, contributing 27.7%. The increase in pretest to posttest scores across all aspects of critical thinking suggests that the model is effective in stimulating deeper thinking skills, particularly in aspects that were previously

lower. The implication of these findings is that teachers may consider adopting the 3CM model as an innovative instructional approach that not only enhances students' emotional and creative engagement but also significantly improves critical thinking skillsan essential competence in addressing the challenges of 21st-century learning

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORS

Nur Janah is a Master's student in Mathematics Education at Ahmad Dahlan University. As an educator, she is committed to designing innovative and effective teaching methods to enhance student participation and understanding. She actively monitors the learning progress of each student to ensure they receive the guidance needed to achieve academic success. She can be contacted via email at 2207050009@webmail.uad.ac.id.

Ifa Fauziah is a student of Indonesian language and literature study program at Universitas Gadjah Mada. She has a deep interest in fiction writing and is active in various social community activities. She can be contacted via email: ifafauziah@mail.ugm.ac.id.

Deny Hadi Siswanto is a Mathematics teacher at SMA Muhammadiyah Mlati. As a teacher, he is actively involved in developing teaching materials such as modules, worksheets, and effective classroom activities. In addition, he is actively participating in extracurricular activities, such as joining the teacher movement program in Sleman Regency. He can be contacted via email at denysiswanto11@guru.sma.belajar.id.