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Enhancing mathematical critical thinking through the core instructional model: The role of emotional intelligence

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Abstract

This study investigates the effects of the CORE instructional model on enhancing students' critical thinking skills in mathematics, focusing on the moderating role of emotional intelligence. Critical thinking and emotional intelligence are pivotal in mathematics education, enabling students to analyze, evaluate, and solve complex problems while managing cognitive and emotional challenges. Despite their importance, traditional teaching methods often fail to address these dimensions effectively, necessitating innovative pedagogical approaches. A quasi-experimental design was employed to compare the effectiveness of the CORE model with conventional teaching methods among eighth-grade students. The study also examined the interaction between teaching methods and emotional intelligence levels. Data were collected through a critical thinking test and an emotional intelligence questionnaire, analyzed using descriptive and inferential statistics. Results showed that the CORE model significantly outperformed conventional methods in fostering critical thinking skills. Students with higher emotional intelligence achieved superior outcomes under the CORE model, leveraging self-regulation and reflective practices. Even students with lower emotional intelligence showed notable improvements compared to traditional methods. These findings highlight the importance of integrating cognitive and emotional dimensions into instruction. This study contributes to educational research by demonstrating the CORE model's efficacy and offering insights into its alignment with emotional intelligence. Implications for tailored instructional strategies and future research directions are discussed.

Keywords: CORE Instructional Model; Critical Thinking in Mathematics; Emotional Intelligence in Education; Experimental design

1. Introduction

Mathematics education plays a pivotal role in developing critical thinking skills, which are essential for solving complex problems in the 21st century. Critical thinking in mathematics encompasses activities such as analyzing, evaluating, and synthesizing information to draw reasoned conclusions. These skills are crucial for students to navigate not only academic challenges but also real-world applications of mathematical concepts. However, the development of critical thinking in mathematics remains a significant challenge, particularly in secondary education. Many students view mathematics as a difficult and abstract subject, which often leads to disengagement and poor performance. This perception is corroborated by studies such as those by Susandi et al. (2022), who reported that students often struggle with understanding, analyzing, and solving mathematical problems, with average critical thinking proficiency being alarmingly low at only 17.71%.

Emotional intelligence (EI) has emerged as a critical factor influencing students' engagement and success in mathematics. Emotional intelligence, which encompasses the ability to recognize, manage, and utilize emotions effectively, has been shown to enhance motivation, foster positive attitudes, and mitigate the stress associated with learning challenging subjects like mathematics (Reinhold et al., 2021). A growing body of research highlights the

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interplay between emotional intelligence and critical thinking. Students with high emotional intelligence are better equipped to manage their anxieties, maintain focus, and engage in reflective thought processes, which are essential for mathematical problem-solving (Goleman, 2021). This connection underscores the need for instructional models that address both cognitive and emotional aspects of learning.

Despite the recognized importance of critical thinking and emotional intelligence in mathematics education, traditional teaching methods often fail to address these aspects adequately. Conventional approaches, which rely heavily on teacher-centered lectures, provide limited opportunities for students to engage actively with the material or develop higher-order thinking skills. As observed by Hussein et al. (2019), such methods tend to produce passive learners who are poorly equipped to handle complex problem-solving tasks. Consequently, innovative pedagogical models are necessary to foster both critical thinking and emotional intelligence effectively.

One promising solution to this challenge is the implementation of student-centered learning models that emphasize active engagement and cognitive development. The CORE (Connecting, Organizing, Reflecting, Extending) instructional model, rooted in constructivist learning theory, represents one such approach. This model encourages students to connect prior knowledge with new information, organize and reflect on their learning, and extend their understanding through practical applications. By actively involving students in the learning process, the CORE model aims to develop critical thinking skills and foster deeper understanding. Research by Putri et al. (2020) supports the efficacy of this approach, demonstrating that the CORE model significantly enhances students' ability to analyze and solve mathematical problems.

The CORE model's alignment with emotional intelligence also makes it particularly suitable for mathematics education. Its reflective and interactive components provide students with opportunities to manage their emotions, collaborate with peers, and develop empathy, all of which are integral to emotional intelligence. For instance, Huang et al. (2021) highlighted that students who engage in collaborative and reflective learning activities are better able to regulate their emotions and maintain motivation. Furthermore, the model's emphasis on active participation and problem-solving aligns well with the cognitive and emotional demands of critical thinking, as described by Faridi et al. (2021).

However, while the CORE model has shown promise in enhancing critical thinking and emotional intelligence, research on its application in mathematics education remains limited. Most existing studies focus on general educational outcomes rather than specific competencies such as critical thinking in mathematics. Additionally, the interaction between the CORE model and students' emotional intelligence levels has not been thoroughly explored. This gap in the literature highlights the need for further investigation into the effectiveness of the CORE model in addressing these dual aspects of learning.

This study aims to address these gaps by examining the impact of the CORE instructional model on critical thinking in mathematics, with a particular focus on the role of emotional intelligence. The research investigates whether students taught using the CORE model exhibit greater improvements in critical thinking compared to those taught using conventional methods. It also explores the interaction between the CORE model and varying levels of emotional intelligence, providing insights into how this model can be tailored to meet diverse learner needs. By bridging these gaps, the study seeks to contribute to the growing body of literature on innovative pedagogical practices and their potential to enhance mathematics education.

2. Methodology

This study employed a quasi-experimental design to investigate the effects of the CORE instructional model on students' mathematical critical thinking skills, considering their emotional intelligence levels. The research adopted a 2×2 factorial design categorized by teaching methods (CORE and conventional) and emotional intelligence levels (high and low). This design allowed the examination of the main effects of teaching methods and emotional intelligence, as well as their interaction on critical thinking performance.

The study was conducted at SMP Negeri 11 Gorontalo during the second semester of the 2023/2024 academic year (January to February 2024). The research population comprised 110 eighth-grade students divided into four classes. A random sampling technique was used to select two classes, with one serving as the experimental group taught using the CORE model and the other as the control group taught using conventional methods. The experimental group included 28 students, while the control group consisted of 27 students.

The dependent variable in this study was students' mathematical critical thinking skills, assessed through a structured evaluation. The independent variables were the instructional methods (CORE and conventional) and students'

emotional intelligence levels (high and low). Emotional intelligence levels were measured using a validated questionnaire and categorized into high and low groups. The CORE instructional model emphasized active student participation through the following phases: Connecting, Organizing, Reflecting, and Extending. The control group received instruction through teacher-centered lectures, emphasizing direct explanations and problem-solving exercises without collaborative or reflective activities.

Two main instruments were utilized in this study:

- **Mathematical Critical Thinking Test:** A set of essay-based questions aligned with the Pythagorean Theorem, designed to assess interpretation, analysis, evaluation, and inference skills. The test underwent rigorous content and construct validation by subject matter experts and a reliability analysis using Cronbach's Alpha ($\alpha = 0.736$).
- **Emotional Intelligence Questionnaire:** A 40-item questionnaire based on Goleman's framework, measuring five dimensions of emotional intelligence: self-awareness, self-regulation, motivation, empathy, and social skills. Each item was rated on a Likert scale ranging from strongly disagree to strongly agree. The instrument was validated through expert reviews and statistical reliability testing, ensuring its suitability for this research.

Data collection comprised three stages:

- **Pre-Test:** Administered to both experimental and control groups to assess baseline critical thinking skills.
- **Intervention:** The experimental group underwent eight weeks of instruction using the CORE model, while the control group received traditional lecture-based teaching. Both groups were taught the same mathematical concepts, specifically the Pythagorean Theorem.
- **Post-Test and Questionnaire:** Following the intervention, a post-test assessed students' mathematical critical thinking skills. Simultaneously, students completed the emotional intelligence questionnaire to categorize their emotional intelligence levels.

The study employed both descriptive and inferential statistical techniques:

- **Descriptive Analysis:** Mean, standard deviation, and frequency distributions were calculated for students' test scores and emotional intelligence levels.
- **Inferential Analysis:** A two-way ANOVA was conducted to determine the main and interaction effects of teaching methods and emotional intelligence on critical thinking skills. Post-hoc Tukey tests were performed to identify specific differences between groups. Data analysis was conducted using SPSS software version 23, with a significance level set at 0.05.

The study adhered to ethical guidelines for educational research. Informed consent was obtained from all participants, and their anonymity and confidentiality were maintained throughout the study. Ethical approval was granted by the relevant institutional review board.

This methodological framework ensured a rigorous and systematic approach to investigating the effectiveness of the CORE instructional model in enhancing mathematical critical thinking skills while addressing the role of emotional intelligence.

3. Results and Discussion

3.1. Overview of Findings

This study explored the impact of the CORE instructional model on students' critical thinking skills in mathematics, specifically in the context of the Pythagorean Theorem, and examined the moderating role of emotional intelligence. The results revealed that the CORE instructional model significantly outperformed the conventional teaching method in enhancing critical thinking skills. Additionally, a notable interaction effect between teaching methods and emotional intelligence levels was identified, highlighting the importance of tailoring instructional strategies to students' emotional profiles.

3.2. Effectiveness of the CORE Model in Enhancing Critical Thinking

The experimental group, taught using the CORE instructional model, demonstrated significantly higher scores in critical thinking compared to the control group, which was taught using conventional methods. The results of the two-way

ANOVA indicated a statistically significant main effect of the teaching method on critical thinking ($F = 27.230$, $p < 0.05$). Students in the CORE group achieved an average score of 44.79, compared to 34.52 in the conventional group. These findings align with prior research emphasizing the efficacy of active learning models in fostering critical thinking (Putri et al., 2020; Herlina et al., 2024). The CORE model's structured phases—Connecting, Organizing, Reflecting, and Extending—encourage students to actively engage with the material, fostering deeper understanding and problem-solving skills.

The results support the theoretical underpinnings of the CORE model, rooted in constructivist learning theories, which posit that active involvement in the learning process enhances cognitive development. By connecting prior knowledge to new concepts, organizing information systematically, and engaging in reflective practices, students are better equipped to analyze and synthesize mathematical problems. This iterative process aligns with critical thinking frameworks that emphasize interpretation, analysis, evaluation, and inference (Hussein et al., 2019; Faridi et al., 2021).

3.3. Interaction between Teaching Method and Emotional Intelligence

A significant interaction effect was observed between teaching method and emotional intelligence levels on critical thinking skills ($F = 7.534$, $p < 0.05$). Students with high emotional intelligence exhibited notably better critical thinking outcomes in the CORE instructional model compared to their counterparts in the conventional teaching group. This finding aligns with Reinhold et al. (2021), who emphasized the role of emotional intelligence in enhancing cognitive processes. Students with high emotional intelligence in the CORE group achieved an average score of 57.50, significantly higher than the 44.11 average score of their peers in the conventional group. This suggests that emotionally intelligent students benefit from the CORE model's emphasis on active engagement and reflective learning, which aligns with their capacity to manage emotions and maintain focus during problem-solving tasks.

Conversely, students with low emotional intelligence also performed better under the CORE model than in the conventional method, though the magnitude of improvement was less pronounced. These students scored an average of 31.71 in the CORE group compared to 27.56 in the conventional group. While the CORE model's structured and interactive approach provided some benefits, the lower performance of these students underscores the challenges faced by individuals with limited emotional regulation in adapting to demanding cognitive tasks. This observation aligns with findings from Cui (2021), who noted that emotional intelligence plays a pivotal role in managing the cognitive and affective demands of learning.

3.4. Comparison across Emotional Intelligence Levels

The performance differences between high and low emotional intelligence groups were more pronounced in the CORE instructional model than in the conventional method. This result highlights the importance of emotional intelligence in moderating the efficacy of active learning strategies. Students with high emotional intelligence leveraged their abilities to self-regulate, empathize, and collaborate effectively, which are integral components of the CORE model's collaborative and reflective phases. These findings resonate with Goleman's (2021) conceptualization of emotional intelligence as encompassing self-awareness, self-regulation, motivation, empathy, and social skills—all of which enhance engagement and learning outcomes in student-centered environments.

In contrast, the relatively smaller gains among students with low emotional intelligence suggest the need for additional scaffolding and support in implementing the CORE model. While the model provides opportunities for interaction and reflection, students with limited emotional regulation may struggle to fully engage in these processes. As suggested by Huang et al. (2021), integrating targeted emotional intelligence interventions within instructional frameworks may further enhance learning outcomes for these students.

3.5. Comparison to Conventional Teaching Methods

The control group, taught using conventional methods, exhibited consistently lower performance across both emotional intelligence levels. This finding underscores the limitations of traditional teacher-centered approaches, which emphasize rote memorization and passive learning. Such methods provide limited opportunities for students to engage in critical thinking or leverage their emotional intelligence. Previous research (Sihaan et al., 2022) has similarly highlighted the shortcomings of conventional teaching in fostering higher-order cognitive skills and addressing individual learner needs.

The conventional method's reliance on direct instruction and limited interaction contrasts sharply with the CORE model's emphasis on active participation and reflective practices. As a result, students in the conventional group lacked the opportunities to connect new knowledge with existing concepts, organize their understanding systematically, and

reflect on their learning experiences. These limitations were particularly evident among students with low emotional intelligence, who performed the worst in this instructional setting.

3.6. Implications for Practice

The findings of this study have significant implications for mathematics education. First, they highlight the effectiveness of the CORE instructional model in enhancing critical thinking skills, particularly when tailored to students' emotional intelligence levels. Educators should consider adopting the CORE model as a viable alternative to conventional teaching methods, especially for fostering critical thinking and engagement in mathematics.

Second, the results emphasize the importance of integrating emotional intelligence into instructional design. Students with high emotional intelligence excelled in the CORE model, suggesting that fostering emotional intelligence skills can further enhance the model's effectiveness. For students with lower emotional intelligence, additional support mechanisms, such as structured guidance during reflective activities or explicit training in emotional regulation, may be necessary to optimize learning outcomes.

Third, the interaction between teaching method and emotional intelligence underscores the need for differentiated instruction. Teachers should assess students' emotional intelligence levels and adapt their instructional strategies accordingly. For instance, providing more structured support for students with low emotional intelligence while encouraging autonomy and collaboration among those with high emotional intelligence can help maximize the benefits of active learning models like CORE.

Limitations and Future Research

While this study provides valuable insights, it is not without limitations. The quasi-experimental design, while robust, does not account for potential confounding variables such as prior knowledge or motivation levels. Future research could employ randomized controlled trials to strengthen causal inferences. Additionally, the study focused on a single mathematical topic (Pythagorean Theorem) and a specific grade level, limiting the generalizability of the findings. Expanding the scope to include diverse mathematical topics and grade levels would provide a more comprehensive understanding of the CORE model's efficacy.

Another limitation is the reliance on quantitative measures of critical thinking and emotional intelligence. Incorporating qualitative methods, such as interviews or classroom observations, could provide richer insights into the dynamics of the CORE model's implementation and its interaction with emotional intelligence

4. Conclusion

This study highlights the significant impact of the CORE instructional model on enhancing students' critical thinking skills in mathematics, particularly when considering the moderating role of emotional intelligence. The findings demonstrate that the CORE model, with its structured phases of Connecting, Organizing, Reflecting, and Extending, is more effective than conventional teaching methods in fostering critical thinking. Students with higher emotional intelligence benefited the most, leveraging their self-regulation, empathy, and motivation to excel under the CORE model. However, even students with lower emotional intelligence showed improved performance compared to their counterparts in the conventional group, underscoring the model's potential across diverse learner profiles.

The study emphasizes the importance of integrating cognitive and emotional dimensions into educational practices. It suggests that tailored instructional strategies that align with students' emotional intelligence levels can maximize learning outcomes. This research contributes to the existing body of knowledge by providing empirical evidence on the interplay between instructional methods and emotional intelligence in mathematics education.

Future research should explore the CORE model's application to other subjects, grade levels, and cultural contexts. Additionally, integrating qualitative approaches could provide deeper insights into the mechanisms underlying the observed effects, thereby refining its implementation in varied educational settings.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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