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Advanced Learning Dynamics: The Role of CCM-CCA Models in Addressing Misconceptions and Enhancing Critical Thinking Across Cognitive Styles

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Abstract **– Understanding the interplay between teaching methods and cognitive styles is crucial for developing effective and inclusive learning strategies. This research aims to describe the effectiveness of CCM CCA-based learning in reducing misconceptions and improving critical thinking skills, as reviewed from a cognitive perspective. The research method employed in this study is a mixed-methods approach, specifically the exploratory design model. Data on conceptual changes (to reduce misconceptions) and students' critical thinking skills were obtained using critical thinking skills test instruments. Meanwhile, students' cognitive styles were obtained using the group embedded figure test (GEFT) translation instrument, which is valid and reliable. The data analysis used is an effectiveness test using the N-gain formula. The results show that CCM-CCA-based learning is effective in reducing misconceptions and improving critical thinking skills, particularly in terms of cognitive style. The important role of cognitive styles in shaping the development of essential thinking skills, which implies the need for cognitively adaptive learning design.**

Keywords **– CCM CCA, misconceptions, critical thinking skills, cognitive style.**

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1. Introduction

The rapid advancements in science and technology have driven governments to prioritize improving the quality of human resources to remain competitive on a global scale. One effective strategy is to develop individuals with strong life skills and higher-order thinking abilities. The argumentation aligns closely with the demands of 21st-century education, which emphasize the cultivation of critical thinking and problem-solving, creativity and innovation, as well as communication and collaboration skills. Modern education identifies critical thinking as the most essential competency for success in today's world [1], [2]. To address these demands, educational practices are increasingly focused on fostering these core competencies. A deep conceptual understanding serves as the foundation for supporting higher-order thinking, particularly critical thinking. However, studies show that many students have yet to achieve advanced levels of critical thinking [3]. This issue persists because practical learning approaches often fail to develop critical thinking skills [4], [5].

Moreover, misconceptions in learning further hinder the development of critical thinking skills. Misconceptions, often stemming from a lack of deep conceptual understanding, pose significant challenges to fostering higher-order thinking and problem-solving abilities [6]. These barriers emphasize the need for innovative teaching approaches that not only address misconceptions but also cultivate critical thinking skills. One promising approach is the conceptual change model with cognitive conflict approach (CCM-CCA), which integrates cognitive conflict to stimulate conceptual restructuring. By introducing cognitive dissonance, this model prompts students to critically evaluate their pre-existing beliefs, facilitating deeper understanding and reducing persistent misconceptions.

This targeted intervention aligns with modern educational strategies that accommodate diverse cognitive styles, enabling personalized and compelling learning experiences that support 21st-century educational goals [7], [8].

These misconceptions, often deeply rooted in personal experiences, pose considerable challenges in shifting towards a scientifically accurate understanding. Even when instructional strategies are implemented to address these misconceptions, many students still fail to adequately reconstruct their thinking. Students who successfully navigate this process of cognitive restructuring engage in higher-order cognitive skills, such as critical thinking, creative problem-solving, and logical reasoning [9]. To foster meaningful learning, it is crucial to provide learning environments that emphasize the importance of conceptual change. Such environments enable students not only to clarify misconceptions but also to develop the critical thinking skills necessary for deeper comprehension and application of knowledge.

Given the significant role misconceptions play in hindering students' cognitive development, fostering critical thinking skills is a crucial focus in modern education. Critical thinking, defined as the ability to analyze, evaluate, and synthesize information, is widely acknowledged as a fundamental component of effective learning [10]. In the context of contemporary education, critical thinking is not merely a cognitive skill but an indispensable tool for addressing complex problems and adapting to the rapidly changing demands of the 21st century [11]. Consequently, educational strategies must evolve to prioritize the cultivation of these skills, ensuring that students are prepared to challenge assumptions, explore multiple perspectives, and engage in informed decision-making. By addressing misconceptions and embedding critical thinking within the learning process, educators can significantly enhance students' ability to apply knowledge creatively and effectively, ultimately equipping them to meet future challenges [12], [13].

Critical thinking remains a cornerstone of effective education, emphasizing the ability to reason, evaluate evidence, and make informed decisions. Its development is paramount in fostering a learner's ability to navigate complex problems and adapt to a rapidly evolving world. The research underscores that students with strong critical thinking skills are better equipped to deconstruct misconceptions, analyze underlying assumptions, and reframe their understanding based on logic and evidence [14], [15]. By embedding critical thinking into the educational framework, learners are encouraged to question their preconceived notions and approach learning with a more analytical and reflective mindset.

This focus not only helps dispel persistent misconceptions but also prepares students to engage meaningfully with problem-solving tasks that mirror real-world challenges [16], [17].

Building on the importance of critical thinking in modern education, another crucial factor influencing students' learning processes is their cognitive style. Each individual possesses a unique method of organizing thoughts, actions, perceptions, and memories. These individual differences extend to how students approach learning situations, shaping how they receive, manage, and integrate their experiences when responding to various teaching methods. Cognitive style refers to the manner in which individuals compile and process information, and it plays a pivotal role in influencing students' choices and academic development [18]. Therefore, understanding and recognizing cognitive style is essential for educators, as it significantly impacts the learning experience and students' ability to engage with complex concepts.

Recent studies highlight the significant role of cognitive and emotional factors in enhancing learning. Research indicates that various pedagogical approaches, such as personalized learning and collaborative strategies, can markedly improve students' cognitive engagement, motivation, and overall learning outcomes. For example, studies have shown that learning environments designed to encourage sensory exploration and active participation foster both cognitive and emotional engagement, leading to higher academic performance and more profound understanding [19], [20]. Furthermore, research suggests that adopting more individualized and adaptive learning strategies allows for addressing diverse learning needs, thus enhancing cognitive abilities and critical thinking skills [21]. These findings emphasize the importance of aligning effective teaching methods with students' unique cognitive styles to create more inclusive and impactful learning experiences.

Addressing the challenges posed by misconceptions and the need for enhanced critical thinking requires innovative, targeted learning approaches that foster conceptual change. One such approach is the CCM-CCA model, which incorporates a cognitive conflict strategy to actively engage students in reevaluating their existing knowledge structures. The conceptual change model with cognitive conflict approach (CCM-CCA), abbreviated as CCM-CCA, is a learning model designed to facilitate conceptual change by presenting cognitive conflict stimuli that challenge misconceptions, thereby reducing erroneous preconceptions and promoting a deeper understanding [22].

The CCM-CCA model represents a transformative educational framework designed to mitigate misconceptions and enhance students' critical thinking skills through a targeted cognitive conflict strategy. This model provides an innovative solution to address persistent conceptual misunderstandings, particularly prevalent in physics education, where abstract and counterintuitive concepts often lead to errors in comprehension [23]. As modern educational paradigms increasingly prioritize critical thinking as a cornerstone of 21st-century skills, the CCM-CCA model aligns seamlessly with these objectives by offering a research-based strategy to overcome learning barriers. Its focus on actively addressing misconceptions, rather than merely transmitting knowledge, underscores its potential to empower learners to become independent problem-solvers and critical thinkers. Recent studies have highlighted the importance of such approaches in fostering intellectual resilience and adaptability in complex learning environments, making the CCM-CCA model a vital tool in contemporary education [24], [25].

Despite the increasing emphasis on critical thinking as a pillar of modern education, a notable gap persists in addressing how entrenched misconceptions obstruct the development of higher-order cognitive skills. While studies have extensively underscored the importance of critical thinking in fostering analytical and problem-solving capacities [26], [27], limited attention has been devoted to strategies that concurrently mitigate misconceptions and enhance critical thinking. Many existing educational approaches overlook the necessity of personalized and contextualized learning experiences tailored to confront individual cognitive barriers, such as misconceptions [28]. Moreover, although frameworks promoting critical thinking are widely advocated, empirical evidence regarding their efficacy in reducing misconceptions remains scarce, particularly in diverse classroom contexts [29]. Misconceptions, often rooted in personal experience or flawed prior knowledge, exhibit resilience to change without deliberate, targeted interventions [30]. Addressing this dual challenge, enhancing critical thinking while simultaneously eradicating misconceptions, is vital for fostering conceptual clarity and cognitive growth. By embedding critical thinking into learning processes to challenge and reconstruct erroneous mental models, educators can align with the broader objectives of 21st-century education, emphasizing adaptability, creativity, and informed decision-making [31], [32]. This research aims to bridge the identified gap by exploring innovative strategies that integrate critical thinking into educational practices, ultimately preparing students to navigate complex challenges and overcome misconceptions.

The article explores the development of a pedagogical framework that integrates the conceptual change model with a cognitive conflict approach to address key challenges in contemporary education. It emphasizes strategies that mitigate misconceptions while nurturing critical thinking skills through the alignment of cognitive conflict stimuli with students' cognitive styles. By exploring the dynamics of cognitive adaptation, the discussion provides insights into how learners' conceptual understanding can be transformed into more scientifically accurate perspectives. This approach is presented as a potential solution to persistent educational gaps, aiming to enhance the efficacy of teaching methods in fostering analytical reasoning and conceptual clarity, which are vital for 21st-century learners navigating increasingly complex intellectual demands.

2. Methodology

The research methodology is designed to systematically describe the stages and procedures used to conduct the research. The description includes the research design, which serves as the basic framework for answering the research problem; the determination of a sample that represents the population; The instruments and data collection techniques used to obtain valid and reliable data; and the data analysis methods applied to process and interpret the research findings scientifically.

2.1. Research Design

The research was conducted using a mixed-methods approach, specifically employing the exploratory design model [33]. This method consists of three processes: (1) Qualitative process; (2) Quantitative process; and (3) The data interpretation process that is based on the first and second processes.

2.2. Research Samples

In this study, selecting an appropriate research sample is crucial to ensure the validity and reliability of the findings. The participants were selected based on their enrollment in a relevant course, enabling a structured experimental design.

The research sample consisted of 100 students from the Physics Education program at FKIP, University of Mataram, who were enrolled in the Mechanics course. These students were distributed across three different classes. For the experimental procedure, the students were divided into two groups: An experimental group and a control group, comprising a total of 100 students across the three classes.

2.3. Research Instruments and Data Collection

Data on students' conceptual changes (to reduce misconceptions) and critical thinking skills were collected using assessment sheets from student worksheets during the learning process, as well as critical thinking skills test instruments. The critical thinking skills instrument consists of five essay questions, developed based on five key indicators of critical thinking: Basic clarification, basic decision-making, inference, evaluation, and reasoning. Each item is designed to measure students' ability to analyze, interpret, and evaluate information in alignment with these specific indicators. Misconceptions were specifically analyzed using an instrument directly related to cognitive styles, namely the group embedded figure test (GEFT). This approach ensures that cognitive styles are taken into account when evaluating misconceptions.

The GEFT instrument, a perceptual test developed from the embedded figures test (EFT) [34], consists of three groups of questions. The first part presents a set of images, prompting students to identify simple shapes embedded within the complex figures. The second part requires students to interpret the figures based on their previous descriptions. In the third part, students are asked to redraw the figures according to their own interpretations. This sequence is designed to assess students' cognitive style, particularly their ability to visualize information. The first group is not scored because it serves as a practice set to familiarize respondents with the test instructions and procedures. The actual test, which is scored, comprises the second and third groups of questions, with each correct answer earning 1 point and each incorrect answer earning 0 points. The collected data were then analyzed using a simple statistical mean score.

2.4. Data Analysis

The data analysis used in this research is effectiveness analysis to determine the increase in critical thinking skills in terms of cognitive style through CCM CCA-based learning. To analyze this increase, normalized N-gain value analysis will be used using the formula [35]:

$$\text{N-gain} = \frac{\text{Spost}-\text{Spre}}{\text{Smaks}-\text{Spre}} \text{X } 100\% \qquad (1)$$

N-gain analysis is used to assess the improvement in critical thinking skills after students' study with CCM-CCA.

The validation data of the learning tools and instrument tests were analyzed by calculating the average score of each aspect given by two validators. The validity criteria were determined based on the most frequently occurring category.

The validity of each aspect of the model and learning tools was determined by referring to the criteria presented in Table 1 [36].

Table 1. Validation assessment criteria for the model and learning tools

Score Interval	Category	Description
$1.0 \leq P \leq 1.75$	Very Invalid	Cannot be used and still requires expert consultation
$1.75 \leq P \leq 2.75$	Invalid	Can be used with major revisions
$2.75 \leq P \leq 3.25$	Valid	Can be used with minor revisions
$3.25 \leq P \leq 4.0$	Very Valid	Can be used without revision

Regarding the validation process, two expert validators in the field of physics education, both professionally and pedagogically qualifiedwere involved. The validation focused on two main aspects: Content validation, which includes the need, novelty, and alignment of the development with theoretical foundations; and construct validation, which examines the consistency of the components with the research framework.

The experts provided feedback using a validation instrument specifically designed for this purpose. The researcher then analyzed the validators' assessments using the percentage of agreement method to determine the level of consistency and reliability of the evaluations.

The reliability of the validation results was assessed using inter-observer agreement, calculated according to the formula [37].

$$\text{Percentage of agreement (R): } 1 - \frac{A-B}{A+B} \text{ x } 100\% \qquad (2)$$

R represents reliability; A refers to the frequency of behavioral aspects observed by the evaluator who reported a higher frequency, while B refers to the frequency reported by the evaluator with a lower frequency. The validation results are considered reliable if the percentage of agreement (R) exceeds 75%.

3. Results

This study aimed to assess the effectiveness of the developed CCM-CCA learning model by measuring students' critical thinking abilities before and after the intervention. The assessment focused on evaluating students' capacity to analyze, evaluate, and reason logically within the context of physics learning. By comparing students' performance in the experimental and control groups, the study aimed to determine whether the implemented instructional approach led to significant improvements in critical thinking.

The results of students' critical thinking abilities were obtained using a test instrument in the form essay with five questions based on critical thinking indicators. The results of the initial and final tests for students in the experimental and control classes are presented in Table 2.

Table 2. Pre-test and test scores in the experimental class and control class

Data	Pre-test		Post-test	
	Experiment Class	Control Class	Experiment Class	Control Class
Amount of Students	30	27	30	27
The Highest Score	45	40	80	75
The Lowest Score	5	5	45	25
Score Average	22,17	23,33	65,33	52,41

Based on the data in Table 2, there were notable differences in students' critical thinking scores between the initial and final tests, particularly between the experimental and control groups. Initially, both groups demonstrated very low levels of critical thinking, with mean scores of 22.17 and 23.33, respectively. These baseline results indicate that students from both groups initially demonstrated limited ability to engage in analytical reasoning, argument evaluation, and structured problem-solving, core aspects of critical thinking. The similarity in their initial scores also confirms the groups' equivalence prior to the intervention, thereby establishing a valid comparison for measuring the impact of the instructional treatment.

Following the implementation of the intervention, the experimental group experienced a substantial increase in their critical thinking performance, reaching an average score of 65.33, which, while categorized as "low," marks a clear departure from the initial "very low" level. In contrast, the control group demonstrated only a modest improvement, with a post-test average of 52.41, which remains within the "very low" category. This marked divergence in outcomes strongly suggests that applying the CCM-CCA significantly enhanced students' critical thinking skills. The structured integration of conceptual conflict and collaborative learning activities likely played a pivotal role in engaging students more deeply with the content and fostering higher-order thinking processes. These findings provide compelling support for the use of CCM-CCA as an effective pedagogical strategy for developing critical thinking in physics education.

It is important to note, however, that although 100 students were initially registered in the study, only 57 participants (30 in the experimental group and 27 in the control group) were included in the final analysis. This discrepancy occurred because several students applied for academic leave after enrolling in the course, while others did not attend or participate in the course activities despite having officially registered for the credits. These circumstances were beyond the researcher's control and are not uncommon in higher education settings, particularly when students are managing multiple academic and personal responsibilities. As such, the data analysis focused only on those students who actively participated in the full intervention and completed both pre- and post-tests.

Further analysis using the N-gain test reveals that the experimental group achieved a medium N-gain score of 0.55, compared to the control group's 0.38, indicating the superiority of the CCM-CCA model, as shown in Table 3.

Table 3. N-gain scores and cognitive style-based pre-test and post-test scores of experimental and control classes

Class	N-gain	Cognitive Style			
		Field Dependent		Field Independent	
		Pre-Test	Post-Test	Pre-Test	Post-Test
Experiment	0.55	25.83	69.17	21.25	64.38
Control	0.38	11.67	28.33	24.79	54.79

This finding highlights the model's effectiveness in promoting measurable learning gains, particularly in critical thinking abilities. The medium-level gain in the experimental group suggests that the model successfully bridges the gap between students' prior knowledge and new conceptual understanding. In contrast, the relatively lower gain in the control group suggests limited improvement, possibly due to the absence of targeted cognitive conflict and collaborative engagement, which are central features of the CCM-CCA approach.

The analysis of students' cognitive styles provides deeper insights into the effectiveness of CCM-CCA in fostering critical thinking skills. The experimental group, which was exposed to the CCM-CCA instructional model, demonstrated significant improvements in both field-dependent and field-independent student categories. Specifically, students categorized as field dependent improved their critical thinking scores from a pre-test average of 25.83 to a post-test average of 69.17. Similarly, students with a field-independent cognitive style demonstrated progress, increasing from 21.25 in the pre-test to 64.38 in the post-test. This consistent growth across both groups reflects the model's ability to address varying cognitive processing preferences, suggesting a robust instructional design that facilitates the development of higher-order thinking skills through structured conceptual conflict and peer collaboration.

In contrast, the control group, which received conventional instruction, exhibited notably lower gains, particularly among students with a field-dependent cognitive style. These students improved only modestly, from 11.67 in the pre-test to 28.33 in the post-test. Although field-independent students in the control group showed a better gain, from 24.79 to 54.79, their progress remained below that of the experimental group. These results suggest that while field-independent learners may still be able to navigate traditional instruction due to their self-directed learning tendencies, the absence of collaborative scaffolding and structured conceptual engagement hampers the learning outcomes of field-dependent learners under conventional pedagogies.

In addition to analyzing critical thinking skills, this study also examined students' misconceptions in physics concepts, which were identified through a detailed analysis of test responses.

The misconception scores were derived by evaluating the consistency and accuracy of students' answers, with particular attention to conceptual errors commonly observed in mechanics. To provide a more comprehensive interpretation, the results were further categorized based on students' cognitive styles, field dependent and field independent, using scores obtained from the GEFT. This approach enabled the identification of patterns in the retention or reduction of misconceptions across both experimental and control groups' cognitive styles, offering deeper insights into the interplay between teaching models and students' conceptual understanding. The results are shown in Table 4.

Table 4. Distribution of student misconceptions across questions on physics concepts

Type	Q1	%	Q2	%	Q3	%	Q4	%	Q5	%
M1	8	20.00%	8	20.00%	8	20.00%	8	20.00%	8	20.00%
M2	6	15.00%	10	25.00%	6	15.00%	10	25.00%	6	15.00%
M3	1	2.50%	1	2.50%	1	2.50%	1	2.50%	1	2.50%
M4	3	7.50%	3	7.50%	3	7.50%	3	7.50%	3	7.50%
M5	3	7.50%	3	7.50%	3	7.50%	0	0.00%	0	0.00%
None	19	47.50%	19	47.50%	18	45.00%	18	45.00%	18	45.00%

The types of misconceptions are as follows: Misconceptions regarding the concept of linear motion (M1), misconceptions concerning Newton's laws of motion (M2), misconceptions related to the concept of circular motion (M3), misconceptions surrounding the concept of inertia (M4), and misconceptions about weight force and tension force (M5).

4. Discussion

The findings of this study shed light on the effectiveness of the CCM-CCA learning model in enhancing students' critical thinking abilities. Critical thinking is essential for solving complex problems, particularly in both abstract and concrete domains, such as those related to optical instruments. Prior studies have emphasized the role of structured learning models in addressing students' misconceptions and fostering active engagement [38], [39]. In this context, the CCM-CCA model provides an organized framework where learning begins with orientation and ends with conceptual change reviews. The study investigates not only the model's general impact on students' critical thinking but also its interaction with cognitive styles, a factor that has been shown to influence how students process and apply information [40].

Unlike conventional learning, the CCM-CCA model involves a phased learning process that actively engages students in questioning, restructuring, and applying ideas. These phases not only encourage active participation but also address existing misconceptions, as illustrated by the example of light reflection and refraction. The implementation of the CCM-CCA model in this study was guided by a structured instructional plan that followed the model's sequential phases. These included introducing conceptual conflict, engaging peers collaboratively, and restructuring understanding through guided reflection and application. Each phase was deliberately embedded in classroom activities to ensure that students had the opportunity to confront their prior knowledge, engage in meaningful dialogue, and refine their ideas through active learning.

This phased approach naturally encouraged students to revisit and revise their misconceptions as they progressed through the lessons. For instance, during discussions on topics such as light reflection and refraction, students were prompted to explore and justify their reasoning, often leading to moments of conceptual conflict that became turning points for deeper understanding.

The structure of the CCM-CCA model supported these moments by fostering an environment in which students were not only allowed but encouraged to question, clarify, and reformulate their thinking. As a result, the learning process became more than just content delivery; it was a dynamic interaction with ideas, gradually shifting students from misconceptions toward a scientifically accurate understanding. The phases ensure that students revise their initial flawed assumptions, such as the belief that reflection occurs only on flat surfaces or that refraction is unrelated to the medium's density. This is consistent with research assertions that structured interventions can drive conceptual change [41].

This structured learning process not only facilitated conceptual change but also highlighted the influence of cognitive styles on students' ability to process and internalize scientific concepts. The results, shown in Table 3, indicate that cognitive style plays a pivotal role in determining the efficacy of instructional models. Field-independent students excel in processing abstract information and breaking down complex problems [42]. Meanwhile, the control group showed that even conventional methods benefit field-independent students more than field-dependent ones, reinforcing the importance of adapting teaching methods to cognitive styles. Field-independent students exhibit higher critical thinking abilities due to their analytical and problem-solving capacities [43], [44].

Building on the analysis of students' misconceptions, it is crucial to explore how these misunderstandings can be addressed through targeted instructional strategies to foster deeper conceptual understanding and prevent recurring errors in fundamental physics concepts. The data in Table 3 reveal the distribution of misconceptions among students for five questions, along with the percentage of students with no misconceptions. Overall, the "No Misconception" category dominates, with percentages ranging from 45% to 47.5% across the questions. This suggests that a significant proportion of students possess a good understanding of the concepts being assessed. However, the data also highlights a recurring pattern of misconceptions, particularly in the M1 and M2 categories, which consistently show the highest prevalence among the identified misconception types. Research indicates that misconceptions often arise from prior knowledge conflicting with scientific explanations, suggesting the need for targeted instructional strategies to address these persistent errors [45].

Among the misconception types, M1 and M2 exhibit notable prevalence: M1 affects 20% of students across all questions, and M2 peaks at 25% in questions 2 and 4. These findings indicate areas where students may struggle with specific conceptual elements.

The consistency of M1 across all questions suggests a deep-seated misunderstanding that is not limited to specific contexts. M2, on the other hand, demonstrates variability, possibly indicating that the nature of the questions influences the students' comprehension. This aligns with those who emphasized that misconceptions are context-dependent and require contextualized teaching interventions to ensure conceptual clarity [46]. Other misconceptions, such as M3, M4, and M5, occur at much lower levels, ranging from 2.5% to 7.5%, with M5 disappearing entirely in questions 4 and 5. While these numbers are smaller, their presence still signifies the importance of identifying and addressing these misconceptions through teaching strategies, such as conceptual change approaches. The absence of M5 in later questions may indicate either improved understanding or a lack of questions targeting this specific misconception. Frequent assessment and feedback can help uncover such nuanced shifts in student understanding [47]. Thus, while most students demonstrate a sound understanding, the prevalence of misconceptions underscores the need for a robust, evidence-based instructional framework to effectively address these conceptual gaps.

To further contextualize these findings, it is important to acknowledge certain considerations regarding the study's scope and implications. Although the initial sample size was set at 100 participants, approximately 65% remained actively engaged, providing a sufficiently representative basis for meaningful analysis. Moreover, while no apparent biases were detected in the results, future studies could enhance the reliability of assessments by refining instruments that directly integrate critical thinking and misconception analysis. In terms of applicability, the CCM-CCA model holds significant promise beyond the scope of this study. Its structured approach to fostering conceptual change through cognitive conflict makes it a valuable instructional strategy for developing higher-order thinking skills (HOTS). This model has the potential to be implemented not only in higher education but also in secondary schools, across various subjects, and in other educational settings, thereby further extending its impact.

In summary, the CCM-CCA learning model is effective in enhancing students' critical thinking abilities, particularly when tailored to individual cognitive styles. Future research could explore the application of this model in broader contexts or with different scientific materials to further validate its efficacy. Additionally, integrating diagnostic teaching approaches to address specific misconceptions could amplify its benefits, ensuring students achieve both conceptual clarity and critical thinking competence.

5. Conclusion

The study highlights the impact of well-structured learning approaches in addressing misconceptions and enhancing students' critical thinking skills. In the experimental class, students with both field-dependent and field-independent cognitive styles demonstrated notable improvements in critical thinking performance in the medium category, with an n-gain of 0.55. This indicates that the structured phases of the CCM-CCA model emphasizing conceptual conflict, collaborative activities, and structured reasoning, create a learning environment that supports cognitive development across different learner profiles. Given these findings, educators can consider incorporating the CCM-CCA model into their instructional practices, particularly in subjects requiring deep conceptual understanding and analytical reasoning. The model can be adapted for various educational levels, from secondary schools to higher education, by modifying the complexity of conceptual conflict scenarios and the nature of collaborative activities. Additionally, professional development programs could integrate CCM-CCA-based training to equip teachers with the necessary skills to implement this approach effectively. While further investigation is necessary to explore long-term effects and other influencing factors, these results highlight the potential of the CCM-CCA model as an instructional strategy that fosters critical thinking in diverse classroom settings and enhances students' ability to engage with complex scientific concepts.

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