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Efforts to Improve Students' Critical Thinking Skills in Mathematics Learning by Implementing the Discovery Learning Model in Elementary Schools

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Abstract: This study aims to examine the effectiveness of the Discovery Learning model in improving elementary students' critical thinking skills in mathematics learning. The ability to think critically is an essential cognitive competency for understanding mathematical concepts, evaluating reasoning, and solving non-routine problems; however, many elementary students still demonstrate low analytical and reflective abilities. This research employed a quasi-experimental design involving two intact classes: an experimental group that received mathematics instruction using Discovery Learning and a control group that was taught through conventional direct instruction. Data were collected through a validated critical thinking test consisting of indicators such as identifying problems, analyzing information, evaluating arguments, and constructing solutions. The results revealed that students in the experimental group achieved significantly higher posttest scores, with a mean gain of 0.67 compared to 0.34 in the control group. Students taught through Discovery Learning also demonstrated greater fluency in providing justifications and articulating reasoning processes. These findings indicate that Discovery Learning promotes deeper cognitive engagement, encourages inquiry-based reflection, and strengthens students' ability to construct and evaluate mathematical ideas. The study has practical implications for elementary mathematics instruction, emphasizing the need for learner-centered pedagogical approaches that foster critical thinking from an early age.

Keywords: Discovery Learning, Critical Thinking Skills, Elementary Mathematics.

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INTRODUCTION

Developing students' critical thinking skills has become a central focus in contemporary mathematics education, particularly at the elementary school level, where foundational cognitive processes are shaped. Critical thinking enables learners to analyze mathematical problems, evaluate solution strategies, justify reasoning, and make informed decisions. According to Ennis (2018), critical thinking is essential for engaging with mathematical concepts at a higher cognitive level and plays a crucial role in preparing students for lifelong learning in an increasingly complex world. However, despite its importance, many studies have reported that elementary school students still struggle to think critically, especially when confronted with non-routine tasks that require analysis, inference, or justification (Hidayati, 2020). This persistent gap suggests the need for instructional models that actively stimulate inquiry, exploration, and reflective reasoning.

In the Indonesian context, national assessments and classroom observations consistently reveal that students' mathematical performance often leans heavily toward rote memorization rather than conceptual understanding or analytical thinking. According to Sari (2021), many elementary students can perform algorithmic procedures but face difficulties when asked to explain reasoning, identify relationships, or evaluate alternative solution pathways. Such conditions indicate that traditional direct instruction approaches may not be sufficient to promote deeper levels of cognitive engagement. As Piagetian developmental theory suggests, children in the concrete operational stage need instructional experiences that encourage active discovery and manipulation of ideas (Piaget, 1970). Therefore, approaches centered on exploration and guided inquiry may provide a more effective means of developing critical thinking among young learners.

Discovery Learning is one instructional model that aligns well with the cognitive and developmental needs of elementary students. According to Bruner (1961), Discovery Learning encourages learners to construct knowledge through exploration, experimentation, and problem-solving. Rather than receiving information passively, students are guided to discover mathematical concepts independently through structured tasks and teacher facilitation. This constructivist foundation helps learners establish meaningful connections among mathematical ideas and fosters higher-order cognitive processes. Research by Hosnan (2016) indicates that Discovery Learning increases students' motivation, curiosity, and analytical abilities, which are essential components of critical thinking. In classrooms where Discovery Learning is implemented effectively, students are more likely to engage in questioning, hypothesizing, and evaluating multiple solution strategies.

Several empirical studies support the effectiveness of Discovery Learning in improving critical thinking. For example, Nurhadi (2019) found that elementary students taught through Discovery Learning demonstrated significantly better abilities in analyzing problems and articulating reasoning compared with students who received traditional instruction. Similarly, Rahayu (2020) reported that Discovery Learning promotes higher levels of reflective thinking due to its emphasis on active participation, group collaboration, and the systematic exploration of mathematical relationships. International research echoes these findings; according to Mayer (2004), guided discovery environments provide cognitive scaffolding that helps students process information more deeply and organize it effectively. These empirical results provide a strong rationale for adopting Discovery Learning to enhance critical thinking skills in mathematics.

However, despite the growing evidence supporting Discovery Learning, its implementation remains inconsistent in many elementary schools. One major challenge is that teachers may lack the pedagogical knowledge required to design inquiry-based mathematical tasks or to facilitate structured discovery effectively. According to Putri (2021), many teachers are still more comfortable with teacher-centered approaches due to familiarity, time constraints, or perceived pressures to cover curriculum content quickly. This results in limited opportunities for students to engage in reflective thinking or to collaboratively explore mathematical ideas. Furthermore, Toharudin (2017) found that some teachers struggle to adapt their roles from information transmitters to facilitators, which is essential in discovery-based contexts. Consequently, the potential benefits of Discovery Learning are not fully realized in typical classroom settings.

Another gap lies in the limited number of experimental studies conducted at the elementary level to assess the impact of Discovery Learning specifically on critical thinking outcomes in mathematics. While some studies have focused on problem-solving performance or conceptual understanding, the direct relationship between Discovery Learning and critical thinking requires deeper exploration. As noted by Saefullah (2020), many existing studies do not differentiate between generic inquiry skills and explicit indicators of critical thinking such as evaluating arguments, identifying assumptions, or developing conclusions. Therefore, an empirical investigation that specifically examines these indicators is needed to contribute to the existing body of knowledge.

Curricular demands also underscore the urgency of cultivating critical thinking in mathematics. The Indonesian Ministry of Education emphasizes higher-order thinking skills (HOTS) as part of the national curriculum framework, encouraging teachers to design learning activities that require analysis, evaluation, and synthesis. According to Kurniasari (2021), elementary students are expected to develop the capacity to reason logically, interpret mathematical representations, and justify solution strategies. However, standardized assessments show that students often perform poorly on items requiring justification or evaluation, suggesting a gap between curricular expectations and classroom reality. Discovery Learning may offer a means to bridge this gap by providing structured opportunities for students to engage with mathematical problems more deeply.

Additionally, critical thinking is linked closely to 21st-century competencies such as creativity, communication, and collaboration. In Discovery Learning environments, students are required to work together to explore, analyze, and discuss mathematical findings. According to Trilling and Fadel (2009), these collaborative interactions support the development of cognitive flexibility and intellectual independence—qualities essential for critical thinking. Therefore, integrating Discovery Learning into elementary mathematics not only supports academic goals but also prepares students for broader life competencies.

The conceptual basis of Discovery Learning further strengthens its potential to support critical thinking development. The model consists of six main stages: stimulation, problem identification, data collection, data processing, verification, and generalization (Hosnan, 2016). Each stage systematically supports critical thinking processes. During stimulation and problem identification, students are prompted to question phenomena and identify relevant mathematical issues. Data collection and processing require students to explore patterns, evaluate information, and compare solution strategies. Verification encourages validating hypotheses using mathematical reasoning, while generalization involves synthesizing findings into broader concepts. These stages mirror widely accepted frameworks of critical thinking proposed by Ennis (2018) and Facione (2015), highlighting the theoretical alignment between Discovery Learning and cognitive development.

Despite these theoretical and empirical arguments, practical gaps persist, warranting the present research. First, there is limited experimental evidence specifically targeting elementary students' critical thinking skills in mathematics using Discovery Learning. Second, more contextualized research is needed to understand how Discovery Learning operates within real classroom settings where students' backgrounds, teacher practices, and school environments vary significantly. Third, the extent to which Discovery Learning affects specific dimensions of critical thinking—such as interpretation, analysis, evaluation, and inference—remains underexplored. Finally, developing critical thinking from early education is crucial, yet most research has focused on secondary or tertiary levels, leaving a gap at the foundational stage where cognitive habits begin to form.

Therefore, this study seeks to address these gaps by investigating the effect of the Discovery Learning model on elementary students' critical thinking skills in mathematics. By employing a quasi-experimental design with validated critical thinking indicators, the study provides empirical insights into the potential of Discovery Learning to enhance analytical reasoning at the primary education level. This research contributes not only to the theoretical understanding of inquiry-based learning but also to practical recommendations for teachers seeking to improve the quality of mathematics instruction. The findings are expected to inform curriculum development, teacher professional training, and classroom practices aimed at fostering higher-order cognitive skills from an early age.

METHODS

This study employed a quasi-experimental research design to examine the effectiveness of the Discovery Learning model in enhancing elementary school students' critical thinking skills in mathematics. A quasi-experimental approach was chosen because random assignment of participants was not feasible within the natural classroom setting, yet the design still allowed for systematic comparison between the experimental and control groups (Creswell, 2014). Two intact classes from a public elementary school were selected purposively, with one class assigned as the experimental group receiving Discovery Learning instruction and the other as the control group receiving traditional direct instruction. This design enabled the researchers to observe changes in students' critical thinking skills attributable to differences in instructional approaches.

The participants consisted of 56 fifth-grade students, with 28 students in each group. All students had relatively similar academic backgrounds and prior exposure to mathematics learning, as indicated by school documentation and pretest results. According to Fraenkel and Wallen (2019), selecting participants from similar grade levels and academic environments helps increase internal validity by reducing variability due to extraneous factors. The study took place in an elementary school located in an urban district, where mathematics teachers had expressed concerns about students' limited reasoning and analytical skills. The selection of this school was strategic, as it aligned with the research aim of improving critical thinking through inquiry-based models.

The primary instrument used to collect data was a Critical Thinking Skills Test (CTST), which was developed based on established indicators proposed by Facione (2015), including interpretation, analysis, evaluation, inference, explanation, and self-regulation. The test consisted of essay-type items that required students to analyze mathematical problems, construct arguments, validate reasoning, and articulate conclusions. Essay questions were selected because they allow deeper assessment of reasoning processes compared with multiple-choice items (Brookhart, 2010). In addition to the CTST, an observation sheet was used to monitor the implementation fidelity of the Discovery Learning model in the experimental group. This ensured that each stage—stimulation, problem identification, data collection, data processing, verification, and generalization—was carried out consistently according to the procedural framework described by Hosnan (2016).

Instrument validation was conducted through expert judgment, involving three specialists in mathematics education who reviewed the test items for content relevance, cognitive level, and linguistic appropriateness. Their feedback contributed to refining the test to ensure that it aligned with critical thinking constructs and was appropriate for the learners' cognitive development stage. Construct validity was further examined through a pilot test administered to a comparable group of students outside the sample. The results were analyzed using item discrimination and difficulty indices, with items falling within acceptable statistical ranges retained for the final test. Reliability was assessed using Cronbach's alpha, yielding a coefficient of 0.82, indicating high internal consistency (Tavakol & Dennick, 2011).

The procedures of the study began with administering a pretest to both groups to measure their initial critical thinking abilities. The pretest results confirmed that the groups were equivalent before treatment, supporting internal validity. The experimental group was then taught using the Discovery Learning model over six instructional sessions, each lasting approximately 80 minutes. During these sessions, the teacher facilitated student inquiry by presenting mathematical problems in real-life contexts, encouraging hypothesis formulation, and guiding students through exploration and verification. Students worked collaboratively in small groups, allowing them to engage in discussion, evaluate differing viewpoints, and refine their reasoning processes. The teacher's role was primarily that of a facilitator who provided scaffolding and prompted reflective thinking when necessary, aligning with the constructivist principles underlying Discovery Learning (Bruner, 1961).

Meanwhile, the control group received instruction through traditional direct teaching. In this model, the teacher explained mathematical procedures, provided examples, and assigned practice exercises. Student involvement was primarily limited to listening, note-taking, and responding to teacher questions. Although this approach ensured coverage of curriculum content, it offered limited opportunities for extended reasoning, inquiry, or collaborative problem-solving. As noted by Kirschner, Sweller, and Clark (2006), direct instruction may lead to efficient acquisition of procedural skills but may not sufficiently promote deeper cognitive engagement or critical analysis.

Throughout the intervention, classroom observations were conducted to ensure that the Discovery Learning model was implemented with high fidelity. The observation sheet included indicators such as the extent of student involvement, quality of teacher facilitation, and adherence to each stage of discovery. Two trained observers independently evaluated each lesson, and inter-rater consistency was confirmed through Cohen's kappa, which yielded a value of 0.79, indicating substantial agreement (McHugh, 2012). Observations also documented the degree of student participation, noting behaviors such as questioning, hypothesizing, discussing alternative solutions, and evaluating arguments—behaviors typically associated with critical thinking.

After the instructional period concluded, both groups completed a posttest identical in structure to the pretest. The difference in pretest and posttest scores was analyzed to determine the extent of improvement in critical thinking skills. Quantitative data analysis included descriptive statistics such as mean, median, and standard deviation, followed by inferential testing. An independent samples t-test was used to compare posttest scores between groups, while a paired samples t-test analyzed within-group improvements. Effect size was calculated using Cohen's d to measure the magnitude of the treatment's impact. These analyses followed recommendations by Field (2018) for educational research involving comparisons of instructional interventions.

The data analysis process also incorporated normalized gain (n-gain) scores to measure the effectiveness of the Discovery Learning model relative to students' initial performance. According to Hake (1998), n-gain analysis provides a more accurate picture of learning improvements because it accounts for pretest performance variations. Students in the experimental group were expected to demonstrate higher n-gain values due to increased engagement in higher-order cognitive tasks, as suggested by prior research on inquiry-based learning (Rahayu, 2020).

Ethical considerations were strictly observed throughout the study. Permission was obtained from the school principal, teachers, and parents, and participants were informed that the study would not affect their academic grades. Anonymity and confidentiality were maintained by coding student responses and storing data securely. Ethical guidelines followed the standards recommended by the American Educational Research Association (AERA, 2011). In summary, this methodological framework allowed the researchers to systematically assess the impact of Discovery Learning on students' critical thinking skills. The combination of validated instruments, rigorous implementation procedures, and appropriate statistical analyses ensured that the findings would contribute meaningfully to the literature on innovative mathematics instruction at the elementary level.

RESULTS

The results of this study describe the empirical findings obtained from the implementation of the Discovery Learning model in enhancing elementary students' critical thinking skills during mathematics instruction. Data were collected through pre-test and post-test assessments, classroom observations, and student activity documentation. The analysis focuses solely on the presentation of findings without interpretation, in accordance with standard scientific reporting (Creswell & Creswell, 2020).

The pre-test results revealed that students' initial critical thinking ability was generally in the low category. Based on the rubric adapted from Facione (2015), the average pre-test score across all students was 48.2 out of 100, indicating limited ability in identifying problems, analyzing information, and drawing inferences. Only 12% of students met the minimum criteria for satisfactory critical thinking performance. These data suggest that students had not yet developed adequate skills in evaluating mathematical information or solving non-routine problems. Similar trends have been noted in previous research in Indonesian elementary settings, where critical thinking skills are often underdeveloped due to teacher-centered instruction (Fauzi & Sa'dijah, 2020).

Following the implementation of the Discovery Learning model over six instructional sessions, notable changes were observed in students' engagement patterns and task performance. Classroom observation notes showed that students began demonstrating more active participation, frequently asking questions, proposing problem-solving strategies, and engaging in group discussions. The average observation score for cognitive engagement increased from 2.1 to 3.7 on a 4-point scale, reflecting significant improvement. According to Lee and Lang (2019), such increases in engagement serve as indicators of strengthened critical reasoning processes.

The post-test results indicate a substantial improvement in students' critical thinking skills. The average post-test score increased to 81.4, representing a 33.2-point gain from the pre-test. The proportion of students achieving the passing criterion rose to 86%, demonstrating that most learners were able to analyze mathematical problems, evaluate multiple solution strategies, and construct logical conclusions. The gain score analysis further revealed that 72% of students fell into the high-improvement category (gain > 0.7), while only 4% remained in the low-improvement category (gain < 0.3). These patterns reflect the effectiveness of structured discovery activities in promoting cognitive restructuring and independent reasoning (Mayer, 2020).

Additional qualitative data were obtained from student worksheets and reflective journals. The analysis of worksheets indicated that students were progressively more capable of documenting their thought processes, identifying relationships between mathematical concepts, and articulating reasons for choosing particular solution strategies. This aligns with findings from Wati and Nurlaelah (2021), who reported that discovery-oriented tasks support deeper conceptual exploration among elementary learners. In their reflective journals, many students stated that the discovery activities helped them "figure things out by themselves," highlighting the motivational aspect of the instructional approach.

The triangulation of pre-test/post-test results, observation data, and student documentation further supports the consistency of the findings. A convergence of evidence shows that students demonstrated measurable progress in all four components of critical thinking assessed: problem identification, information analysis, inference making, and evaluation of solutions. The strongest improvement was observed in the inference-making component, with average scores increasing from 42.7 in the pre-test to 84.9 in the post-test. This suggests that the discovery-based tasks requiring students to predict outcomes and justify conclusions contributed meaningfully to this area of growth (Yildirım & Acar, 2021).

A narrative summary of the assessment data shows clear patterns of advancement. During the early stages of the intervention, students' responses tended to be brief, fragmented, and reliant on procedural recall. By the final stage, their answers displayed more coherence, detail, and analytical depth. For example, many students began providing multi-step explanations rather than simply listing computational results. Observation records also note a shift from passive listening to active collaborative problem-solving. These patterns are consistent with reports that discovery-based instruction encourages learners to construct mathematical meanings through social and cognitive interaction (Nugroho et al., 2020).

The results also show a positive trend in students' behavioral engagement. During the first learning session, only 38% of students met the criteria for active participation, such as contributing ideas, asking questions, and engaging in peer dialogue. By the sixth session, this percentage increased to 89%. The tasks requiring students to explore patterns, classify information, and test hypotheses appeared to stimulate higher levels of curiosity and initiative. As stated by Alfieri et al. (2019), such student-driven engagement is foundational to effective discovery-based learning environments.

In addition to individual improvement, group performance during discovery activities also improved. Early in the study, group discussions were often dominated by 1–2 outspoken students, while others remained silent. Over time, group interaction became more equitable, with most members contributing ideas and challenging one another's reasoning. Observation sheets also indicated a rise in collaborative problem-solving quality. This shift may be attributed to structured group exploration phases inherent in the discovery approach, which require students to negotiate understanding collectively (Hmelo-Silver et al., 2020).

Data from teacher field notes further indicate smoother classroom management and increased student autonomy as the intervention progressed. During the initial sessions, some students struggled to follow multi-step discovery instructions and required repeated clarification. By the concluding sessions, students navigated the tasks more independently, referencing prior discoveries and using them as analogies for new problems. These findings correspond with the view that discovery learning fosters transfer of learning and self-regulated exploration (Kirschner et al., 2018).

Overall, the results demonstrate a consistent upward trend across all indicators of critical thinking and student engagement. The integration of discovery-based tasks, problem exploration stages, group discussions, and reflective documentation contributed to measurable gains in students' ability to reason mathematically and analyze complex tasks. Thus, the empirical evidence provides a robust foundation for further discussion on the pedagogical implications of Discovery Learning in elementary mathematics education.

Further analysis of item-level performance on the critical thinking assessment reveals differential patterns of improvement across question types. Questions requiring identification of relevant information showed an average increase of 29 points from pre-test to post-test, while items demanding multi-step reasoning demonstrated an increase of 36 points. Items that required evaluating the validity of a solution showed the highest improvement, with an average gain of 41 points. These results indicate that students exhibited notable growth across all cognitive dimensions assessed, although the specific magnitude varied by task complexity. The distribution of post-test scores also shifted significantly, with 72% of students scoring above 80, compared to only 8% in the pre-test.

Additional data from classroom observation logs indicate a steady rise in constructive student behaviors during discovery activities. In the first two sessions, many students hesitated to propose ideas or challenge peers' reasoning. By the final sessions, however, "idea-sharing frequency" scores reached an average of 3.5 out of 4, compared to the initial average of 1.8. Moreover, the frequency of students asking clarification questions increased from an average of 5 per session to 18 per session. These observations suggest heightened cognitive engagement during the learning process, as students increasingly took initiative in negotiating meaning and verifying mathematical relationships.

Analysis of students' reflective journal entries also showed qualitative changes in metacognitive awareness. In early entries, students' reflections were typically short, descriptive, and focused on task completion. By the end of the intervention, reflection entries included more analytical statements describing challenges, strategies used, and self-evaluations of understanding. For example, several students wrote that they "compared different methods before choosing one," or that they "checked errors by retracing steps." Such entries indicate an increased ability to recognize personal thinking processes. Journal rubric scoring showed a rise from an average of 1.9 to 3.6 (out of 4), indicating more detailed and coherent reflections.

Furthermore, the analysis of group worksheet submissions showed improvement in the accuracy and organization of group-produced reasoning. In the initial stages, group worksheets often contained incomplete explanations, missing justifications, or procedural answers without conceptual grounding. By the final stages, group submissions showed clearer reasoning chains, more explicit use of evidence, and the inclusion of diagrams or tables to support their conclusions. The average completeness score for group worksheets rose from 54% in early sessions to 87% in later sessions. These improvements were consistent across all four observed student groups.

A review of audio-recorded group discussions confirmed increasing student collaboration and reasoning depth. Early recordings showed long pauses, minimal exchanges, and occasional dominance by one student. Later recordings captured more equal participation, with students asking probing questions such as "Why does that work?" or "What if we change this number?" Students also began referencing prior discoveries during discussions, indicating improved integration of new and previous knowledge. The average rating for "quality of reasoning exchange" increased from 2.0 to 3.8 on a 4-point scale.

The evaluative data from teacher field notes also highlighted a reduction in student dependency on teacher guidance. In the first learning session, the teacher documented 27 instances of students requesting direct answers or clarification. By the final session, this number decreased to 9, with students more frequently seeking help from peers or using problem-solving heuristics independently. Additionally, the time students required to begin working after receiving instructions decreased from an average of 4.7 minutes in the first session to 1.9 minutes in the last session. This indicates an increase in autonomy and comprehension of procedural expectations.

Lastly, a summary of students' performance on enrichment tasks illustrates their ability to transfer learned reasoning strategies to novel problems. Enrichment task scores ranged from 78 to 92, with an average of 85.3. These tasks were not directly aligned with the instructional examples but required students to apply inference-making and evaluative reasoning to unfamiliar contexts. The high average performance on enrichment items suggests that students were capable of applying the reasoning skills gained during the Discovery Learning intervention to broader mathematical problems. The consistency of these findings across assessment forms strengthens the reliability of the results.

DISCUSSION

The findings of this study demonstrate that the application of the Discovery Learning model substantially enhanced students' critical thinking abilities in the context of mathematics learning in elementary school. The observed improvements across multiple indicators—including identifying relevant information, evaluating solution validity, constructing reasoning chains, and applying concepts to novel tasks—reflect the central premise that learning environments encouraging exploration and problem-solving can amplify cognitive development. According to Bruner (1961), discovery-oriented instruction promotes deeper information processing and facilitates long-term retention. The increasing performance trends identified in this study reaffirm this theoretical assertion and position Discovery Learning as a viable pedagogical approach for fostering higher-order thinking in young learners.

The improvements in students' critical thinking performance also align with prior research emphasizing the importance of active engagement in the learning process. As noted by Hmelo-Silver (2004), the process of knowledge construction becomes more robust when learners are encouraged to question, hypothesize, and test ideas collaboratively. The findings in this study, particularly those from group discussion transcripts and student reflective journals, indicate that students became more comfortable with articulating their reasoning and challenging the views of their peers over time. These behavioral changes suggest an increased willingness to engage in cognitive conflict, which is considered a hallmark of critical thinking development (Kuhn, 2015). The shift from passive reception to active construction of knowledge was evident in both quantitative and qualitative data, reinforcing the pedagogical value of Discovery Learning.

Another significant finding pertains to the transformation in students' metacognitive awareness as observed through reflective journal entries. Students gradually shifted from simple descriptions of classroom activities to more nuanced analyses of strategies, errors, and decisions made during problem-solving. This evolution aligns with Schraw and Dennison's (1994) assertion that metacognitive regulation plays a crucial role in strengthening problem-solving effectiveness. The progression in journal quality observed in this study suggests that Discovery Learning not only enhances students' critical thinking but also promotes their ability to monitor and evaluate their cognitive processes. Such developments are critical for supporting independent learning and long-term academic growth.

The increased autonomy noted in teacher field notes also highlights the pedagogical benefits of discovery-based environments. By the end of the intervention, students demonstrated a reduced dependence on direct teacher guidance, instead relying on peer collaboration and self-regulated strategies. This finding resonates with the work of Kirschner et al. (2006), who argue that structured, inquiry-based learning can foster independence when balanced with appropriate scaffolding. The reduced frequency of teacher-dependent interactions in this study suggests that the Discovery Learning model fostered a productive balance between guidance and self-directed inquiry, enabling students to assume greater ownership of their learning processes.

Moreover, the ability of students to transfer reasoning strategies to enrichment tasks signifies that learning was not limited to rote application but extended to conceptual understanding. Transferability is widely considered a key indicator of deep learning (Perkins & Salomon, 1992), and the results of this study demonstrate that students were able to adapt and apply cognitive strategies to unfamiliar contexts. This finding is particularly noteworthy in the context of elementary mathematics, where students often struggle to generalize concepts beyond textbook examples. The strong performance on enrichment tasks reinforces the idea that Discovery Learning cultivates flexible thinking and adaptability—competencies essential for critical thinking development.

Additionally, the changes observed in collaborative group behaviors reflect an increased engagement in socially mediated reasoning. Vygotsky's (1978) sociocultural theory posits that learning is constructed through interaction with others, and the growth in high-quality reasoning exchanges documented in this study aligns with this theoretical framework. As students became more adept at articulating their thoughts and responding to peer contributions, the social dimension of the learning process appeared to contribute significantly to their cognitive development. The use of dialogue as a tool for jointly constructing understanding demonstrates the powerful interplay between collaboration and critical thinking, further highlighting the value of Discovery Learning in group-based environments.

Despite these strengths, the study also reveals several challenges inherent in implementing Discovery Learning in an elementary setting. Early sessions documented hesitancy among students to share ideas, a reliance on teacher cues, and a limited ability to generate hypotheses independently. These initial challenges support the concerns raised by Mayer (2004), who argues that unguided learning environments may overwhelm novice learners. However, as this study progressed, structured scaffolding and guided questioning by the teacher appeared to mitigate these challenges, enabling students to gradually participate more actively in the discovery process. This progression underscores the importance of balancing discovery with explicit support, suggesting that the success of the model depends on the quality and calibration of instructional scaffolding.

Another point worth considering is the variation in improvement across different critical thinking components. While all areas showed notable gains, multi-step reasoning and solution evaluation tasks exhibited the highest increases. This suggests that the iterative and exploratory nature of Discovery Learning particularly strengthens cognitive skills that involve systematic analysis and judgment. In contrast, tasks requiring initial identification of relevant information showed smaller, though still significant, improvements. These patterns may indicate that while Discovery Learning effectively enhances higher-level reasoning, additional support may be needed to develop foundational skills in identifying critical information within mathematical problems.

Furthermore, the substantial improvements in communication-based indicators—such as the frequency of clarification questions and the quality of reasoning chains—highlight the importance of discourse as a mediating tool. In mathematics learning, discourse fosters conceptual clarity and supports the construction of shared meaning (Sfard, 2008). The rise in student-initiated dialogue observed in this study suggests that Discovery Learning not only strengthens individual cognition but also cultivates a communicative classroom culture conducive to critical thinking. These findings imply that mathematics instruction should integrate structured opportunities for dialogue as a core component rather than an auxiliary activity.

CONCLUSION

The findings of this study demonstrate that the implementation of the Discovery Learning model significantly enhances elementary school students' critical thinking abilities in mathematics learning. Throughout the intervention, students showed substantial improvements across multiple indicators, including their ability to identify relevant information, construct logical reasoning chains, evaluate solution validity, and apply concepts to novel problems. These improvements were consistent across quantitative assessments, observational data, reflective journals, worksheet analyses, and group discussion recordings, which collectively validate the effectiveness of the instructional model. The results further reveal that Discovery Learning fosters meaningful cognitive engagement by encouraging students to explore mathematical concepts, generate hypotheses, collaborate with peers, and justify their thinking through dialogue. As students became more comfortable with inquiry-based tasks, they demonstrated increased autonomy, reduced reliance on teacher guidance, and stronger metacognitive awareness. The gradual development of these dispositions indicates that Discovery Learning does more than improve performance—it cultivates long-term habits of mind essential for critical thinking. Additionally, students' ability to transfer reasoning strategies to enrichment tasks underscores the depth of understanding achieved during the intervention. The growth in communication and collaborative reasoning further highlights the importance of social interaction as a catalyst for cognitive development. Based on these findings, Discovery Learning can be recommended as an effective pedagogical model for strengthening critical thinking in elementary mathematics classrooms. Teachers should consider providing structured scaffolding, opportunities for meaningful dialogue, and tasks that encourage exploration. Future studies may examine the model's long-term effects and its applicability across diverse mathematical

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