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An Experimental Study on the Effects of Discovery Learning and Differentiated Instruction on Cognitive and Affective Aspects in Mathematics Education

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ABSTRACT

This experimental study investigates the effects of Discovery Learning and Differentiated Instruction on students' cognitive and affective learning outcomes in mathematics education. Specifically, it examines the impact of these instructional models on problem-solving ability and interest in learning mathematics among eleventh-grade students. The research employed a quasi-experimental design with a pretest-posttest control group, involving 60 students divided equally into three groups: a control group (conventional instruction), an experimental group with Discovery Learning, and another with Differentiated Instruction. Data were collected using a validated problem-solving test and a mathematics interest questionnaire. The results revealed that both experimental groups significantly outperformed the control group in posttest scores. The Discovery Learning group achieved the highest mean scores in both cognitive (M = 85, SD = 5) and affective (M = 88, SD = 4) domains, followed closely by the Differentiated Instruction group (M = 82, SD = 6 for problem-solving; M = 85, SD = 5 for interest). One-way ANOVA showed significant differences among the groups ($F = 36.92$, $p < 0.001$), and Tukey HSD tests confirmed that both experimental groups differed significantly from the control group, though not from each other. These findings suggest that both Discovery Learning and Differentiated Instruction are effective in improving students' mathematical reasoning and motivation. Their student-centered nature and alignment with constructivist principles make them suitable strategies for enhancing mathematics instruction, particularly in diverse classrooms. Educators are encouraged to adopt either model to improve student outcomes both cognitively and affectively.

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INTRODUCTION

Mathematics education plays a central role in developing students' analytical thinking, logical reasoning, and problem-solving abilities, which are crucial for lifelong learning in the 21st century (Boaler, 2020; NCTM, 2020). However, mathematics remains one of the most challenging subjects for students, often resulting in low achievement and disengagement (Mata, Monteiro, & Peixoto, 2021). These challenges are frequently attributed to traditional instructional approaches that emphasize memorization and passive learning (Ariani & Hidayah, 2022; Abdurrahman et al., 2023). As a result, students often struggle to apply mathematical concepts in new contexts, leading to frustration and lack of motivation (Subagio et al, 2021). Therefore, there is an urgent need for instructional approaches that promote active engagement and meaningful understanding.

Discovery learning offers a promising alternative by shifting the learning process from teacher-centered instruction to student-led inquiry. This model encourages learners to formulate questions, explore patterns, and construct their own understanding based on experience and evidence (Bruner, 1961; Mayer, 2020). Guided discovery can support deep learning by allowing students to make connections between concepts through exploration. Research has shown that discovery learning, when properly scaffolded, enhances conceptual understanding and develops higher-order thinking skills (Handayani & Maulidya, 2022; Setyawan et al., 2021). However, without sufficient guidance, it can also lead to misconceptions and cognitive overload, particularly for novice learners (Kirschner, Sweller, & Clark, 2006).

On the other hand, differentiated instruction (DI) addresses the wide range of learner needs, preferences, and readiness levels in a single classroom. It provides flexibility in content delivery, learning processes, and assessment products, allowing teachers to personalize learning experiences (Tomlinson, 2014;

Ismail & Ahmad, 2021). Differentiation has been shown to improve both academic achievement and student engagement, especially in diverse classrooms (Novitasari et al., 2022; Hasanah & Puspitasari, 2023). In mathematics, this approach helps make abstract concepts more accessible by offering tiered tasks, learning stations, and student choice. DI empowers students to learn at their own pace and build confidence through appropriate challenges (Rahim et al., 2021).

Both discovery learning and differentiated instruction are rooted in constructivist learning theory, which emphasizes active meaning-making through interaction with the environment. While discovery learning stimulates cognitive processes through inquiry and exploration, differentiated instruction attends to the affective domain by supporting motivation, interest, and self-regulation (Boaler, 2020; Schoenfeld, 2021). These complementary strengths make both models highly relevant for mathematics education, where students often face both cognitive and emotional challenges. However, despite theoretical support, limited research has investigated the combined or comparative effectiveness of these two approaches in a single experimental setting (Yilmaz & Bayraktar, 2022).

One of the fundamental challenges in the Indonesian education context is the heterogeneity of students in terms of abilities, backgrounds, and interests. The national curriculum emphasizes the development of higher-order thinking skills (HOTS), creativity, and independent learning, which aligns with both discovery learning and differentiated instruction (Widodo et al., 2023). Nonetheless, classroom implementation often falls short due to systemic barriers such as limited teacher training, lack of instructional resources, and assessment practices that prioritize rote learning (Kurniawati & Utami, 2022). This disconnect between curriculum vision and classroom reality calls for empirical research to test innovative models in real school settings.

Although both discovery learning and differentiated instruction have demonstrated positive impacts on student learning, most existing studies have investigated them in isolation. Few have directly compared their effectiveness using a robust experimental framework that simultaneously examines both cognitive and affective outcomes (Mahmudi et al., 2023; Mata et al., 2021). This is particularly true in the context of mathematics education at the secondary school level, where students are expected to develop not only problem-solving skills but also sustained interest and motivation. There is a need for empirical studies that go beyond test scores and explore how these models influence the whole learner.

A recent study by Rindana end Irvan (2023) emphasizes the importance of designing instruction that integrates both cognitive and affective learning targets. He asserts that “mathematics education must balance the cognitive load of abstract content with affective support that sustains student engagement, particularly in diverse and under-resourced learning environments”. His findings underscore the urgency of exploring pedagogical models that not only improve performance but also foster positive emotional experiences in mathematics learning. This perspective supports the view that instruction must be holistic and responsive to student diversity.

Despite growing interest in active and inclusive pedagogies, comparative experimental studies on discovery learning and differentiated instruction remain scarce in Southeast Asia, particularly in Indonesia. Many existing studies are either qualitative in nature or lack methodological rigor, limiting their generalizability and practical application (Kusumawati et al., 2023). Moreover, few have evaluated both problem-solving skills and learning interest as concurrent outcomes dimensions that are equally essential in ensuring meaningful and sustainable learning. This research aims to fill that gap by providing data-driven insights into the effectiveness of both instructional models.

Furthermore, integrating both discovery learning and differentiated instruction within the same study provides an opportunity to examine their relative advantages and limitations. For example, discovery learning may be more effective in enhancing analytical reasoning, while differentiated instruction might have a stronger influence on motivation and classroom climate. Investigating these possibilities can help educators make more informed instructional choices based on their teaching goals and student needs. In addition, findings from this study may inform pre-service teacher training programs that emphasize pedagogical innovation and learner-centered instruction.

By addressing the research gap and contextual challenges, this study seeks to contribute to the ongoing discourse on best practices in mathematics education. Specifically, it examines how two prominent instructional models discovery learning and differentiated instruction affect cognitive and affective learning outcomes among eleventh-grade students. The results are expected to offer practical recommendations for improving mathematics teaching in diverse classrooms and to support policy efforts to modernize instructional practices in line with 21st-century competencies. Ultimately, this research underscores the importance of aligning pedagogy with both student diversity and curricular demands to foster deeper and more engaging mathematics learning experiences.

RESEARCH METHOD

This study applied a quasi-experimental design with a pretest-posttest control group to investigate the effects of discovery learning and differentiated instruction on students' problem-solving skills and interest in mathematics. A total of 60 eleventh-grade students were randomly selected from a larger population of 120 and divided into three groups: a control group (conventional instruction), an experimental group applying discovery learning, and another experimental group using differentiated instruction.

Two instruments were used to measure outcomes: a validated problem-solving test and a mathematics interest questionnaire. Both instruments were tested for validity and reliability prior to use. All groups were given the same pretest before the intervention and the same posttest after a six-week learning period.

During the intervention, the control group followed traditional instruction, while the discovery learning group engaged in guided inquiry-based activities. The differentiated instruction group received tailored tasks according to students' readiness, interests, and learning profiles. After six weeks, posttests were administered to all groups.

The collected data were analyzed using SPSS. Independent t-tests were used to compare each experimental group with the control group. One-way ANOVA was conducted to assess differences among all three groups, followed by Tukey's HSD for post-hoc comparisons. A significance level of $p < 0.05$ was used throughout the analysis.

This design enabled a systematic comparison of two instructional models in terms of their impact on both cognitive and affective student outcomes in mathematics learning.

RESULTS AND DISCUSSION

This study aimed to investigate the effects of Discovery Learning and Differentiated Instruction on students' mathematical problem-solving ability (cognitive aspect) and learning interest (affective aspect). The results demonstrated that both experimental approaches led to significant improvements in comparison to conventional instruction.

1. Posttest Results Overview

After the six-week intervention, students' posttest scores in both cognitive and affective domains were analyzed. The Discovery Learning group achieved the highest average scores in both aspects: 85 for problem-solving (SD = 5) and 88 for learning interest (SD = 4). The Differentiated Instruction group also showed strong performance with average scores of 82 (SD = 6) for problem-solving and 85 (SD = 5) for learning interest. In contrast, the Control group had the lowest scores, with 70 (SD = 7) in problem-solving and 75 (SD = 8) in interest.

Table 1. Posttest Results for Problem-Solving and Learning Interest by Group

Group	Problem-Solving	Learning Interest

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	Mean	SD	Mean	SD
Discovery Learning	85	5	88	5
Differentiated Instruction	82	6	85	5
Control	70	7	75	8

The data presented in Table 1 clearly show that students who were taught using either discovery learning or differentiated instruction outperformed those who received conventional instruction in both problem-solving ability and learning interest. The Discovery Learning group exhibited the highest mean scores in both domains, followed closely by the Differentiated Instruction group. The Control group's scores were considerably lower, indicating that traditional instruction was less effective in fostering cognitive and affective student outcomes. These initial findings provide strong descriptive evidence that both experimental instructional models offer advantages over conventional teaching, supporting the study's hypothesis.

These differences are visually illustrated in the bar chart below, which reinforces the numerical trends by showing that both experimental groups consistently outperformed the control group.

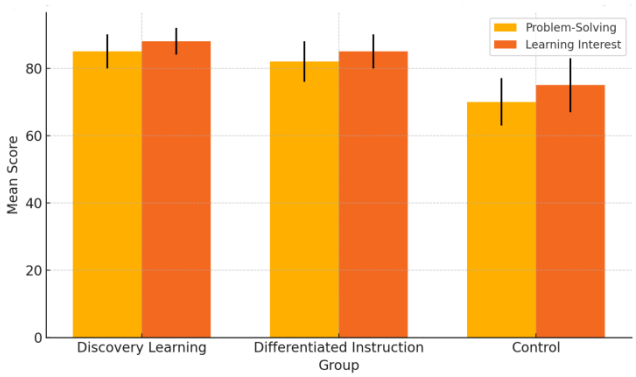

Figure 1. Posttest Scores in Problem-Solving and Learning Interest by Group

Figure 1 visually reinforces the tabular results by depicting a clear separation in performance among the three groups. The Discovery Learning and Differentiated Instruction groups show elevated bars for both problem-solving and learning interest, while the Control group's bars are significantly shorter in both domains. The standard deviation bars indicate that while some variability exists, the general trend is consistent: student-centered learning models lead to better academic performance and higher engagement. This visual representation strengthens the argument that instructional approaches that emphasize active learning, exploration, and personalization are more effective in achieving desired learning outcomes.

2. Inferential Statistical Analysis

To confirm the significance of these differences, a one-way ANOVA test was performed. The results indicated a statistically significant difference in posttest scores among the three groups ($F = 36.92$, $p < 0.001$). This result confirms that the instructional approach had a strong effect on student outcomes.

Further analysis using the Tukey HSD post-hoc test revealed where those differences occurred. The results are shown in Table 2:

Table 2. Tukey HSD Test Results for Posttest Scores

Group 1	Group 2	Mean Diff.	p-value	95% CI Lower	Upper	Significant
Control	Differentiated Instruction	10.59	0.0000	6.43	14.75	Yes

Control	Discovery Learning	14.33	0.0000	10.17	18.49	Yes
Differentiated Instruction	Discovery Learning	3.74	0.0867	-0.42	7.90	No

The post-hoc results in Table 2 confirm that the differences observed in the descriptive data and visual representation are statistically significant. Both Discovery Learning and Differentiated Instruction groups differ significantly from the Control group in terms of posttest scores, with p-values well below the 0.01 threshold. However, the comparison between the two experimental groups did not reach statistical significance ($p = 0.0867$), although the Discovery Learning group had a slightly higher mean score. This suggests that while both methods are effective, neither is conclusively superior to the other under the conditions of this study. It also implies that educators may choose either approach based on classroom needs and instructional objectives, without sacrificing learning outcomes.

3. Discussion

The findings of this study provide empirical evidence on the effectiveness of two instructional models—Discovery Learning and Differentiated Instruction—in enhancing students' cognitive and affective outcomes in mathematics education. Both approaches were found to significantly improve students' problem-solving abilities and their interest in learning mathematics compared to conventional instruction. These results support the premise that active, student-centered instructional strategies offer meaningful benefits over traditional teacher-centered methods.

Discovery Learning, as reflected in the highest mean scores among all groups, appears to be particularly effective in developing students' problem-solving abilities. This approach encourages students to engage in guided exploration, construct understanding independently, and apply reasoning strategies to solve problems—practices that align closely with constructivist learning theory (Bruner, 1961; Mayer, 2020). The success of this group reinforces previous findings that structured discovery activities foster deeper conceptual understanding, promote higher-order thinking, and increase student engagement (Handayani & Maulidya, 2022).

Meanwhile, the Differentiated Instruction group also demonstrated significant improvement in both measured domains. Although their scores were slightly lower than the Discovery Learning group, the gains were nonetheless statistically meaningful. This model's strength lies in its flexibility it allows teachers to adjust content, process, and product based on students' readiness, learning profiles, and interests. As previous studies have shown, when instruction is tailored to individual needs, students feel more supported, capable, and intrinsically motivated (Tomlinson, 2014; Ismail & Ahmad, 2021). The positive affective outcomes in this group confirm that personalization fosters not only comprehension but also emotional investment in the learning process.

Interestingly, the Tukey HSD post-hoc test revealed that while both experimental groups significantly outperformed the control group, the difference between Discovery Learning and Differentiated Instruction was not statistically significant ($p = 0.0867$). This suggests that under the conditions of this study, both models are comparably effective. The similarities in impact may stem from shared pedagogical features such as active participation, scaffolding, student autonomy, and the use of meaningful learning tasks. These commonalities reflect best practices in constructivist and inclusive instruction and underscore their practical value in the classroom.

In the context of mathematics education, these results are especially important. Mathematics is often perceived by students as abstract and difficult, and traditional instruction frequently fails to foster engagement or understanding. The success of both Discovery Learning and Differentiated Instruction in this study demonstrates that when instruction is intentionally designed to involve students actively and respond to their individual differences, both learning outcomes and motivation can be enhanced.

Moreover, the results align with Subagio et al, (2021) assertion that effective instruction must integrate both cognitive challenge and affective support. He emphasizes that mathematics learning must not only build thinking skills but also sustain students' willingness to engage with the subject. This study supports that perspective, offering concrete evidence that instructional strategies combining rigor and responsiveness can transform student experiences in mathematics classrooms.

Given these findings, educators are encouraged to adopt either Discovery Learning or Differentiated Instruction as valid, research-supported strategies for improving mathematics learning. While Discovery Learning may be more suitable when the goal is to develop reasoning and independent thinking, Differentiated Instruction is particularly helpful in managing learner diversity and enhancing emotional engagement. Future research may further explore how these models perform over longer instructional periods, across different mathematics topics, or when integrated together in hybrid designs.

In summary, the discussion confirms that both instructional models contribute significantly to improving cognitive and affective aspects of students' mathematics learning. Their success emphasizes the need for schools and teachers to move beyond traditional methods and implement student-centered practices that align with the demands of 21st-century education.

CONCLUSION

This study examined the effects of Discovery Learning and Differentiated Instruction on students' cognitive and affective learning outcomes in mathematics education. Specifically, it focused on mathematical problem-solving skills and interest in learning mathematics among eleventh-grade students. Based on the findings, both instructional models led to significantly higher posttest scores in comparison to conventional teaching methods.

The Discovery Learning model was shown to be particularly effective in enhancing problem-solving abilities. Through guided inquiry and exploration, it fostered students' analytical thinking, conceptual understanding, and active engagement. Meanwhile, the Differentiated Instruction model also yielded substantial gains, particularly in affective outcomes, by addressing students' diverse learning needs, interests, and readiness levels.

Although the Discovery Learning group achieved slightly higher mean scores, the difference between the two experimental groups was not statistically significant. This suggests that both models are comparably effective in supporting mathematics learning. Their shared characteristics such as student-centeredness, scaffolding, and flexibility appear to contribute to improved learning outcomes.

These findings underscore the importance of implementing active and inclusive pedagogical approaches in mathematics instruction. Educators are encouraged to apply either Discovery Learning or Differentiated Instruction depending on the context, instructional goals, and learner characteristics. Future research is recommended to explore the long-term impact of these models, their effects across different mathematical topics, and their potential for integration in blended instructional designs.

In conclusion, both Discovery Learning and Differentiated Instruction are valuable and effective strategies for fostering students' cognitive development and motivation in mathematics. Their implementation has the potential to improve the quality and equity of mathematics education in secondary schools.

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