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# Effectiveness of Discovery Learning Assisted by GeoGebra in Enhancing Students' Mathematical Literacy

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**ABSTRACT**

GeoGebra-assisted discovery learning offers a promising solution to the challenges of mathematical literacy. This model is not only student oriented but also encourages learners to actively and independently construct mathematical concepts and connect them to real-life experiences. This study aimed to examine the effectiveness of GeoGebra based discovery learning in enhancing students' mathematical literacy and to assess their literacy level after its implementation. An experimental method with a one-group pretest–posttest design was employed. The population consisted of all tenth-grade students at SMA Negeri 1 Singaparna, and the sample was selected through cluster random sampling from class X-3. The instrument was a mathematical literacy essay test, validated by experts and tested for validity and reliability on a separate sample. Data were analyzed using descriptive statistics and N-Gain calculations with IBM SPSS Statistics 24, including the Shapiro–Wilk normality test and a one-sample t-test. The findings revealed a mean N-Gain score of 0.66 (moderate category), indicating the model's effectiveness in improving students' mathematical literacy. Moreover, students' literacy levels after the intervention also fell into the moderate category. Practically, this study provides teachers with learning resources, such as teaching modules, to support instruction and foster collaborative, discovery-based learning that deepens students' understanding of mathematical concepts.



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## Introduction

Education serves as the primary foundation for improving the quality of human resources, which in turn becomes the cornerstone of a nation's progress (Alfiani et al., 2023). High-quality human resources are characterized by individuals who are knowledgeable, skilled, virtuous, responsible, and determined to pursue well-being while contributing to the harmony and prosperity of their families, communities, and the nation (Hamdi et al., 2022). In line with this, education is regarded as a systematic and directed process aimed at developing individual potential through learning, thereby shaping character, attitudes, and abilities required for life (Sholihah et al., 2021). Within this context, mathematics occupies a fundamental role at all levels of education and is highly relevant to daily life (Wahyudi et al., 2023).

Mathematics is a discipline focused on the study of abstract structures and the relationships among their elements (Dewi & Ardiansyah, 2022). Understanding these structures and relationships requires mastery of fundamental concepts that are systematically and logically organized according to specific rules. Hence, mathematics can be viewed as a science that examines regularities through structures, relationships, and concepts developed deductively. A deep understanding of the nature of mathematics is essential for teachers, as it influences the formulation of learning objectives and the selection of strategies appropriate to students' characteristics. Despite its abstract nature, teachers are expected to present mathematical concepts in a contextual and representative manner, particularly because most students remain at the stage of concrete operational thinking. In practice, teachers may employ various media and instructional aids to support students in achieving mathematical competence. The proper use of learning media not only facilitates understanding but also fosters students' awareness of the importance of both the process and outcomes of mathematics learning.

Mathematics learning refers to a structured set of activities designed to provide learning experiences for all students through well-prepared and organized activities. The goal is to ensure that students master the competencies associated with mathematical content (Yayuk, 2019). Each step in the learning process is arranged systematically and sequentially to help students understand the material being taught. Beyond conceptual understanding, mathematics learning also aims to equip students with the ability to face and solve real-life problems. Consequently, students are expected not only to master concepts at a theoretical level but also to apply them in authentic contexts. Such an approach encourages active participation, thereby making mathematics learning more effective and meaningful.

According to the Regulation of the Minister of Education and Culture (Permendikbud) No. 22 of 2016 (Harman et al., 2024), mathematics learning emphasizes the development of four main dimensions. The first dimension involves understanding mathematical concepts, identifying relationships among them, and applying concepts and algorithms efficiently, flexibly, accurately, and precisely in problem solving. The second emphasizes reasoning about mathematical patterns and characteristics to construct arguments, develop proofs, or explain mathematical statements. The third dimension covers problem-solving skills, beginning with understanding problems, formulating mathematical models, solving these models, and presenting appropriate solutions. The fourth dimension highlights communication, where students are expected to express ideas or arguments using diagrams, tables, symbols, or other media to clarify problems and contexts. These four dimensions are directly related to mathematical literacy.

Mathematical literacy refers to an individual's ability to formulate problems, apply mathematical concepts, and interpret mathematical results in real-life situations. This competence encompasses logical thinking processes and the use of concepts, procedures, facts, and mathematical tools to represent, explain, and predict various phenomena (Khotimah, 2021). Mathematical literacy is closely tied to the application of mathematical knowledge in solving everyday problems, making its benefits directly relevant to individuals. It goes beyond theoretical mastery, as it fosters analytical thinking, critical reasoning, and problem-solving in authentic contexts. Therefore, mathematical literacy prioritizes the practical application of mathematics in daily life rather than rote memorization of formulas.

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3491 Volume 5, No 3, Juli - September 2025, pp. 1383– 1397

Preliminary observations conducted with a tenth-grade mathematics teacher at SMA Negeri 1 Singaparna revealed that mathematics learning was generally well implemented. However, several students were still struggling with contextual problems related to the material taught, and some did not attempt to solve the problems at all. These difficulties may stem from the limited use of contextual questions during instruction, which leaves students unaccustomed to engaging with mathematics in real-life situations. As a result, students experienced difficulties in identifying mathematical elements within problems, constructing suitable models, applying those models to obtain solutions, and interpreting solutions in real-world contexts. This condition reflects students' low level of mathematical literacy as evidenced by these indicators.

Discovery learning supported by GeoGebra was selected as a potential solution to these challenges. This model is not only student-centered but also trains students to independently discover concepts and connect them to real-life experiences. Ardianto et al. (2019) reported that Discovery learning with GeoGebra improves students' mathematical abilities, learning outcomes, responses, and classroom engagement. Discovery learning emphasizes the process of inquiry to encourage active learning, where students are guided to discover concepts through data obtained from observation or experimentation (Ena et al., 2022). Knowledge is thus acquired not merely from teacher explanations but also through investigation, discovery, and direct application. GeoGebra functions as an effective visualization tool, particularly in algebra and geometry learning, to enhance students' engagement and understanding (Cahyani, 2020). Similarly, Farihah et al. (2022) found that the model allows students to reflect on content not yet mastered, such as systems of linear equations in two variables (SLETV), and to relate it to real-life contexts, especially in solving word problems through group discussion. These findings align with Hutajulu & Soesanto (2023), who concluded that applying GeoGebra in discovery learning helps students construct mathematical concepts independently, thereby making learning more meaningful.

Further studies support these findings. Dwiningrum (2021) demonstrated that integrating GeoGebra into discovery learning effectively improved students' academic achievement. Hutajulu & Soesanto (2023) showed that this approach significantly strengthened students' conceptual understanding, while Hidayah et al. (2024) argued that GeoGebra-assisted discovery learning was more effective in enhancing mathematical reasoning than conventional methods. Collectively, these studies indicate that discovery learning integrated with GeoGebra improves mathematical competence, particularly in conceptual understanding and reasoning. While prior studies have examined the use of discovery learning with GeoGebra, none has specifically investigated its impact on mathematical literacy. Therefore, this study aims to evaluate the effectiveness of GeoGebra-assisted discovery learning in enhancing students' mathematical literacy and to examine students' literacy levels following its implementation.

In summary, the choice of learning model plays a crucial role in the success of teaching and learning. Teachers must select and apply effective instructional models to ensure that mathematics learning objectives are optimally achieved. One such model that has shown promise in improving mathematical literacy is discovery learning enriched with GeoGebra. accordingly, this study was designed to evaluate the effectiveness of GeoGebra-assisted discovery learning in improving students' mathematical literacy and to assess their literacy levels after its implementation.

## Method

### Research Type, Population, Sample, and Research Design

This study employed a quantitative approach with an experimental method. The design chosen was a pre-experimental design, namely a basic design that involves only one group without a control group. The population of this study comprised all tenth-grade students at SMA Negeri 1 Singaparna. The sample was selected using cluster random sampling, a technique in which intact classes, rather than individuals, are randomly chosen as samples (Sugiyono, 2023). The sampling process was carried out by writing the names of the classes on small pieces of paper and drawing them randomly, resulting in class X-3 being selected as the experimental group. Subsequently, class X-3 was given treatment through the implementation of the discovery learning model supported by GeoGebra. To measure the improvement in students' mathematical literacy, a one-group pretest–posttest design was applied, in which measurements were conducted before and after the treatment (Sugiyono, 2023).

### Research Instrument

Researcher employed a research instrument as a tool to facilitate the data collection process, thereby enabling the collected data to be easily processed and analyzed (Malik, 2018). An essay-type mathematical literacy test was used as the instrument in this study. Each test item was designed to cover all indicators of mathematical literacy and was administered to students both before and after the treatment. The test consisted of two pretest items and two posttest items. Table 1 presents an example of a mathematical literacy test item.

**Table 1.** Example of a Mathematical Literacy Test Item

<table>
<tr><th>Item</th><th>Characteristics</th></tr>
<tr><td>On Sunday, Zahra and her family visited an amusement park in Japan. They planned to try various rides, including the roller coaster, which many considered the most extreme attraction, as shown in the figure below.<br><br>The roller coaster track at the amusement park forms a downward-opening parabola supported by three main pillars: right, middle, and left. The distance from the starting point of the track to the right pillar is 12 meters, while the distance from the end point of the track to the right pillar is 2 meters. The heights of the left and right pillars are equal, namely 24 meters. If the right pillar is assumed to be the Y-axis, determine the equation of the roller coaster track in the form of a quadratic function. | Students are required to identify mathematical aspects of the problem presented in a real-world context, including the known and unknown elements.</td><td>Students are required to transform the contextual problem into an appropriate mathematical model using variables and diagrams. From the given problem, a parabola is formed. Based on the property of a parabola, which is symmetric with respect to its axis, three main coordinate points can be obtained. To determine the roller coaster track, students must formulate the quadratic function. Thus, the element to be determined in this problem is $f(x)$.<br>Students are required to apply the constructed mathematical model to find a solution. Given that the quadratic function passes through three points, the general form of the quadratic function is $y = ax^2 + bx + c$. By substituting the three points, the value of c can be obtained, along with a system of two linear equations in two variables. Through elimination, the values of a and b can then be determined. Afterward, the quadratic function of the roller coaster track can be established.</td></tr>
</table>

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3491 Volume 5, No 3, Juli - September 2025, pp. 1383– 1397

## Procedures and Analysis

Data in this study were obtained using a test as the primary data collection instrument. A test is defined as a series of tasks or questions designed to assess the extent to which an individual or group has mastered a particular skill, body of knowledge, or specific ability (Malik, 2018). In this study, the test consisted of a set of items designed to measure mathematical literacy. The administration of the test was divided into two parts: a pretest and a posttest. Data were collected through an individual mathematical literacy test administered both before and after the treatment. Students' mathematical literacy was assessed using a scoring rubric aligned with the indicators of mathematical literacy. The scoring rubric is presented in Table 2.

**Table 2.** Scoring Rubric for the Mathematical Literacy Test

| Mathematical Literacy Indicator | Scoring Guide for Students' Responses | Score |
|---|---|---|
| Identifying mathematical aspects in problems situated in real-world contexts | No response at all | 0 |
| | Identifies aspects incorrectly | 1 |
| | Identifies aspects partially correctly | 2 |
| | Identifies aspects correctly | 3 |
| Translating the problem into an appropriate mathematical model in the form of variables, diagrams, or graphs | No response at all | 0 |
| | Translates incorrectly | 1 |
| | Translates partially correctly | 2 |
| | Translates correctly | 3 |
| Applying the constructed mathematical model to find a solution | No response at all | 0 |
| | Applies incorrectly | 1 |
| | Applies partially correctly | 2 |
| | Applies correctly | 3 |
| Interpreting mathematical results within the context of the real-world problem | No response at all | 0 |
| | Interprets incorrectly | 1 |
| | Interprets partially correctly | 2 |
| | Interprets correctly | 3 |

Source: Yustinaningrum (2021)

The test results were processed using IBM SPSS Statistics 24 through several steps:

## Descriptive Statistics

Descriptive statistics were employed to summarize the collected data without generalizing to the entire population (Sugiyono, 2023). This included analyzing pretest and posttest scores, as well as effectiveness (N-Gain), using measures such as the number of cases, minimum and maximum scores, and the mean. The purpose was to provide a general overview of the data characteristics.

## Normalized Gain (N-Gain) Test

N-Gain test was used to measure changes in students' ability before and after treatment. Scores were analyzed using the normalized gain formula (Sukarelawan et al., 2024):

N-Gain=(Maximum Score−Pretest Score)(Posttest Score−Pretest Score). The criteria for interpreting the mean N-Gain score are shown in Table 3.

**Table 3.** Normalized Gain (N-Gain) Criteria

| Mean N-Gain Value | Category |
|---|---|
| $0.70 \leq g \leq 1.00$ | High |
| $0.30 \leq g < 0.70$ | Moderate |
| $0.00 < g < 0.30$ | Low |

(Sukarelawan et al., 2024)

## Normality Test

A normality test was conducted to determine whether the data followed a normal distribution (Sintia et al., 2022). The Shapiro–Wilk test was used, as the sample size was fewer than 50. This method is more suitable for small samples, with a significance level of 5%. The hypotheses for the normality test were:

$H_0$: Data are normally distributed

$H_1$: Data are not normally distributed

Based on Sukarelawan et al. (2024), the decision criteria were:

If sig. $> 0.05 \rightarrow$ normality assumption met ($H_0$ accepted)

If sig. $< 0.05 \rightarrow$ normality assumption not met ($H_0$ rejected)

## Hypothesis Testing

If the data met the normality assumption, a one-sample t-test was conducted. If not, a non-parametric one-sample chi-square test was used. This study applied a significance level of $\alpha =$ 5%. The one-tailed hypotheses tested were (Muhid, 2019):

$$H_0: \mu \leq 0.3$$

$$H_1: \mu > 0.3$$

Where $\mu$ represents the mean N-Gain score of students' mathematical literacy. Decision criteria (Muhid, 2019):

If sig. $> 0.05 \rightarrow H_0$ accepted

If sig. $< 0.05 \rightarrow H_0$ rejected

Thus, if $H_0$ is accepted, GeoGebra-assisted discovery learning is not effective for students' mathematical literacy. Conversely, if $H_0$ is rejected, the model is effective.

## Data Analysis to Address Research Questions

The categorization of mathematical literacy levels was conducted to answer the research question regarding students' mathematical literacy after instruction with GeoGebra-assisted discovery learning. The criteria are shown in Table 4 (Sulistiawati et al., 2021).

**Table 4.** Mathematical Literacy Categories

| Interval | Category |
|---|---|
| $x \geq \bar{x} + SD$ | High |
| $\bar{x} - SD < x < \bar{x} + SD$ | Moderate |
| $x \leq \bar{x} - SD$ | Low |

where:

$x$ = respondent's score

$\bar{x}$ = idal mean = ½ (maximum score + minimum score)

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3491 Volume 5, No 3, Juli - September 2025, pp. 1383– 1397

SD = ideal standard deviation = ⅙ (maximum score – minimum score)

Based on the posttest results of the experimental class, the maximum score obtained was 23 and the minimum score was 13. Therefore, the ideal mean was 18 and the ideal standard deviation was 1.66. These values were used to determine the mathematical literacy intervals presented in Table 5.

**Table 5.** Interval Categories of Mathematical Literacy

| Interval | Category |
|---|---|
| $x \geq 20$ | High |
| $16 < x < 20$ | Moderate |
| $x \leq 16$ | Low |

## Results

This study was conducted over six meetings: four sessions for instruction, one session for the pretest, and one session for the posttest. Alongside the development of the mathematical literacy test, the first stage involved preparing a teaching module comprising learning objectives, instructional activities, assessment, learning materials, student worksheets, and individual tasks focused on quadratic equations and functions. Prior to implementation, the researcher consulted with the tenth-grade mathematics teacher at SMA Negeri 1 Singaparna and the academic supervisor to ensure the appropriateness of the syntax applied in the discovery learning model supported by GeoGebra. The implementation actively engaged students in exploring and discovering mathematical concepts through GeoGebra visualizations. Students used construction tools, animations, and manipulations in GeoGebra, which enhanced their understanding and learning engagement. To determine students' prior knowledge before the treatment, a mathematical literacy pretest was administered. The descriptive statistics for the pretest are shown in Table 6.

**Table 6.** Descriptive Statistics for Students' Mathematical Literacy Pretest Scores

| Statistic | N | Minimum | Maximum | Mean |
|---|---|---|---|---|
| Pretest | 38 | 5 | 14 | 9.87 |

As shown in Table 6, the mean pretest score for the experimental class was 9.87, with a minimum of 5 and a maximum of 14. Following the pretest, four instructional meetings (Sessions 2–5) used the GeoGebra-assisted discovery learning model on quadratic equations and functions. At the beginning of each meeting, preliminary activities included greetings, a class-led prayer, and checks of neatness, readiness, and attendance. The teacher informed students that discovery learning with GeoGebra would be used. Learning outcomes, objectives, and subtopics were clearly explained. Motivational prompts connected quadratic equations and functions to real-life applications, and the assessment techniques to be used were outlined. Students then worked in six small groups. The lesson proceeded to the core phase, applying the discovery learning syntax with GeoGebra, encouraging students to actively explore and discover concepts through structured activities.

The lesson began with an introduction to GeoGebra. The researcher presented GeoGebra as an interactive tool to assist with tasks in the materials and in the LKPD related to quadratic functions. Initial observations indicated that some students already had experience with GeoGebra, while others only recognized the name without hands-on use. Students accessed GeoGebra Classic and, in a guided practice, were introduced to core icons and features and then tasked with plotting a quadratic function as an initial application.

Phase 1: Stimulation. Students observed and made sense of a contextual problem (varying by meeting) presented by the instructor and were also introduced to quadratic graphs visualized in GeoGebra. The instructor posed guiding questions about the context and the displayed graphs to stimulate students' thinking. Students could ask questions or respond, creating an initial dialogic interaction. Afterwards, each group received the materials and LKPD to work on collaboratively.

Phase 2: Problem Statement. Students examined the contextual problem (varying by meeting) in the materials and LKPD, focusing on known information and the questions asked. As the problems involved quadratic graphs, students explored relationships among relevant elements using GeoGebra. They then formulated mathematical models (quadratic equations/functions) and represented them visually in GeoGebra.

Phase 3: Data Collection. Students used GeoGebra to explore and solve the contextual problems (varying by meeting) in the materials and LKPD. This included modeling the problem mathematically and plotting the quadratic function. During discussions, the researcher observed by circulating, offering support when students faced difficulties using GeoGebra. The researcher also assessed individual learning autonomy and group collaboration as part of the skills assessment, ensuring each student used GeoGebra appropriately.

Phase 4: Data Processing. Students analyzed the outputs from their GeoGebra explorations within group discussions. Activities included formulating quadratic equations, establishing links between algebraic roots and the quadratic graph, setting up and solving relevant quadratic equations, and determining the axis of symmetry and optimal values using GeoGebra features.

Phase 5: Verification. Students verified their solutions by comparing manual algebraic work with the quadratic graphs produced in GeoGebra. Agreement between the two confirmed the solution; discrepancies prompted students to identify and correct computational errors.

Phase 6: Generalization. Groups presented their solutions to the class. If groups reached similar solutions and procedures, one group was randomly selected to present. If different solution paths led to the same result, several groups presented in turn. The instructor acknowledged participation and collaboration and reinforced the key concepts learned.

In the sixth meeting, the posttest was administered to assess students' knowledge after the treatment. Posttest results are presented in Table 7.

**Table 7.** Descriptive Statistics for Students' Mathematical Literacy Posttest Scores

| Statistic | N | Minimum | Maximum | Mean |
|---|---|---|---|---|
| Posttest | 38 | 13 | 23 | 18.97 |

As shown in Table 7, the mean posttest score for the experimental class was 18.97, with a minimum of 13 and a maximum of 23. The test was administered in the first and sixth meetings. Based on the scoring rubric, the total possible score for both the pretest and the posttest was 24. There were four items in total (two pretest items and two posttest items), with each item worth a maximum of 12 points. The test involved 38 students. Normalized gain (N-Gain) was computed for further analysis. Descriptive statistics for the pretest and posttest are summarized in Table 8.

**Table 8.** Descriptive Statistics for Pretest and Posttest

| Test | N | Minimum | Maximum | Mean |
|---|---|---|---|---|
| Pretest | 38 | 5 | 14 | 9.87 |
| Posttest | 38 | 13 | 23 | 18.97 |

Table 8 shows a mean difference of 9.10 between the pretest and posttest, indicating a higher mean at posttest and suggesting improvement following the GeoGebra-assisted discovery learning intervention. N-Gain was then computed by comparing the difference

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3491 Volume 5, No 3, Juli - September 2025, pp. 1383– 1397

between the pretest and posttest scores with the difference between the ideal maximum and the pretest score. Summary statistics for N-Gain are shown in Table 9.

**Table 9.** Descriptive Statistics for N-Gain Scores

| | N | Minimum | Maximum | Mean |
|---|---|---|---|---|
| N-Gain | 38 | 0.42 | 0.93 | 0.6631 |

As shown in Table 9, the mean N-Gain was 0.66, which falls between 0.30 and 0.70. Thus, the effectiveness of the GeoGebra-assisted discovery learning model on students' mathematical literacy is categorized as moderate. The classification of N-Gain for the experimental class is presented in Table 10.

**Table 10.** N-Gain Classification for the Experimental Class

| Mean N-Gain Interval | Frequency | Relative Frequency | Category |
|---|---|---|---|
| $0.70 \leq g \leq 1.00$ | 14 | 36.84% | High |
| $0.30 \leq g < 0.70$ | 24 | 63.16% | Moderate |
| $0.00 < g < 0.30$ | 0 | 0% | Low |

Table 10 indicates that no students fell into the low category; 24 students were in the moderate category, and 14 students were in the high category. Before hypothesis testing, prerequisite tests were conducted. First, normality was examined using the Shapiro–Wilk test at the 5% significance level. The significance value for the pretest was 0.095 and for the posttest was 0.068. Because both p-values exceeded 0.05, $H_0$ was accepted, indicating that both pretest and posttest data met the normality assumption. Given normality, a one-sample t-test (right-tailed) was used for hypothesis testing; if normality had not been met, a nonparametric one-sample chi-square test would have been used. The significance level was $\alpha = 5\%$. Results are shown in Table 11.

**Table 11.** One-Sample Right-Tailed t-Test

| Data | Mean Difference | p-Value | Conclusion |
|---|---|---|---|
| N-Gain | 0.66313 | $0.000 < 0.05$ | $H_0$ rejected |

Based on Table 11, the two-tailed significance reported by the software is $p = 0.000$ (< 0.05). Therefore, $H_0$ is rejected and $H_1$ is accepted, indicating that the use of the GeoGebra-assisted discovery learning model is effective for students' mathematical literacy. To address the research question on students' mathematical literacy after instruction with GeoGebra-assisted discovery learning, frequency distributions were analyzed, as shown in Table 12.

**Table 12.** Frequency Distribution of Students' Mathematical Literacy with GeoGebra-Assisted Discovery Learning

| Score Interval | Interpretation | Frequency | Percentage |
|---|---|---|---|
| $x \geq 20$ | High | 18 | 47.37% |
| $16 < x < 20$ | Moderate | 11 | 28.95% |
| $x \leq 16$ | Low | 9 | 23.68% |
| **Total** | | **38** | **100%** |

The mean posttest score for mathematical literacy was 18.97, which falls within the moderate category. Table 12 shows that 47.37% of students were in the high category, 28.95% in the moderate category, and 23.68% in the low category. Students scoring 20 or above consistently identified mathematical aspects in contextual problems, translated problems into appropriate mathematical models, applied these models to obtain solutions, and interpreted the results in real-world contexts. These students generally solved nearly all items with maximum scores on each indicator, demonstrating not only conceptual understanding but also the ability to apply and connect results to real situations, evidence of meeting learning objectives across all literacy indicators. Students scoring between 16 and 20 were categorized as moderate. They were generally proficient at identifying and modeling problems but still struggled with applying the model and interpreting results in authentic contexts. These students require strengthening particularly on the indicators of applying mathematical concepts to obtain solutions and interpreting results within real-world contexts. Students scoring 16 or below had difficulty identifying mathematical aspects in contextual problems, modeling the problems mathematically, applying the model to obtain solutions, and interpreting results within the real-world context. They tended to solve only basic items and were weaker in modeling, application, and interpretation. This indicates that learning objectives were not fully achieved and that these students require further support, especially on the indicators of translating problems into mathematical models, applying concepts to obtain solutions, and interpreting results in context.

## Discussion

Instruction was implemented by forming heterogeneous student groups based on a range of academic abilities. The purpose of this grouping was to stimulate interaction and the exchange of ideas among group members when solving the assigned problems. In the initial meeting, several students in the experimental class experienced difficulties completing the materials and LKPD, which made instructional time less than optimal. These challenges arose because quadratic equations and functions were new topics, and some students had not yet mastered prerequisite content such as basic algebra, the concept of function, function graphs, and linear equations. Accordingly, the researcher first reinforced prerequisite knowledge and then provided more structured guidance for working through the materials and LKPD to improve time efficiency. From the second meeting onward, the obstacles previously faced by students began to diminish. This was evident from the improvement in students' ability to complete the materials and to discover concepts through group discussion. While working on the LKPD, students also became more accustomed to contextual problems, and many were able to solve them with the aid of GeoGebra. Nevertheless, some students frequently forgot to reinterpret their computations within the real-world context. The researcher therefore consistently reminded students to draw explicit conclusions from their calculations so that the connection to authentic situations would be clear.

These findings support Dwiningrum (2021), who reported that using GeoGebra in teaching quadratic functions through the discovery learning model can improve students' academic achievement. In the present study, the model likewise proved effective in enhancing mathematical literacy, as students were actively engaged in solving real-world problems that linked mathematical concepts with daily life. The use of discovery learning assisted by GeoGebra encouraged students to identify the mathematical elements of real-world problems, translate those problems into mathematical language or models, use the models to obtain solutions, and interpret the results within authentic contexts. This aligns with Hutajulu & Soesanto (2023), who argued that applying discovery learning with GeoGebra is an important step toward strengthening students' conceptual understanding so they can solve mathematical problems accurately.

In this study, students were given opportunities to explore various concepts related to quadratic equations and functions by leveraging GeoGebra. This occurred because discovery learning promotes active involvement in independently discovering concepts through group discussion, which are then consolidated into conclusions and generalized. The results resonate with Liunesi et al. (2024), who found that discovery learning assisted by GeoGebra can improve students' mathematical literacy on the topic of systems of linear equations in two variables. In

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3491 Volume 5, No 3, Juli - September 2025, pp. 1383– 1397

the current context, the same model and medium were effective for quadratic equations and functions. Hence, GeoGebra-assisted discovery learning is suitable for topics in both Geometry and Algebra/Functions.

Teachers must select appropriate instructional models and media so that learning becomes more interactive, engaging, enjoyable, and non-monotonous. In mathematics, discovery learning is expected to strengthen students' understanding and yield long-term learning benefits, with positive effects on their mathematical competencies. The strategic use of learning media is also essential; in particular, GeoGebra is highly beneficial in mathematics instruction (Puspitasari et al., 2022). Student engagement in GeoGebra-assisted discovery learning was evident across activities such as identifying problems, collecting and processing data, conducting verification, and interpreting discussion outcomes in real-world contexts. Through these phases, students developed mathematical literacy both via collaborative, self-directed learning and via scaffolding provided by the researcher during discussions. This is consistent with Vygotsky's view (Wardani et al., 2023) that there are three forms of student performance in problem solving: (1) success achieved independently, (2) success achieved with assistance, and (3) failure to achieve success. Scaffolding is support given to help students attain goals they could not yet reach alone. The role of the teacher or a more capable peer is thus critical in guiding students toward higher levels of development. In this regard, tasks in discovery learning were designed with appropriate difficulty so that, after receiving initial support, students were able to complete the tasks independently. Vygotsky's theory therefore provides a key foundation for discovery learning.

The results indicate that implementing discovery learning with GeoGebra has a positive effect on students' mathematical literacy. This can be explained through Vygotsky's constructivist framework, particularly the roles of social interaction, language, the Zone of Proximal Development (ZPD), and scaffolding. During instruction, students actively interacted with the researcher and with peers while exploring mathematical concepts using GeoGebra. Such activity is consistent with Vygotsky's principle that cognitive development is substantially influenced by the social and cultural environment, including participation in joint learning activities (Suyatno et al., 2023). These interactions provided the space for students to build understanding progressively (from not knowing to knowing) with the help of more capable others (teachers or peers).

The findings also reinforce Jerome Bruner's theory (Purnomo, 2022), especially that effective learning requires students' active involvement in discovering knowledge for themselves, as emphasized in discovery learning. Students were encouraged to construct understanding through exploratory processes and to draw their own conclusions. Bruner further explained that intellectual development proceeds through three stages, enactive, iconic, and symbolic. In the implementation of discovery learning, students first engage in direct, concrete experiences (enactive), then move to images or concrete representations (iconic), and ultimately achieve abstract thinking using symbols or language (symbolic).

Overall, applying discovery learning assisted by GeoGebra in mathematics instruction at SMA Negeri 1 Singaparna provides empirical evidence that an inquiry-oriented, discovery-focused approach situated in real-world contexts can significantly improve students' mathematical literacy. These results align with theories emphasizing contextual and problem-based learning as pathways to strengthening students' mathematical competencies. However, several limitations emerged. Although mathematical literacy improved, most students achieved only a moderate category on the N-Gain measure, suggesting that effectiveness was not yet optimal. One contributing factor was that some students struggled to operate GeoGebra due to limited prior technical skills, resulting in class time being diverted to learning the software rather than exploring concepts. Limited instructional time also posed a constraint: discovery learning requires sufficient duration for the discovery process to unfold, yet actual lessons must adhere to school time allocations. Consequently, discovery learning was not maximized, particularly for students who needed more time to internalize concepts.

## Conclusion

Based on the interpretation of the analyzed data, hypothesis testing, supporting theoretical foundations, and the results of the pretest and posttest analyses, it can be concluded that the discovery learning model assisted by GeoGebra is effective in improving students' mathematical literacy. Furthermore, students' mathematical literacy after instruction with GeoGebra-assisted discovery learning was categorized as moderate. In light of these findings, several recommendations can be put forward. For students, it is advisable to regularly practice solving contextual problems in order to strengthen their mathematical literacy, while also being more careful in performing calculations and drawing accurate conclusions from the results obtained. For teachers, it is recommended to apply a variety of instructional models supported by appropriate learning media, one of which is discovery learning with GeoGebra, as well as to provide contextual problem-solving exercises so that students' mathematical literacy can continue to develop. For future researchers, it is expected that further studies will explore other instructional models that incorporate GeoGebra to enhance different aspects of students' mathematical competence, as well as investigate the application of discovery learning supported by alternative media in efforts to further improve students' mathematical literacy.

## Conflict of Interest

The authors declare that there is no conflict of interest.

## Authors' Contributions

S.S. contributed to the development of the research instrument, study design, theoretical framework, data collection, data processing, data analysis, presentation of results and discussion, revision of the study, and integration of information throughout the article. N.D. and D.S.V. contributed to the development of the theoretical framework and approved the final version of the manuscript. The overall percentage contributions of the authors to the conceptualization, preparation, and revision of this article are as follows: S.S.: 40%, N.D.: 30%, and D.S.V.: 30%.

## Data Availability Statement

The authors declare that the data supporting the findings of this study will be made available by the corresponding author, [S.S.], upon reasonable request.

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