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The Improve High School Student's Computational Thinking Ability and Mathematical Resilience with Project Based Learning Assisted by GeoGebra

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Abstract

This study attempts to enhance high school learners' computational thinking and mathematical resilience skills. This study employs quantitative approaches with a quasi-experimental research design, and the type of research is Non-Equivalent Group Design. The tools used in this study were computational thinking skills tests and mathematical resilience questionnaires. From the results of the survey conducted, it is known that: 1) the Project Learning model accompanied by GeoGebra significantly improves computational thinking skills, and Project-Based Learning (PjBL) model has moderate improvement; 2) computational thinking skills of high school students who were taught through Project-Based Learning model aided by GeoGebra improved significantly compared to those taught with the Project-Based Learning model; 3) Project-Based Learning model aided by GeoGebra has a positive effect on the mathematical resilience of high school students, but only to a moderate extent.

Keywords: computational thinking; geogebra; mathematical resilience; project-based learning; quadratic function

INTRODUCTION

Computational thinking is a method of problem-solving where students should use concepts ranging from abstractions, patterns, and so on to process, analyze data, create solutions to problems through algorithmic thinking, and generalize the problem-solving process to a wider variety of issues (García-Peñalvo & Mendes, 2018). Computational thinking is one of the core skills for students in the digital age and in this industrial era, which refers to the use of fundamental and core concepts the use of computer science to analyze and solve real-world problems (Zhu et al., 2025). Through computational thinking skills, it can also stimulate students to think creatively in solving problems (Metin et al., 2024).

High school students in Indonesia also do not have high computational thinking skills. In research by Abdul et al. (2022) students in Malaysia only achieved average scores post-test as big as in Geometry learning. Based on research by Jung & Seo (2021), students in Korea also have not achieved good computational thinking skills with an average score of post-test High school students is 3.14/4.00. This statement is supported by the results of research conducted by Amelia (2020), which showed that high school students' computational thinking abilities are still relatively low. This is proven by the average post-test score of no more than 55.027 out of a maximum score of 100. This is established by the average post-test score which is only 55.027 out of a maximum score of 100, indicating that although there was some improvement, students still struggled to reach a high level of mastery. This suggests that while the instructional intervention had a positive effect, it may not have been sufficient to fully develop students' understanding or that additional time and support might be necessary.

Apart from cognitive abilities, affective abilities are also highly significant in learning, especially mathematics learning. One of these affective abilities is mathematical resilience. In the context of mathematics, Newman in Ulhasna et al. (2024) stated that mathematical resilience is a quality attitude in learning mathematics which includes the ability to be confident in one's success through hard work, showing perseverance in facing difficulties, being willing to think, reflect and research. Mathematical resilience is crucial in learning mathematics because, in the process of learning mathematics, they will face challenges, tensions, and difficulties that will make students unhappy learning mathematics (Johnston-Wilder et al., 2021). Students' mathematical resilience has not shown satisfactory results. According to research conducted by Al-Ghifari (2023), out of 53 students, only 11 students, or 20,75% of students had high mathematical resilience with a score of ≥ 70.8.

Considering that less than a quarter of the students demonstrated a strong ability to persist, adapt, and stay motivated when facing mathematical challenges. A score above 70.8 is considered an indicator of high mathematical resilience, so the notion that only 11 out of 53 students reached this threshold suggests that most students may struggle with maintaining confidence and persistence in learning mathematics. This highlights a need for targeted interventions to foster resilience in more students, especially in challenging subjects like math. Students' mathematical resilience has not shown satisfactory results. Low mathematical resilience is not only influenced by the difficulty level of the material in mathematics but also by the learning model applied by the teacher and the learning media used (Rahayu, 2020).

The current problem is that mathematics learning still does not fully support students who like mathematics and tends to make students afraid to study mathematics. Even though several schools have implemented the Independent Curriculum, the implementation process has not been implemented properly so it has not provided flexibility because it does not provide space for students to explore *to develop an understanding* or *to acquire insight* into the material being taught (Novianto & Abidin, 2023). When they are given challenges and problems, they tend to be afraid and find it difficult to solve them. Saturated learning and lack of motivation for students are one of the causes of low mathematical resilience in students (Harianto, 2021).

One of the problem-solving abilities that students must have in this 21st-century learning era is the ability to think computationally (Kite & Park, 2024). Seeing such learning conditions, changes need to be made in the learning process. PjBL is a learning model that can be applied in both the 2013 curriculum and the independent curriculum. Research on the implementation of PjBL as part of efforts to improve students' mathematical abilities has been carried out and the results have had a positive impact on improving students' mathematical abilities. Based on research by Fadhil (2023), learning using the PjBL learning model indicates improvement in high school students' creative thinking abilities. Research conducted by Anwar (2021) also revealed that learning using the PjBL model can improve high school students' critical thinking skills compared to the expository learning model. Apart from that, research conducted by Pilawinata, et al. (2024) applies PjBL can also improve students' ability to understand mathematical concepts. Based on research conducted by Sitanggang & Haryanto (2023) high school students who receive model learning PjBL have a higher quality of mathematical understanding than students who receive learning with direct instruction and students give positive responses and feel motivated to learn mathematics because learning mathematics becomes more meaningful. Other research also reveals that the learning model PjBL not only increases cognitive abilities but also affective abilities, and mathematical resilience. Liu (2024) research shows that students who received the learning model PjBL (online) have higher motivation for learning mathematics, which is a part of resilience's mathematics element, than students who receive conventional (online) learning. Study PjBL Much has been done to improve students' mathematical abilities and mathematical resilience while research PjBL GeoGebra assistance has not been implemented *as an attempt* to enhance high school students' computational thinking skills and mathematical resilience.

The role of learning media is also crucial to support smoothness and success in the PjBL process. GeoGebra learning media can help improve students' computational thinking skills and mathematical resilience. According to the research of Yohannes & Chen (2023), GeoGebra helps students to understand mathematical concepts more systematically which is a part of computational thinking skills (algorithm thinking). Prince (2025) conducted the GeoGebra generating graph to help students have a perspective from several patterns which is a part of computational thinking skills (pattern recognition). In addition, Septian (2022) stated that GeoGebra-assisted PjBL can improve students' skills in solving problems given and can improve collaboration between students in groups to focus on important things in completing projects. In line with the opinion of Septian and Prabawanto (2020), the undertaking of learning media in project-based activities helps students become accustomed to collaboratively solving mathematical problems and making decisions to arrive at problem solutions. This, in turn, positively impacts students' computational thinking skills, which are higher than those of students who complete projects without the aid of GeoGebra. From the opinions of these experts, it can be concluded that the application of GeoGebra-assisted PjBL is one of the learning models that facilitates students to improve their computational thinking skills in solving and solving the given mathematical problems assisted by GeoGebra learning media.

Despite the growing recognition of the importance of computational thinking and mathematical resilience in 21st-century education, there remains a lack of integrated approaches that effectively enhance both competencies simultaneously, particularly at the senior high school level. Most prior studies have focused either on computational thinking or mathematical resilience in isolation, with a limited exploration into how innovative instructional models like PjBL, especially when supported by dynamic digital tools such as GeoGebra, can holistically enhance these skills. Therefore, this research is novel in its approach, integrating PjBL with GeoGebra to simultaneously foster the development of computational thinking and mathematical resilience. This study aims to fill the existing gap by providing empirical evidence on the effectiveness of this integrated model in senior high school mathematics education.

METHOD

Research Type

The approach used in this research is a quantitative approach that aims to test hypotheses from the data that has been collected. According to Jelena & Jelena (2022), the method used is quasi-experimental. The design used in this research is the Nonequivalent Control Group Design which consists of two classes, namely the experimental class and the control class. The experimental class is a class that is given learning using the Project–Based Learning model assisted by GeoGebra while the control class is a class that uses the Project–Based Learning model.

Research Subject

This study involved Grade X students from two classes at Senior High School (SHS) Number 2 Bandung in the 2023/2024 academic year. A total of 70 students participated, selected through purposive sampling based on specific criteria such as class availability, prior knowledge, and willingness to participate in the research.

Research Procedure

The research was carried out in three main stages. In the preparation stage, the researcher designed lesson plans based on the PjBL model, developed and validated test instruments and questionnaires to assess computational thinking and mathematical resilience, and coordinated with the school and the mathematics teacher. The implementation stage began with administering a pre-test to evaluate students' initial levels of computational thinking and mathematical resilience. This was followed by conducting Project–Based learning activities supported by GeoGebra, which focused on problem-solving and real-world project tasks. After the learning intervention, a post-test was given to measure any improvements. In the final stage, the researcher collected and organized the data and carried out data analysis to evaluate student learning outcomes and the overall effectiveness of the intervention.

Data Collection

Data collection techniques are the strategies researchers use to obtain data that substantiate their study. This is crucial in research since the fundamental goal of any research is to collect data (Herlawan et al., 2023). Observation is a data collection technique involving a complex process of observing and recalling (Ulum & Pujiastuti, 2020). This study used participant observation, where the researcher was directly involved in the activities experienced by the research subjects, doing what the participants did while observing them (Pixyoriza et al., 2022). This was done to evaluate the implementation of PjBL according to the planned lesson structure.

In this study, tests were used to measure the skills, knowledge, and abilities of individuals or groups. The test specifically measured computational thinking ability. It was administered twice: once before the learning intervention (pre-test) and once after the intervention (post-test), both for the experimental and control groups, to assess enhancement in computational thinking skills.

A questionnaire is a data collection method that presents written questions or statements to be answered by respondents (Yuliana & Waluyo, 2024). In this study, the questionnaire was used to measure whether there was an improvement in students' mathematical resilience before and after the PjBL with GeoGebra intervention. It was administered before the pre-test and again before the post-test in the experimental class, ensuring it did not interfere with the learning process.

Data Analysis

The data analysis in this study was conducted after all data were collected, to draw conclusions aligned with the research objectives. The analysis involved categorizing the data based on students' computational thinking skills and mathematical resilience, followed by data tabulation and appropriate statistical tests. For the computational thinking tests, pre-test and post-test data were analyzed using normality tests (Shapiro-Wilk), homogeneity tests (Levene's test), and mean difference tests, including the independent sample t-test or Mann-Whitney test, depending on data distribution and variance assumptions. To measure the quality of learning outcomes, normalized gain (N-gain) was calculated, and its values were interpreted using established categories: high ($g > 0.7$), medium ($0.3 < g \leq 0.7$), and low ($g \leq 0.3$). The difference in N-gain scores between the experimental class (taught using PjBL with GeoGebra) and the control class was then evaluated using the same set of statistical tests. For the mathematical resilience questionnaire data, responses were first processed using the Method of Successive Intervals (MSI) and then subjected to normality and homogeneity tests. To determine whether there was a significant difference in students' mathematical resilience before and after the intervention, the Wilcoxon signed-rank test was applied. All statistical analyses were performed with a significance level of $\alpha = 0.05$.

The approach used in this research is a quantitative approach that aims to test hypotheses from the data that has been collected. According to Jelena & Jelena (2022), the method used is quasi-experimental. The design used in this research is the Nonequivalent Control Group Design which consists of two classes, namely the experimental class and the control class. The experimental class is a class that is given learning using the Project–Based Learning model assisted by GeoGebra while the control class is a class that uses the Project–Based Learning model.

The stages of PjBL assisted by GeoGebra in this study are:

1. Giving Basic Questions

   Learning begins with basic questions related to the material to be studied. Questions are given to conduct an in-depth investigation of students' understanding.
2. Designing Product Planning

   In this step, teachers assist students in collaboratively designing projects, selecting activities that address the core questions, and determining the necessary project implementation requirements. At this stage, students can use GeoGebra to start developing project completion strategies more efficiently.
3. Preparing Product Making Schedule

   Teachers and students can agree on the project work schedule until the project is submitted. Additionally, teachers guide students in creating a more effective plan for using GeoGebra.
4. Monitoring the Activeness and Development of the Project

   In this step, the teacher monitors the activeness/participation of students during the project, monitors the realization and development of the project, and guides students if there are obstacles/difficulties with GeoGebra. Students carry out the project according to schedule, record stages, and discuss problems using GeoGebra to complete the project with the teacher. Teachers can assist with the GeoGebra classroom feature.
5. Testing the results

   At this stage, the teacher evaluates the performance of each student in completing the project with the assistance of GeoGebra, monitors student participation, and measures the project's success based on the plan. Additionally, the teacher discusses the project prototype.
6. Evaluation of Learning Experience

   The teacher facilitates the presentation process, responds to the project results, and provides evaluation/assessment. In GeoGebra, students submit a report on the project work and its outcomes, which is subsequently assessed by their peers or instructors. This evaluation provides conclusions on the project results and is linked to learning materials.

The form of this research design is depicted in the following diagram.

O_1	X	O_2
O_3		O_4

O_1: *Pre–test* Computational Thinking Ability and the Student's Mathematical Resilience in the Experimental Class

O_2: *Post–test* Computational Thinking Ability and the Student's Mathematical Resilience in the Experimental Class

O_3: *Pre–test Computational Thinking Ability and* the Student's Mathematical Resilience in the Control Class

O_4: *Post-test Computational Thinking Ability and* the Student's Mathematical Resilience in the Control Class

X : PjBL Model Learning assisted by GeoGebra.

This research involved 70 students in grade X in one of the Bandung City State High Schools with 35 students in each class (control and experiment). The test given is in the form of a description of 4 questions that correspond to pillars of computational thinking ability and a mathematical resilience questionnaire of 24 statements. There are four main pillars of computational thinking to find solutions in this process, namely problem decomposition, pattern recognition, abstraction and generalization and algorithmic thinking (Kim & Jeong, 2021). These resilience indicators are divided into several aspects, namely empathy, analyzing the cause of the problem, controlling emotions, controlling motivation, never giving up, achieving what is desired (reaching out).The data analysis technique uses the N-Gain score to see the quality of the increase in computational thinking ability and the independent sample t-test parametric test to see whether the increase in the ability of the experimental class is higher than the increase in computational thinking ability of the control class. Normalized processing gain is calculated by the formula:

$$Normalized\ Gain\ Score\ (g) = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score}$$

According to Hake in Fitriyanti et al. (2023) stated that the quality of improvement that occurs in both classes can be seen using the normalized gain formula and estimated using the gain categories in the Table 1.

Table 1. Normalized Gain (N–Gain) Score

N-Gain	Description
N-gain > 0,7	High
0,3 < N-gain ≤ 0,7	Medium
N-gain ≤ 0,3	Low

Table 1 displays the description of N-Gain score. It is provided by Hake's Normalized Gain Table, which is commonly used in educational research to measure the improvement of instructional interventions, especially in quasi-experimental or pretest-posttest designs.

RESULTS

The improvement of computational thinking skills

The results of this research indicate that the integration of PjBL, facilitated by GeoGebra, markedly improves students' computational thinking abilities and their resilience in mathematics. This outcome aligns with the theoretical framework of constructivism, which emphasizes learning as an active, contextualized process of constructing knowledge rather than acquiring it. According to Bell (2010), PjBL encourages students to engage in complex, real-world tasks, the integration of fostering critical thinking, collaboration, and problem-solving—key components of computational thinking.

In this study, the students in experimental group designed a city layout that incorporated land, sea, and air elements through quadratic function graphs. They also simulated and analyzed the trajectory of an "Angry Bird" using the GeoGebra canvas. These projects required students to decompose real-world problems into smaller sub-tasks (decomposition), identify patterns and relationships (pattern recognition), develop abstract representations (abstraction), and formulate algorithmic solutions—all core elements of computational thinking as defined by Metin (2024).

The implication of GeoGebra as a dynamic visualization tool supported these processes by making abstract mathematical concepts more tangible. Gurmu et al. (2024) emphasize that dynamic geometry software like GeoGebra can enhance students' engagement and conceptual understanding, especially when integrated into student-centered learning approaches. The ability to manipulate graphs and visualize trajectories in real time allowed students to explore the properties of quadratic functions and apply them to authentic scenarios, promoting deeper conceptual understanding and logical reasoning.

Furthermore, the project fostered mathematical resilience—the students' ability to persist in solving challenging problems and view mistakes as part of the learning process. According to Morgan (2025), mathematical resilience includes confidence, persistence, and a cheerful outlook toward problem-solving. The iterative and exploratory nature of the project encouraged students to revise their models, test different hypotheses, and engage in reflective thinking. This process nurtured a growth mindset, as students encountered and overcame difficulties in modeling real-life situations with mathematics.

The results also align with more recent findings by Kalinowski et al. (2024) who found that integrating mathematical modeling in project-based tasks increases student perseverance and belief in their mathematical capability. By engaging in meaningful, contextual projects, students not only improved their technical skills but also developed emotional and cognitive strategies to manage mathematical challenges.

Table 2. Pre-test computational thinking ability

Data	Sig.(2-tailed)	Conclusion
Pre-test computational thinking ability	0,972	There is no significant difference in the average initial computational thinking ability

In contrast, the control class, which followed instructions but drew and made it manually with a pencil and a block of paper (without GeoGebra), showed lower gains in computational thinking and resilience. This supports existing literature suggesting that traditional methods often emphasize procedural fluency over conceptual understanding, offering fewer opportunities for the students to develop their higher order thinking skills and resilience (Elhilal, 2025)

Table 2 displays the 2-tailed significance value in the Mann-Whitney test for the pretest score either higher than or equal. The initial computational thinking skills in the experimental and control classes were not notably different based on the criteria of hypothesis testing. Internal validity is thus established before treatment, so indicating that the treatment directly affects the results. After that, the research design treated both classes; then, a post-test evaluation gauges the students' final degrees of proficiency. Using the parametric independent sample t-test—where the conditions for the parametric test are satisfied, that is, the post-test data for both classes is homogeneous and normally distributed. Table 3 below shows the computed results.

Table 3. N-Gain Categories Computational Thinking Ability

Level	Experimental Class	Control Class
N–Gain Average	0,77 (High)	0,63 (High)
Maximum Score	1	1

Based on Table 3, it can be seen that the average N-gain score for experimental class students' computational thinking ability is and the control class is which means that according to the N-gain index criteria in Table 1, the quality of improvement in computational thinking ability the experimental class is in the high category, while the quality of improving the computational thinking abilities of control class students is in the medium category. However, whether the increase in computational thinking ability was significantly higher than the average computational thinking ability of the control class, an inferential statistical analysis was conducted to answer this question. The inferential statistical testing using parametric tests was undertaken in the review before testing the normality and homogeneity of the N-gain score data. The findings from the independent parametric t-test are presented in Table 4.

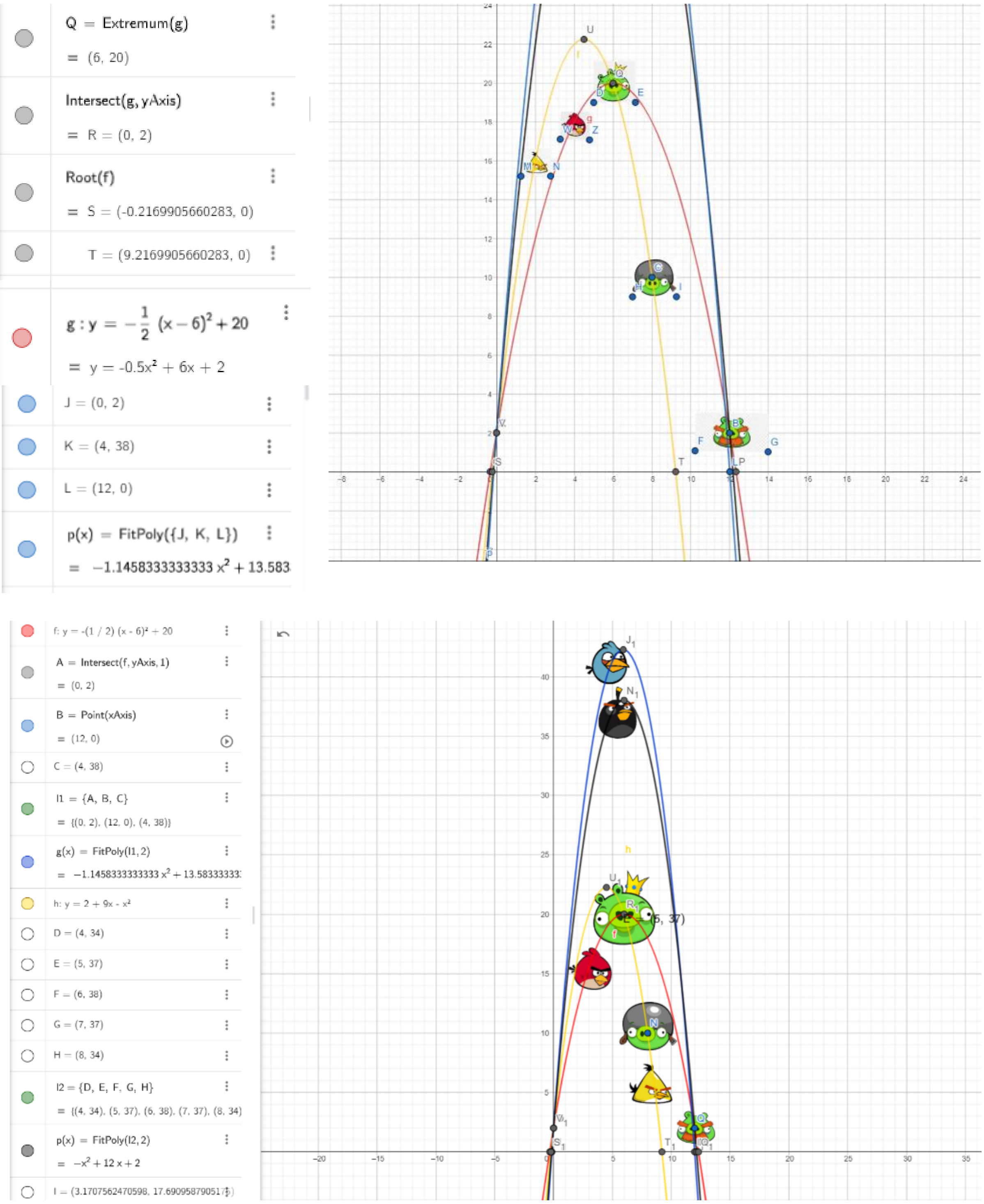
Table 4. Computational Thinking Ability Result

Data	Sig.	Conclusion
N-Gain Score of Computational Thinking Ability	0,011	The increase in computational thinking skills of the experimental class that received Project–Based Learning model learning assisted by GeoGebra was higher than the control class that received Project–Based Learning model learning

Based on Table 4, the 1-tailed significance value in the independent sample t-test for the N-gain score of students' computational thinking abilities is 0.011 or smaller than $\alpha = 0.05$. By paying attention to the test criteria above, H_0 is rejected, meaning that the increase in students' computational thinking abilities in the experimental class is significantly higher than in the control class.

In addition to statistical data, Figure 1 illustrates one of the learning tasks using GeoGebra, where students modeled the trajectory of a projectile ("Angry Bird") using a quadratic function in Figure 1. In Figure 1, a student-created simulation of projectile motion using GeoGebra. Students manipulated quadratic parameters to simulate the parabolic flight of an object, aligning it with mathematical modeling concepts such as vertex and symmetry axis.

Quantitative data processing was carried out using SPSS 26 software. Before analyzing the N-Gain score data, a test of differences in initial computational thinking abilities was carried out using the Mann-Whitney non-parametric test, because the pre-test data for the two classes was not normally distributed. The calculation results are as follows Table 2.



Student answer

Task 10

Sebutkan dan jelaskan jenis burung manakah yang dapat melawan masing – masing jenis Piggie tersebut. Beri alasan secukupnya!
a. King Pig :
b. Moustache Pig:
c. Coorperate Pig :

Answer

a. King Pig : 1. Yellow : karena lintasan yang dilalui oleh burung yellow melewati titik (6, 20) tempat King Pig berada.
2. Red : karena lintasan yang dilalui oleh burung red melewati titik (6, 20) tempat King Pig berada.

b. Moustache Pig : 1. Black : karena lintasan yang dilalui oleh burung black melewati titik (12, 2) tempat Moustache Pig berada.
2. Red : karena lintasan yang dilalui oleh burung red melewati titik (12, 2) tempat Moustache Pig berada.

c. Coorperate Pig : 1. Yellow : karena lintasan yang dilalui oleh burung yellow melewati titik (8, 10) tempat Coorperate Pig berada.

English Version

Mention and explain which type of bird can defeat each type of Piggie. Provide a brief reason!

a. King Pig:

1. *Yellow: because the trajectory of the yellow bird passes through the point (6, 20), where King Pig is located.*
2. *Red: because the trajectory of the red bird passes through the point (6, 20), where King Pig is located.*

b. Moustache Pig:

1. *Black: because the trajectory of the black bird passes through the point (12, 2), where Moustache Pig is located.*
2. *Red: because the trajectory of the red bird passes through the point (12, 2), where Moustache Pig is located.*

c. Corporate Pig:

1. *Yellow: because the trajectory of the yellow bird passes through the point (8, 10), where Corporate Pig is located.*

Figure 1. Student Experimental Class's Activity with Geogebra to Find the Angry Bird Trajectory

Another example of student work involved designing a city layout integrating mathematical elements (land, sea, air routes) based on quadratic curves and geometry principles. Figure 2. A GeoGebra-based city layout project showing the application of quadratic curves to infrastructure elements. Students used real-time geometric construction to combine creativity with mathematical logic and function graphing, and it helped students to release their mathematical thinking process.

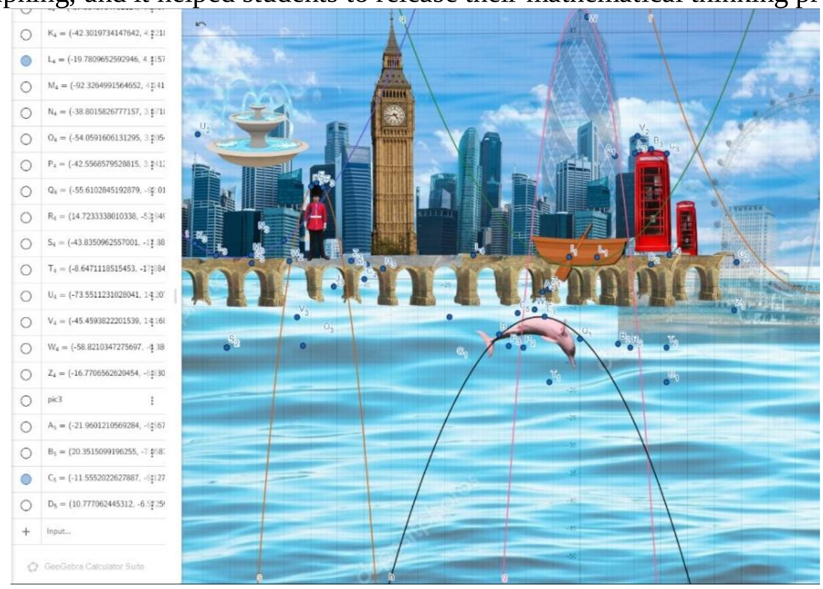


Figure 2. Student Experimental Classes Activity with Geogebra to Design a city layout

The results and discussion section takes up 70% of the document. The research data provided is processed data rather than raw data. Graphs, tables, diagrams, or even text can be used to illustrate research findings. Results must be analyzed and interpreted before discussing them. The research results are written in order, and the results are analyzed sequentially according to the data collected.

The Improvement of Mathematical Resilience

Conversely, the increase in computational thinking skills among PjBL students using GeoGebra software was much higher than among those in the PjBL instruction-only group.

This paper first hypothesizes whether the PjBL model using GeoGebra Software improves the mathematical resilience of students. Administered at the beginning and end of the experimental class, the information on the mathematical resilience of students was gathered using an attitude scale of 24 items. The average N-gain results are shown in Table 5.

Table 5. Parametric N-Gain Score Results of Mathematical Resilience

Data	Minimum	Maximum	$\bar{X}$	SD	Variance
N-Gain Score Mathematical Resilience Questionnaire	-0.37	6.92	0,42	1,22	1,494

Based on the N-gain score in Table 5, one can deduce from Table 5 that the average N-gain score of the mathematical resilience ability of the students who learn using the Project model is dissimilar from the others. PjBL is supported in medium quality by GeoGebra program.

DISCUSSION

The Improvement of Computational Thinking Student

The analysis of the average N-Gain score reveals that the PjBL assisted by GeoGebra yields significant improvements in students' computational thinking skills, categorized as high. The PjBL model without GeoGebra falls into the medium category. This disparity underscores the substantial benefits of integrating GeoGebra into enhancing computational thinking skills.

Engaging in projects helps to improve student's mathematical skills and aids in the development of vital skills such as teamwork and collaboration. Indeed, as noted by Rehman et al. (2024), PjBL fosters collaboration, one of the attributes that adds to students' understanding of mathematics. Working as a team and putting ideas together is often essential while addressing real-life problems, therefore creating an atmosphere that encourages interaction, discussions, and achievement of shared objectives. The effectiveness of GeoGebra in this context can be attributed to its ability to support key components of computational thinking, from decomposition, pattern recognition, abstraction, to algorithmic thinking. In the initial learning phase, where students encounter foundational problems, the experimental group leveraged GeoGebra to test hypotheses, visualize graphs, and dynamically analyze functions. This finding is consistent with Kovács & Vajda (2022) who observed that GeoGebra facilitates precise and detailed representations of mathematical problems, promoting a deeper understanding.

Furthermore, the project planning phase enhanced students' problem analysis and systematic thinking. GeoGebra facilitated real-time visualization and correction, allowing students to improve their strategies efficiently. As Siregar (2017) argues, GeoGebra is an effective tool for identifying solving patterns during the process of completing an assignment. This approach facilitates the recognition of repeating elements, which aids the development of computational thinking skills. This finding supports Zainudin et al. (2025) who argued that technological tools like GeoGebra enhance project accuracy and help students identify optimal solutions. At the project implementation stage, students in the experimental group demonstrated greater ease in exploring functions, especially quadratic ones, by plotting graphs and manipulating parameters interactively. In contrast, students in the control group, who did not use GeoGebra, required more time and effort to complete similar tasks, showing less flexibility in exploration. This supports Vennila et al. (2024) who emphasized the importance of dynamic visual tools in facilitating group-based analytical thinking.

The Improvement of Mathematical Resilience

These findings are consistent with Dewey's experiential learning theory, Piaget's view on active cognitive construction, and Bruner's emphasis on discovery learning. GeoGebra supports these theoretical frameworks by allowing students to construct knowledge through manipulation, exploration, and collaborative inquiry. Additionally, Kolb in Matsuo (2024) suggests that meaningful experiences enhance analytical ability an outcome demonstrated in this study's experimental group. Although the improvement in students' mathematical resilience is categorized as moderate, several indicators show that GeoGebra-assisted PjBL fosters persistence, collaboration, and confidence. Students in the experimental group showed an increased willingness to engage with difficult problems, demonstrated perseverance, and collaborated actively within groups. This increase in motivation is linked to the autonomy, relevance, and active involvement that PjBL provides during the learning process. These factors help sustain students' engagement, especially when working on complex or real-world problems (Wijnia et al., 2024) That is related to the computational thinking process.

The learning process entailed real-world, context-based projects that involved modeling land, air, and sea objects using quadratic functions. This relevance helped students view mathematics as meaningful and applicable, reducing anxiety and fostering motivation. Mutanga (2024) emphasizes that PjBL encourages perseverance by presenting real-life challenges in collaborative settings, which was evident in this study. Several classroom observations further support this: students shared knowledge about using GeoGebra, sought resources independently, and proposed ideas confidently. These behaviors align with Hendriana et al. in Ulhasna et al. (2024). concept of mathematical resilience, which includes diligence, confidence, and reflection. The collaborative exploration afforded by GeoGebra helped maintain engagement and reduce the likelihood of giving up, consistent with the findings of Nainggolan & Dewi (2024) and Adhikari (2021). PjBL can enhance students' abilities and boost their interest in learning to demonstrate mathematical resilience (Prianggono et al., 2023). GeoGebra can help students to be enthusiastic and not give up on working on project assignments and that is an indication of mathematical resilience (Putri et al, 2019).

The results demonstrate that GeoGebra-assisted PjBL has better outcomes than conventional PjBL to enhance computational thinking skills, with additional benefits in fostering mathematical resilience. While the gains in resilience were not as strong as those in computational thinking, the qualitative data suggests that with more sustained or extended interventions, resilience outcomes may also reach higher categories. The use of dynamic and interactive learning tools like GeoGebra allows students to better navigate complex problems, collaborate meaningfully, and persist in the face of mathematical challenges.

CONCLUSION

As has been analyzed in this study, the incorporation of GeoGebra in Project Based Learning (PjBL) enhances the student's computation thinking skills and their mathematical resilience. Particularly, students taught using the PjBL model and aided with GeoGebra progressed significantly better in computational thinking than their counterparts who were only taught through the PjBL model. Furthermore, the use of GeoGebra in the instructional model also moderately advanced students' mathematical resilience. This evidence highlights the striking benefits that dynamic instruction technologies offer in PjBL settings for secondary school learners, particularly in enduring understanding and problem-solving initiatives in geometry and algebra.

However, the study does have some weaknesses. This could have taken place in one classroom which indicates that the sample size is small and grade or age specific. These factors may restrict the range of the scope of the conclusions that may be drawn from the findings. In addition, the study did not account for skill retention over the extended time nor assess the impact that students of other backgrounds and learning styles may have on the results. The inclusion of secondary students could aid in studying the impacts of a more diverse student population. Strengthening the claim could come from combining the other additional technological tools with the PjBL frameworks and assessing it from a longitudinal perspective. Other qualitative analyses may include examining student perceptions and levels of engagement which may provide insights into how GeoGebra aids in enhancing computational thinking, mathematical resilience and explaining the magnitude of its impact.

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DECLARATIONS

Author Contribution	:	MVA: Conceptualization, Writing - Original Draft, Editing and Visualization; NN: Writing - Review & Editing, Formal analysis, and Methodology, Supervision; KY: Formal analysis, and Methodology
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Additional Information		Additional information is available for this paper.

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