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Implementation of Project-Based Learning with Scratch to Enhance Students' Computational Thinking on Linear Function

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Abstract

This study aims to: (1) determine students' learning mastery in terms of computational thinking skills, based on a mastery threshold of 70, both individually and classically after the implementation of the Project-Based Learning (PjBL) model assisted by Scratch media; (2) identify whether there is a significant difference in the improvement of computational thinking skills between students taught using the PjBL model with Scratch and those taught through direct instruction on the topic of linear functions at SMP Negeri 19 Singkawang; and (3) observe student learning activities after the application of the PjBL model assisted by Scratch. This quantitative research employed an experimental method with a nonequivalent control group design. The sample was selected using probability sampling, specifically simple random sampling, resulting in class VIII E as the experimental group and class VIII A as the control group. The findings indicate that: (1) students' computational thinking skills achieved the mastery threshold both individually and classically after the intervention; (2) a significant difference in skill improvement was found between the experimental and control groups; and (3) students demonstrated active engagement in learning activities following the implementation of the PjBL model assisted by Scratch.

Keywords: Computational Thinking; Linear Function; Project Based Learning; Scratch

1. Introduction

Computational thinking skills among junior high school students remain a significant challenge, particularly in solving mathematical problems that require systematic and structured reasoning. In the topic of linear functions, students frequently struggle to interpret relationships between variables, constructing equations, and representing them graphically. These difficulties indicate that students have not yet developed strong computational thinking skills, particularly in abstraction, algorithmic thinking, and decomposition. As linear functions form a foundational concept for understanding more advanced mathematical topics, these issues require serious attention in mathematics education.

In mathematics education, computational thinking is widely recognized as a fundamental skill that supports students' ability to solve problems systematically. Wing (as cited in Hadi, 2021) defines computational thinking as a fundamental ability encompassing problem-solving, system design, and the application of computer science concepts. In mathematics learning, this ability enables students to analyze problems logically, structure solution processes, and apply mathematical reasoning to real-world situations. This aligns with the current curriculum (Permendikbud No. 16 of 2022), which emphasizes the development of students' problem-solving abilities through meaningful, contextual learning activities.

However, several studies indicate that students' computational thinking abilities remain low. Kamil (2021) reported that junior high school students achieved low average scores in computational thinking, while Jamna (2022) found that only a small number of students met all computational thinking indicators, particularly struggling with algorithms and debugging. These findings suggest that students experience difficulty applying systematic, structured thinking when solving mathematical problems.

This condition is also evident at SMP Negeri 19 Singkawang. A preliminary study conducted in Class VII D revealed that students' computational thinking skills were generally low across abstraction, algorithms, and decomposition indicators. Classroom observations further showed low student engagement during mathematics lessons, characterized by limited participation, lack of attention, and reluctance to ask or answer questions. This situation was influenced by teacher-centered instruction, in which learning media were mainly used for evaluation rather than to support students' thinking processes.

Low student engagement was particularly noticeable in learning linear functions. According to the mathematics teacher, many students struggled to apply linear functions to real-life situations and to construct graphs correctly. This was reflected in the previous year's summative assessment results, in which fewer than half of the students met the minimum mastery criterion. These findings highlight the need for an instructional approach that not only improves students' learning outcomes but also actively engages them in meaningful learning processes.

One potential approach to address these challenges is implementing the Project-Based Learning (PjBL) model. Project-Based Learning (PjBL) is a student-centered learning model that emphasizes learning through meaningful projects based on real-world problems. In this approach, students engage in investigation, planning, and problem-solving throughout the project (Azzahra, 2023). From a constructivist perspective, this learning model aligns with Piaget's theory, which emphasizes that knowledge is actively constructed through direct experience, and Vygotsky's social constructivist theory, which highlights the role of social interaction and teacher scaffolding in cognitive development. Through collaborative project work, students are encouraged to discuss ideas, negotiate meaning, and refine their understanding with guidance from the teacher, making PjBL a pedagogically appropriate model for fostering higher-order thinking skills, including computational thinking. Previous research has shown that PjBL can significantly improve students' computational thinking abilities by engaging them in problem identification, strategy design, data analysis, and decision-making (Hadi, 2021).

In addition, the use of learning media such as Scratch, a block-based visual programming language, supports the development of computational thinking by enabling students to represent abstract mathematical concepts through interactive simulations and programs. Brennan & Resnick (2012) emphasize that Scratch facilitates key computational thinking practices, including abstraction, algorithm design, decomposition, and generalization, through its visual and modular programming environment. Wulandari (2021) also reported that Scratch-based learning media enhance students' motivation and conceptual understanding by making mathematical ideas more concrete and observable.

However, previous studies have largely focused on measuring computational thinking as an outcome, with limited attention to how students engage cognitively during the learning process. In particular, there is still a lack of research examining the integration of instructional design, student learning activities, and the development of computational thinking within authentic classroom contexts. In addition, linear functions are often treated merely as instructional content, rather than as a medium to support the development of computational thinking practices. This indicates a gap in the literature regarding the integration of instructional design, learning activities, and the development of computational thinking in mathematics learning.

This study contributes by: (1) integrating Project-Based Learning, Scratch media, and computational thinking within a single instructional design in the context of learning linear functions; (2) combining the measurement of students' computational thinking achievement with the analysis of students' learning activities during the learning process; and (3) examining how linear functions can function not only as instructional content but also as a medium to support the development of computational thinking. Furthermore, this study provides both empirical and pedagogical contributions by offering an integrated framework for fostering computational thinking in mathematics learning.

Based on this background, the present study aims to investigate the implementation of Project-Based Learning supported by Scratch in the learning of linear functions at the junior high school level. This study focuses not only on students' computational thinking achievement, as measured through pretest and posttest results, but also on students' learning activities and cognitive engagement during the learning process. Therefore, it aims to provide a more comprehensive understanding of how instructional design supports the development of computational thinking in mathematics learning.

2. Method

This study employs a quantitative approach. The research design used is a Quasi-Experimental Design. Specifically, the design applied is the Nonequivalent Control Group Design, as this study involves treatment of the independent variable, namely the Project-Based Learning (PjBL) model assisted by Scratch media, to examine its effect on the dependent variables: students' computational thinking skills and learning activities. The structure of the research design is presented in Table 1:

Table 1. Nonequivalent Control Group Design

Class	*Pretest*	Treatment	*Posttest*
Experimental Class	O_1	X_1	O_2
Control Class	O_3	X_2	O_4

Explanation:

X_1 : Treatment with PJBL Model Assisted by Scratch Media.
X_2 : Treatment with Direct Learning Model.
O_1 : *Pretest* in Experimental Class.
O_2 : *Posttest* in Experimental Class.
O_3 : *Pretest* in Control Class.
O_4 : *Posttest* in Control Class.

The population in this study consisted of eighth-grade students at SMP Negeri 19 Singkawang in the 2024/2025 academic year, comprising five classes: VIII A, VIII B, VIII C, VIII D, and VIII E.

The sampling technique used was probability sampling, specifically simple random sampling. The selected sample includes class VIII E as the experimental class and class VIII A as the control class.

The study was conducted in four meetings, including one pretest session, two learning sessions, and one posttest session. The pretest and posttest sessions were each allocated 2 x 40 minutes, while the instructional sessions were conducted over 3 x 40-minute meetings, following the school's regular mathematics schedule. In the experimental class, learning was implemented using the Project-Based Learning (PjBL) model, supported by Scratch media, on the topic of linear functions. The learning stages followed the PjBL syntax, which consisted of: (1) determining the project activities, (2) identifying the steps for completing the project, (3) developing the project implementation schedule, (4) completing the project with teacher facilitation and monitoring, (5) preparing reports and presenting/publishing the project results, and (6) evaluating the project process and outcomes. During the project, students worked in groups to construct linear function graphs and develop Scratch programs to test linear equations and analyze the rate of change. In the control class, learning was conducted using the direct instruction model. The learning activities consisted of teacher explanations of linear function concepts, worked examples, guided practice, and individual exercises. Learning media were limited to textbooks and worksheets, and students did not engage in project-based activities or use Scratch. The instructional time and number of meetings in the control class were equivalent to those in the experimental class to ensure comparability between groups.

The data collection instruments used in this study are a computational thinking skills test and a student learning activity observation sheet. The data collection techniques applied are measurement and direct observation. The measurement technique involves administering a pretest and posttest on linear functions. The test used in this study consisted of essay questions that assessed four indicators of computational thinking skills: abstraction, algorithms, decomposition, and generalization. The direct observation technique involves using observation sheets to assess student learning activities, conducted by a peer teacher and one mathematics subject teacher at SMP Negeri 19 Singkawang.

The instruments used in this study were subjected to validity and reliability testing prior to data collection. Content validity was established through expert judgment involving two mathematics education experts and one experienced mathematics teacher. The experts evaluated the instruments in terms of content relevance, clarity, and alignment with the computational thinking indicators, namely abstraction, algorithms, decomposition, and generalization. Based on their feedback, several revisions were made to improve the quality of the test items and observation sheet. Construct validity was examined using the Pearson Product-Moment correlation to determine the correlation between each item score and the total score. The results showed that all items had correlation coefficients higher than the critical value, indicating that the items were valid. To ensure reliability, the computational thinking test was analyzed using Cronbach's Alpha. The results showed that the pretest reliability coefficient was 0.91, and the posttest coefficient was 0.92, indicating that both instruments have high reliability.

The data analysis in this study was conducted through several systematic stages, as illustrated in Figure 1. First, posttest scores were analyzed to determine students' computational thinking achievement in terms of learning mastery. In addition, pretest and posttest scores were used to calculate students' improvement using N-Gain scores. Second, prerequisite tests, including normality and homogeneity tests, were conducted to determine the appropriate statistical methods. Furthermore, the data analysis was aligned with the research objectives. To determine students' learning mastery, a one-sample t-test was used for individual mastery, and a one-proportion left-tailed test was used for classical mastery. To examine differences in improvement in computational thinking skills between groups, an independent two-sample t-test or a Mann-Whitney U test was used, depending on the data distribution. Finally, student learning activity data were analyzed using descriptive statistics to support the quantitative findings.

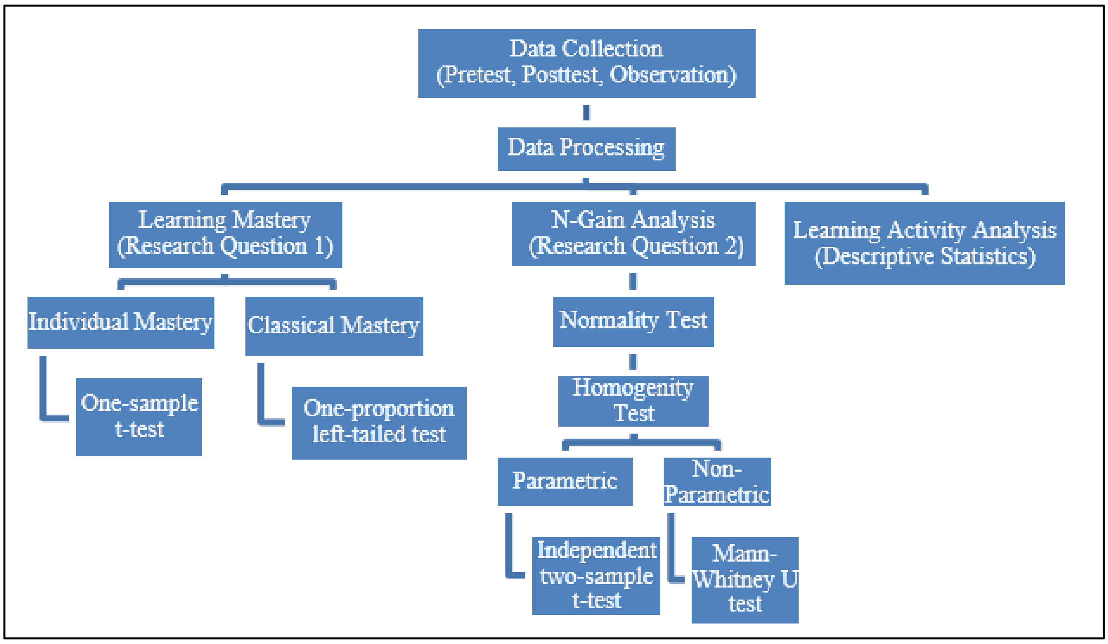

Figure 1. Data Analysis Procedure

The data analysis techniques used in this study are as follows:

a. To address the first research problem, which is to determine the achievement of students' learning mastery in terms of their computational thinking skills (with the minimum mastery criterion being a score of 70), both individually and classically, after the implementation of the PjBL model assisted by Scratch media, a one-sample t-test is used for individual mastery, and a one-proportion left-tailed test is used for classical mastery.

b. To address the second research problem, which is to determine whether there is a difference in the improvement of students' computational thinking skills between those taught using the PjBL model assisted by Scratch media and those taught using direct instruction on the topic of linear functions at SMP Negeri 19 Singkawang, an independent two-sample t-test (two-tailed) is used if the N-Gain data are normally distributed and homogeneous. If the data are not normally distributed and not homogeneous, the Mann-Whitney U test will be used.

c. To address the third research problem, which is to assess student learning activities after the implementation of the PjBL model assisted by Scratch media at SMP Negeri 19 Singkawang, descriptive analysis is used.

3. Results and Discussion

3.1. Results

Overall, the results indicate that students taught using the Project-Based Learning (PjBL) model assisted by Scratch media achieved the expected learning mastery and demonstrated greater improvement in computational thinking skills compared to those taught using direct instruction. The experimental class fulfilled both individual and classical mastery criteria and showed higher gains across all computational thinking indicators. Statistical analysis further revealed a significant difference between the two groups with a very large effect size, indicating a strong educational impact of the intervention. Additionally, students displayed active engagement during the learning process, particularly in mental and listening activities, suggesting meaningful cognitive involvement. To provide a clearer overview of these findings, the main results are summarized in Table 2.

Table 2. Summary of Main Findings

Aspect	Experimental Class	Control Class	Conclusion
Mean Posttest	75.19	-	Above mastery threshold
Individual Mastery	Achieved	-	Significant
Classical Mastery	≥ 75% students	-	Achieved
N-Gain	0.70 (High)	0.50 (Medium)	Higher Improvement
t-test	$t = 7.831$		Significant difference
Effect Size	$d = 1.96$		Very large effect
Learning Activity	73.86% (Active)	-	Positive engagement

a. Results of Individual and Classical Learning Mastery

Individual and classical learning mastery are determined from posttest data from the experimental class. The mastery threshold for mathematics, aligned with institutional academic benchmarks, was set at 70 at a public junior high school in Singkawang City. Based on the normality test of the experimental class posttest data, the data are normally distributed.

1) Individual Learning Mastery

Table 3. Individual Learning Mastery of Experimental Class Students

	Individual Learning Mastery of Students
$t_{calculated}$	3.19
t_{table}	1.69
Decision	H_0 is rejected and H_a is accepted
Conclusion	The average score of students reaches the mastery threshold

Based on Table 3, the one-sample t-test results show $t_{calculated}(3.19) \geq t_{table}\ (1.69)$. The decision is to reject H_0 and accept H_a, indicating that the average student score in the class taught using the Project-Based Learning (PjBL) model assisted by Scratch media has reached the mastery threshold.

2) Classical Learning Mastery

Table 4. Classical Learning Mastery of Experimental Class Students

	Classical Learning Mastery of Students
$z_{calculated}$	0.50
$-z_{table}$	-1.65
Decision	H_0 is accepted and H_a is rejected
Conclusion	The proportion of students achieving the mastery threshold is greater than or equal to 75%

Based on Table 4, the results of the proportion test with the benchmark for classical mastery were set at 75% of the total 33 students show that $z_{calculated}(0.50) \geq -z_{table}(-1.65)$. The decision is to accept H_0 and reject H_a, indicating that the proportion of students achieving the mastery threshold is at least 75%.

These findings suggest that implementing the Project-Based Learning (PjBL) model, supported by Scratch media, is effective in helping students achieve the expected level of computational thinking performance. This indicates that engaging students in project-based activities combined with interactive digital media can facilitate a deeper understanding of mathematical concepts. Furthermore, this result highlights the potential of integrating technology into mathematics instruction to improve overall student learning outcomes.

b. Differences in Students' Computational Thinking Skill Improvement

1) N-Gain Calculation of Computational Thinking Skills

Table 5. Calculation of N-Gain for Each Computational Thinking Ability Indicator in Experimental Class and Control Class

No	Computational Thinking Skill Indicator	Experimental Class				Control Class			
		Pretest	*Posttest*	*N-Gain*	Criteria	*Pretest*	*Posttest*	*N-Gain*	Criteria
1	*Abstraction*	107	264	1.00	High	81	192	0.66	Medium
2	*Algorithms*	38	238	0.88	High	32	178	0.68	Medium
3	*Decomposition*	30	170	0.60	Medium	14	101	0.37	Medium
4	*Generalization*	25	122	0.41	Medium	8	97	0.37	Medium
	Total	200	794	2.89		135	568	2.08	
Overall N-Gain of All Indicators			0.7		High		0.5		Medium

Based on Table 5, among the overall indicators of computational thinking skills, in the experimental class, two indicators were in the high N-Gain category, while the other two were in the moderate category. In contrast, in the control class, all indicators fell into the moderate N-Gain category. Overall, the total N-Gain in the experimental class was categorized as high, while in the control class, it was categorized as moderate. Descriptively, the N-Gain data from the experimental and control classes differed. Therefore, inferential statistical analysis was conducted to determine whether there was a significant difference in the improvement of computational thinking skills between students taught using the Project-Based Learning (PjBL) model assisted by Scratch media and those taught using direct instruction in the linear function topic at a public junior high school in Singkawang City. However, before performing the independent-samples t-test, prerequisite tests were conducted: normality and homogeneity tests.

2) Normality Test of N-Gain in Computational Thinking Skills

Table 6. Calculation of N-Gain Data Normality Test for Students' Computational Thinking Ability

Statistic	Class	
	Experimental	Control
$\mathcal{X}^2{}_{Calculated}$	3.99	1.48
Number of Students (n)	33	31
Significance Level (α)	5% or 0,05	5% or 0.05
$\mathcal{X}^2{}_{table}$	7.815	7.815
Decision	H_0 accepted	H_0 accepted
Conclusion	Normal	Normal

Based on Table 6, the calculated chi-square value for the experimental class show that $\mathcal{X}^2{}_{Calculated}(3.99) \leq \mathcal{X}^2{}_{table}(7.815)$, H_0 is accepted, meaning the data are normally distributed. Similarly, the control class had $\mathcal{X}^2{}_{Calculated} = 1.48$, a value that is also less than the critical value of 7.815; thus, H_0 is accepted, and the data are normally distributed. Given that both classes had normally distributed data, the next step was to perform a homogeneity test.

3) Homogeneity Test of Computational Thinking Skills

Table 7. Calculation of N-Gain Data Homogeneity Test of Students' Computational Thinking Ability

Statistic	Class	
	Experimental	**Control**
Variance (S^2)	0.007	0.013
$F_{Calculated}$	1.760	
Number of Students (n)	33	31
Significance Level (α)	5% or 0.05	
F_{table}	1.817	
Decision	H_0 accepted	
Conclusion	Homogeneous	

Based on Table 7, the results of the F-test show $F_{Calculated}(1{,}760) < F_{table}(1.817)$, H_0 is accepted, indicating that the data are homogeneous. Given that the N-Gain data for both the experimental and control classes are normally distributed and homogeneous, an independent sample t-test was then conducted to determine whether there was a significant difference in the improvement of students' computational thinking skills between those taught using the PjBL model assisted by Scratch media and those taught using direct instruction.

4) Comparison Between Experimental and Control Classes Using Independent Sample t-Test

Table 8. Two-Sample T-Test Calculation

Statistic	Class	
	Experimental Class	**Control Class**
Mean ($\bar{x}$)	0.699	0.501
Variance (S^2)	0.007	0.013
Pooled Standard Deviation (S_p)	0.101	
Sample Size (n)	33	31
$t_{Calculated}$	7.831	
df	62	
Significance Level (α)	5% or 0.05	
t_{table}	1.999	
Cohen's d	1.96	
95% Confidence Interval	[0.15 , 0.25]	
Decision	H_0 rejected	

Based on Table 8, the results of the two-sample t-test indicated that students in the experimental class demonstrated significantly greater improvement (M = 0.699, SD_p = 0.101) than those in the control class (M = 0.501), $t(62) = 7.831$, $p < 0.001$. Beyond statistical significance, the magnitude of the difference was substantial. The effect size, as measured by Cohen's *d*, was 1.96, indicating a very large practical effect. In addition, the 95% confidence interval for the mean difference ranged from 0.15 to 0.25, suggesting that the improvement in computational thinking skills was consistently greater for students taught using Project-Based Learning assisted by Scratch. These findings demonstrate that the observed difference is not only statistically significant but also educationally meaningful.

c. Results of Student Learning Activity Observation

Table 9. Percentage of Student Learning Activity Observation Results

Activity	Meeting 1	Meeting 2	Average	Criteria
	Persentage (%)	Persentage (%)		
Visual Activities	73.48	79.55	76.52	Very Active
Oral Activities	76.77	79.80	78.28	Very Active
Listening Activities	81.06	81.82	81.44	Very Active
Writing Activities	55.56	67.17	61.36	Active
Drawing Activities	66.67	69.70	68.18	Active
Motor Activities	66.67	68.69	67.68	Active
Mental Activities	81.82	83.84	82.83	Very Active
Emotional Activities	69.70	79.55	74.62	Active
Total	57.72	610.10	590.91	
Overall Average	73.86			
Criteria	Active			

Table 9 shows that the overall average for student learning activities was 73.86%, indicating active participation. To provide a clearer visual overview of the distribution of student learning activities, the average percentage of each activity indicator is also illustrated in Figure 2.

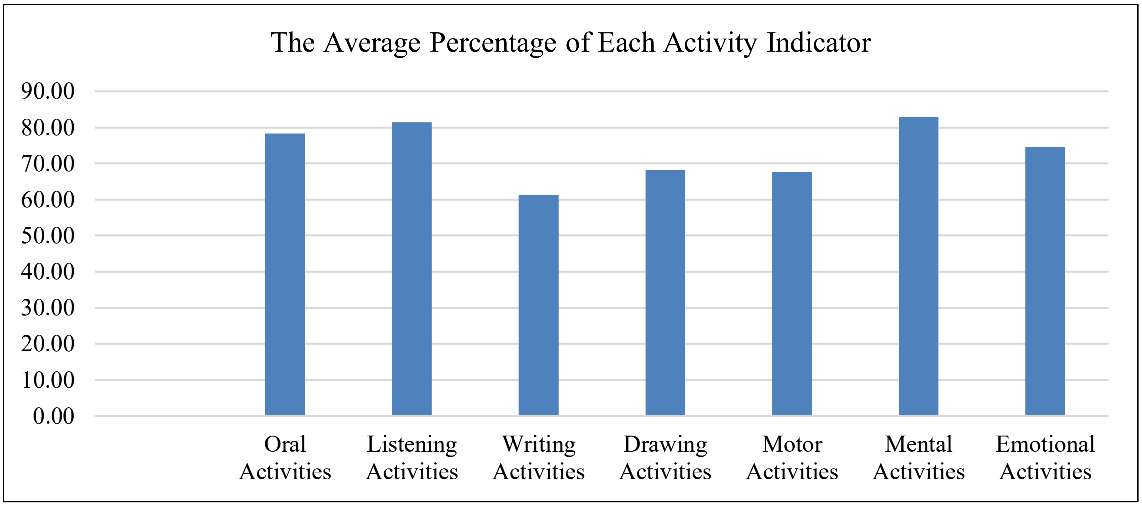

Figure 2. The Average Percentage of Each Activity Indicator

As illustrated in Figure 2, Mental Activities and Listening Activities obtained the highest average percentages, both categorized as very active. while other activities were generally in the active category. These findings indicate that students were actively engaged both cognitively and behaviorally during the learning process. High levels of mental engagement suggest that students were engaged in problem-solving and collaborative thinking, which may have contributed to improvements in their computational thinking skills.

3.2. Discussion

a. Students' Computational Thinking Ability Reaches the Minimum Mastery Criteria Both Individually and Classically After the Implementation of the Project-Based Learning (PjBL) Model Assisted by Scratch Media.

The achievement of mastery in individual and classical learning in students' computational thinking indicates that integrating Project-Based Learning (PjBL) with Scratch provides a learning environment that effectively supports students' understanding and problem-solving processes. This finding suggests that learning activities that require students to actively explore problems, collaborate with peers, and construct solutions contribute meaningfully to students' mastery of computational thinking skills.

This effectiveness can be further explained by constructivist learning theory, as proposed by Piaget (1972), which emphasizes that students actively construct knowledge through interaction with problems and learning experiences. In the context of PjBL, students are not merely receiving information they are reorganizing their cognitive structures through exploration and problem-solving activities. Recent studies have reaffirmed that Piagetian constructivism remains highly relevant in mathematics education, particularly in designing learning experiences that guide students from concrete exploration to abstract mathematical reasoning (Rahmadani et al., 2026). Furthermore, from a socio-constructivist perspective, Vygotsky (1978) argues that collaborative learning and teacher scaffolding allow students to operate within their Zone of Proximal Development (ZPD), enabling them to achieve higher levels of understanding. Recent evidence in mathematics education continues to support the importance of scaffolding and collaborative learning as essential elements for promoting conceptual understanding and mathematical reasoning (Saidul & Widyasari, 2025).

Recent studies also support this finding. Project-based learning has been shown to create authentic problem-solving contexts that significantly enhance students' computational thinking and conceptual understanding (Ji & Wong, 2025; Tarigan et al., 2025). These findings suggest that PjBL's effectiveness lies in its ability to engage students in meaningful knowledge construction rather than in passive information reception.

The use of Scratch as a learning medium also plays a crucial role in supporting mastery. Recent studies have shown that interactive digital learning media enhance students' conceptual understanding and improve the quality of mathematics learning (Rizkiana et al., 2025; Nadirah et al., 2024). As one form of interactive digital media, Scratch enables abstract mathematical concepts, such as linear functions and rates of change, to be represented visually and interactively. This visualization helps students connect symbolic representations with concrete outcomes, making complex concepts easier to understand. In addition, the interactive nature of Scratch increases students' motivation and engagement, which positively affects learning persistence. This finding aligns with Widjayanti (2019) and Wulandari (2021), who reported that interactive and visual digital media support students' learning mastery by enhancing motivation and conceptual clarity. This finding is also supported by recent research indicating that digital project-based environments significantly improve students' computational thinking and learning outcomes by enhancing conceptual understanding and engagement (Liu et al., 2024; Selano et al., 2024).

These findings are consistent with recent studies showing that PjBL integrated with digital media improves students' mastery of learning and higher-order thinking skills (Ji & Wong, 2025; Selano et al., 2024). However, unlike these studies, which primarily focused on general learning outcomes or creativity, the present study specifically demonstrates mastery in computational thinking within the context of linear functions using Scratch. This indicates that integrating Scratch-based projects not only enhances overall achievement but also supports deeper conceptual understanding in mathematics.

b. There Is a Difference in the Improvement of Students' Computational Thinking Abilities Between the Experimental and Control Classes.

The greater improvement in students' computational thinking abilities in the experimental class compared to the control class indicates that the PjBL model, supported by Scratch, is more effective than direct instruction in fostering higher-order thinking skills, with a substantial and educationally meaningful impact on students' computational thinking development. This finding highlights the importance of learning environments that actively involve students in constructing knowledge rather than passively receiving information.

Pedagogically, PjBL encourages students to engage in problem-solving processes that resemble authentic mathematical practices, such as identifying relevant information, designing solution strategies, and evaluating outcomes. These processes require students to continuously apply computational thinking skills throughout the learning activities. In contrast, direct instruction tends to focus on teacher explanations and procedural practice, which may limit students' opportunities to independently develop and refine their computational thinking abilities. This interpretation is supported by Sappaile et al (2023), who emphasized that project-based learning promotes students' ability to identify problems, develop strategies, and make decisions grounded in mathematical reasoning.

The integration of Scratch further strengthens the impact of PjBL by providing students with a platform to test, revise, and extend their problem-solving strategies. Through block-based programming, students can decompose complex problems into smaller components, organize solution steps logically, and apply learned patterns to new situations. This process promotes the development of conceptual computational thinking, rather than merely procedural thinking, through integrated activities that involve abstraction, algorithmic thinking, decomposition, and generalization. This finding is supported by Hadi (2021), who observed a substantial increase in students' computational thinking scores after incorporating Scratch into project-based mathematics learning.

From a theoretical perspective, these findings align with the concept of computational thinking proposed by Wing (2006), which emphasizes abstraction, decomposition, and algorithmic thinking as essential components of problem-solving. They also support the framework of Weintrop et al. (2016), suggesting that computational thinking is more effectively developed when integrated within mathematics learning contexts rather than taught as isolated programming skills.

Furthermore, these findings are consistent with constructivist learning theory, which posits that knowledge is constructed through active engagement and meaningful learning experiences. Through project-based activities supported by Scratch, students are given opportunities to explore concepts, collaborate with peers, and reflect on their learning processes, thereby more effectively developing higher-order thinking skills.

These findings are also supported by recent studies showing that integrating project-based learning with digital environments significantly improves students' computational thinking compared to traditional instruction (Ismael et al., 2024; Samodra et al., 2025). Unlike previous studies that primarily focused on programming or general STEM contexts, this study demonstrates that computational thinking can be effectively developed through its integration with mathematical concepts, particularly linear functions. This suggests that computational thinking development is not limited to coding activities but can also be achieved through conceptually grounded mathematics learning.

c. Students' Learning Activities Were Active Following the Implementation of the Project-Based Learning (PjBL) Model Assisted by Scratch Media.

Students' learning activities were categorized as active across all indicators, indicating that the implementation of PjBL assisted by Scratch effectively promotes student engagement. The observation was conducted by two observers, a mathematics teacher and a student teacher, who monitored eight types of activities: visual, oral, listening, writing, drawing, motor, mental, and emotional. These were further detailed into 19 learning activities aligned with the implementation of the Project-Based Learning (PjBL) model assisted by Scratch.

Overall, students' learning activities during the implementation of PjBL assisted by Scratch were categorized as active. During the project completion stage, students were engaged in activities such as discussion, problem-solving, listening to teacher guidance, and developing and testing Scratch-based projects. During the project planning stage, students demonstrated engagement through paying attention to explanations, taking notes, participating in discussions to determine data, and constructing data tables.

The increase in students' learning activities can be explained pedagogically through the characteristics of Project-Based Learning, which positions students as active participants in the learning process. In PjBL, students are required to identify problems, design solution strategies, and complete projects collaboratively, thereby naturally enhancing their cognitive, social, and physical engagement. In addition, using Scratch as a learning medium provides an interactive, visual learning experience that helps students understand concepts while increasing motivation and curiosity. The combination of project-based activities and digital media creates a learning environment that promotes sustained active participation.

These findings are consistent with Ramayati (2024), who reported that PjBL improves students' learning activities through active involvement in projects. Similarly, the use of Scratch has been shown to enhance student engagement due to its interactive and visual nature (Luthfiyyah et al., 2023). Recent studies also indicate that project-based and technology-assisted learning environments significantly improve student engagement and participation (Akhmad et al., 2025; Selano et al., 2024).

However, writing and motor activities showed relatively lower levels than other indicators, although they were still categorized as active. Students' engagement in writing activities, such as note-taking and documenting project processes, was lower than their participation in visual and oral activities. This finding is consistent with Rahmawati and Susanto (2019) and Lestari and Hidayat (2021), who reported that students tend to be more active in visual and oral activities than in written mathematical communication. In addition, motor activities related to using Scratch were not evenly distributed, as some students tended to observe rather than directly manipulate Scratch blocks. This aligns with the findings of Widodo and Kartikasari (2017), who highlight unequal participation in technology-assisted project-based learning environments.

Furthermore, several challenges were identified during the implementation, including time constraints, students' adaptation to Scratch, and differences in prior abilities. These factors influenced the level of student participation, particularly in activities requiring direct engagement. This is supported by Putri and Zulkardi (2020) and Hadi (2021), who emphasized that the successful implementation of project-based and technology-assisted learning requires sufficient time, gradual scaffolding, and students' familiarity with the learning tools.

Overall, integrating the PjBL model with Scratch effectively promotes students' learning activities and engagement. However, future implementations should emphasize more structured facilitation and differentiated support to ensure more balanced participation, particularly in writing and hands-on activities.

d. Theoretical Implications.

The findings of this study have important theoretical implications for mathematics education and the conceptualization of computational thinking. First, the results support and extend constructivist and socio-constructivist learning theories, which emphasize that knowledge is actively constructed through meaningful experiences and social interaction (Piaget, 1972; Vygotsky, 1978). The implementation of Project-Based Learning (PjBL) supported by Scratch creates learning environments where students engage in exploration, collaboration, and reflection, thereby fostering deeper conceptual understanding rather than surface-level procedural knowledge.

Second, this study contributes to the theoretical discourse on computational thinking by reinforcing the view that computational thinking should be understood not merely as a procedural skill or programming competence, but as a cognitive process integrated with mathematical reasoning. Consistent with the frameworks proposed by Wing (2006) and Weintrop et al (2016), the findings indicate that students' engagement in abstraction, algorithmic reasoning, and decomposition emerged through meaningful mathematical activity rather than isolated coding tasks. The observed shift from procedural execution toward conceptual understanding suggests that computational thinking develops most effectively when embedded within authentic mathematical problem-solving contexts.

Third, this study advances theory by positioning linear functions as epistemic objects that mediate students' engagement with computational thinking practices. Rather than being treated solely as instructional content, linear functions functioned as conceptual tools through which students explored relationships between variables, represented patterns of change, and generalized solutions. This perspective aligns with constructionist theory, which emphasizes learning through the creation of meaningful external artifacts (Papert, 1980). By integrating project-based tasks with Scratch-based representations, the study demonstrates how mathematical concepts can serve as cognitive mediators that support the development of conceptual computational thinking.

Overall, the findings extend existing theoretical frameworks by highlighting the role of project-based digital environments in transforming computational thinking from a predominantly procedural activity into a conceptually grounded form of mathematical reasoning.

e. Practical Implications.

Beyond its theoretical contributions, this study offers several practical implications for mathematics education. First, in terms of teacher education and professional development, the findings suggest that mathematics teachers should be supported in developing pedagogical competencies for integrating Project-Based Learning with visual programming tools such as Scratch. Teachers are encouraged to adopt facilitative roles that emphasize scaffolding, guiding inquiry, and supporting students' reflection on their problem-solving processes, as highlighted in prior research on inquiry-based and project-based learning (Hmelo-Silver et al., 2007).

Second, regarding curriculum design, the results underscore the importance of explicitly integrating computational thinking within core mathematics topics rather than treating it as a separate or supplementary skill. In line with recommendations by Grover & Pea (2013) and the National Council of Teachers of Mathematics (NCTM, 2018), computational thinking can be effectively embedded in topics such as linear functions through project-based tasks that require students to model, analyze, and interpret mathematical relationships.

Third, from a digital pedagogy perspective, the use of Scratch provides a powerful representational tool that allows students to visualize mathematical relationships, test hypotheses, and iteratively refine solutions. This supports students' conceptual understanding and sustained engagement with mathematical ideas. Consequently, schools and educational stakeholders are encouraged to incorporate interactive digital tools as part of broader strategies for fostering 21st-century skills, consistent with international educational frameworks (OECD, 2019).

Finally, with respect to the integration of computational thinking in mathematics classrooms, this study demonstrates that project-based approaches supported by digital media can promote meaningful computational thinking development beyond test-score improvement. By emphasizing students' cognitive processes and conceptual understanding, the findings provide practical guidance for educators seeking to design mathematics learning experiences that are both conceptually rich and aligned with contemporary educational goals.

4. Conclusion

Based on the results of the study on the implementation of the Project-Based Learning (PjBL) model assisted by Scratch media in learning linear functions, it can be concluded that students' computational thinking abilities were able to reach the mastery threshold, both individually and classically, after the application of the PjBL model assisted by Scratch media. In addition, there was a significant difference in the improvement of students' computational thinking abilities between students who learned through the PjBL model assisted by Scratch media and those who received instruction through direct learning models. These findings are supported by observations showing that students demonstrated active learning behaviors during the implementation of the PjBL model assisted by Scratch media. For future researchers who intend to investigate the use of the Project-Based Learning (PjBL) model assisted by Scratch media, it is recommended to examine its implementation in other mathematics topics, such as geometry, statistics, probability, and other mathematical concepts, to explore its effectiveness in enhancing students' computational thinking abilities across different content areas. Additionally, future studies may consider integrating the PjBL model, assisted by Scratch media, with other instructional approaches, such as the flipped classroom or problem-based learning, to further investigate the potential to improve learning effectiveness and student engagement. The findings of this study imply that teachers are encouraged to implement Project-Based Learning (PjBL) assisted by Scratch media to enhance students' computational thinking skills and promote active learning. In addition, teachers need to design learning activities that emphasize key computational thinking processes. From a curriculum perspective, these results highlight the importance of integrating computational thinking and technology-based learning into mathematics instruction, as well as providing greater support for project-based learning approaches.

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