JURNAL PEMBELAJARAN DAN MATEMATIKA SIGMA (JPMS)
Vol. 12, No. 2 (2026)
Page: 221 – 230
Doi: https://doi.org/10.36987/jpms.v12i1.9759

ISSN : 2460-593X
E-ISSN : 2685- 5585

THE DEVELOPMENT OF MATHEMATICS LEARNING USING A SCRATCH-ASSISTED PROBLEM-BASED LEARNING MODEL TO IMPROVE MATHEMATICAL REPRESENTATION ABILITY

ANDI KHOL[1*], ARY WORO KURNIASIH[2]

[*]Program Studi Pendidikan Matematika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Negeri Semarang, Jawa Tengah, Indonesia
email:
[1*]Corresponding Author: lanandi97@students.unnes.ac.id
[2]aryworo.mat@mail.unnes.ac.id

Article Info

Article history:
Received Augt 03, 2026
Revised Sept 25, 2026
Accepted Oct 18, 2026

Keywords:
ADDIE
Mathematical Representation
Problem Based Learning
Quadratic Equations
Scratch

ABSTRACT

This study aims to develop and examine the feasibility, readability, and effectiveness of mathematics learning using a Scratch-assisted Problem Based Learning (PBL) model to improve students' mathematical representation abilities on Quadratic Equations. Using the Research and Development (R&D) method with the ADDIE design, this study involved tenth-grade students in Central Java through a Pretest-Posttest Control Group Design. Data were collected via tests, validation sheets, and questionnaires. Results showed the product was highly feasible (88.71%) and had excellent readability (86.47%). The learning was highly effective; the experimental class's posttest average (84.72) exceeded the minimum criteria, achieved 91.67% classical completeness, and obtained a significantly higher N-Gain (0.73) than the control group. Students gave a highly positive response (88.61%). In conclusion, the integration of the PBL model, digital student worksheets (LKPD), and Scratch effectively serves as a cognitive scaffold that facilitates the translation of mathematical representations from verbal to pictorial and symbolic forms, thereby significantly improving students' representation abilities on this specific topic.

Published by LPPM Universitas Labuhanbatu. This is an open-access article under the **Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License (CC BY - NC - SA 4.0)**

1. INTRODUCTION

Mathematical representation skills are one of the essential competencies that students must possess in mathematics education. These skills enable students to express, translate, and connect mathematical concepts through various forms of representation, including verbal, pictorial, symbolic, and mathematical models, thereby facilitating the understanding and solution of mathematical problems. The National Council of Teachers of Mathematics (NCTM) identifies representation as one of the process standards that should be developed alongside problem-solving, reasoning, communication, and mathematical connections [1]. Representation also serves as a cognitive tool that helps students construct, organize, and communicate mathematical ideas throughout the learning process [2]. Furthermore, the ability to translate between different representations is a critical factor in developing conceptual understanding, as students must not only understand mathematical symbols but also establish meaningful connections among verbal, pictorial, and symbolic representations [3]. This perspective is supported by research indicating that mathematical representation skills contribute to the development of students' conceptual understanding, mathematical reasoning, and problem-solving abilities [4].

The importance of mathematical representation skills has become increasingly relevant in the context of the Merdeka Curriculum, which emphasizes student-centered learning through exploration, reasoning, and contextual problem-solving activities [5]. However, the results of the 2022 Programme for International Student Assessment (PISA) indicate that Indonesian students' mathematical literacy

remains below the average of OECD member countries [6]. This situation highlights the need for mathematics instruction to provide learning experiences that develop students' ability to establish connections among different representations, rather than focusing solely on symbolic problem-solving procedures. Therefore, instructional innovations are needed to support the systematic development of students' mathematical representation skills.

The urgency of addressing this issue is further demonstrated by a preliminary study involving 36 tenth-grade students at SMA Negeri 1 Godong. Initial data were collected using a mathematical representation assessment instrument consisting of four open-ended, contextual problems related to quadratic equations. The instrument measured three indicators of mathematical representation: verbal, pictorial, and symbolic. Each item was scored on a scale of 0 to 4 using an analytical rubric based on the completeness and accuracy of students' responses. The results showed that the students' average score was only 49.67, below the minimum proficiency criterion of 75, indicating a low level of mathematical representation skills. Analysis of students' answer sheets revealed that most students experienced difficulties in translating information from word problems into drawings or sketches, identifying variables, constructing mathematical models, and interpreting solutions in the context of the original problems. These findings are consistent with previous studies indicating that students' primary difficulties are not limited to symbolic manipulation but also involve challenges in translating between different forms of mathematical representation [7], [8], [9].

One instructional model considered effective in developing mathematical representation skills is Problem-Based Learning (PBL). This model uses contextual problems as the starting point for learning, encouraging students to identify relevant information, construct various forms of representation, and develop solutions through collaborative inquiry [10], [11]. Previous studies have reported that PBL can improve students' mathematical representation skills by actively engaging them in concept construction throughout the problem-solving process [12], [13]. Meanwhile, advances in digital technology have created opportunities to support PBL implementation through interactive learning media, including Scratch [14], [15].

Nevertheless, a review of recent international literature published between 2021 and 2026 indicates a research gap concerning the integration of Scratch into mathematics education. Previous studies [16], [17], [18] have primarily used Scratch to present pictorial representations or simulate algorithmic concepts. Furthermore, studies integrating Scratch with Project-Based Learning (PjBL) have generally focused on geometry or probability topics and employed worksheets emphasizing coding activities [19]. The representation indicators used in these studies have largely focused on the pictorial presentation of final results, while the use of Scratch to support the translation of pictorial representations into symbolic algebraic forms remains limited. A recent study [20] found that Scratch-based pictorial representations could enhance learning motivation; however, the study also highlighted a limitation concerning the lack of interactive scaffolding to guide students in translating pictorial representations into symbolic forms. Consequently, the use of interactive digital worksheets integrating PBL and Scratch to address students' difficulties in translating between representations when learning quadratic equations remains an area that requires further investigation [21].

To address this research gap, this study proposes an instructional innovation by integrating pedagogical mechanisms directly into the features of Scratch-based learning media. Unlike previous approaches that require students to write code, this study positions students as active users who interact with Scratch simulations by following instructions provided in digital worksheets. Through this approach, Scratch serves not merely as a supplementary medium but also as cognitive scaffolding that supports the construction and translation of mathematical representations [22]. This integration is implemented through three main features designed to support sequential translation between representations. First, the Sketchboard facilitates students' translation of information from verbal representations, such as word problems, into pictorial representations, including geometric sketches and graphs. Second, the Algebra Guide provides interactive instructional support to help students translate pictorial representations into symbolic forms by constructing quadratic equation models. Third, the Root Calculator serves as a verification tool that helps students interpret algebraic solutions in the context of the original problems.

Based on the foregoing discussion, this study aims to develop and evaluate the feasibility, practicality, and effectiveness of a mathematics learning tool that integrates Problem-Based Learning (PBL), Scratch, and digital worksheets. This instructional innovation is expected to support students' mathematical thinking processes, address difficulties in translating between mathematical representations when learning quadratic equations, and contribute to the literature on interactive digital learning environments.

2. RESEARCH METHOD

This study employed a research and development (R&D) approach using the ADDIE model, which consists of five stages: Analyze, Design, Develop, Implement, and Evaluate [23]. The ADDIE model was

selected because it provides a systematic framework for developing learning products [24] that meet the criteria of validity, practicality, and effectiveness [25]. The products developed in this study comprised digital worksheets and Scratch-based interactive learning media integrated into the Problem-Based Learning (PBL) framework for teaching quadratic equations.

The study was conducted during the odd semester of the 2026/2027 academic year at SMA Negeri 1 Godong, Grobogan Regency, Central Java, Indonesia. The study population consisted of all tenth-grade students. Cluster random sampling was employed [26] to select two classes with heterogeneous students and comparable initial abilities. Class X-2, comprising 36 students, was assigned to the experimental group, while Class X-4, also comprising 36 students, served as the control group. In addition, 36 students from Class X-1, who were not included in either the experimental or control group, participated in a limited readability test. The product effectiveness evaluation employed a Pretest–Posttest Control Group Design, as presented in Table 1. The learning intervention consisted of three sessions, each lasting 2 × 45 minutes, for both groups. The experimental group received PBL instruction supported by Scratch-based interactive media, whereas the control group received conventional PBL instruction without Scratch.

Table 1. Average Mathematics Learning Outcomes

Group	Pretest	Treatment	Posttest
R	O_1	X	O_2
R	O_3	-	O_4

The research process was organized into five phases based on the ADDIE model. The first phase, Analyze, involved a needs analysis based on the low mathematical representation skills of 36 students, as indicated by an average score of 49.67. This phase also included an analysis of the cognitive characteristics of tenth-grade students, the Learning Outcomes specified in the Merdeka Curriculum [5], and the difficulties students encountered in translating representations when learning quadratic equations. The second phase, Design, focused on developing a prototype of the instructional module, preparing storyboards for the Scratch-based interactive media features (Sketchboard, Algebra Guide, and Root Calculator), designing the digital worksheet layouts, and developing a test blueprint for the mathematical representation assessment instrument based on the selected indicators. The third phase, Develop, involved producing the interactive media and digital worksheets, followed by a feasibility assessment conducted by a mathematics education lecturer with expertise in subject matter and learning media through two rounds of revisions, as well as by two high school mathematics teachers serving as practitioners. After revision and approval, the product underwent a limited readability test involving 36 students from Class X-1. The fourth phase, Implement, involved conducting the learning intervention in the experimental and control classes. Teachers acted as facilitators, guiding students in using the digital worksheets and Scratch simulations in accordance with the PBL syntax, from problem orientation to evaluation. The final phase, Evaluate, consisted of formative and summative evaluation. Formative evaluation was conducted throughout the design and development stages, with revisions made based on feedback from the validators [27]. Summative evaluation was conducted in the final stage to assess the effectiveness of the developed product using pretest and posttest data [28]. The overall development process is illustrated in Figure 1.

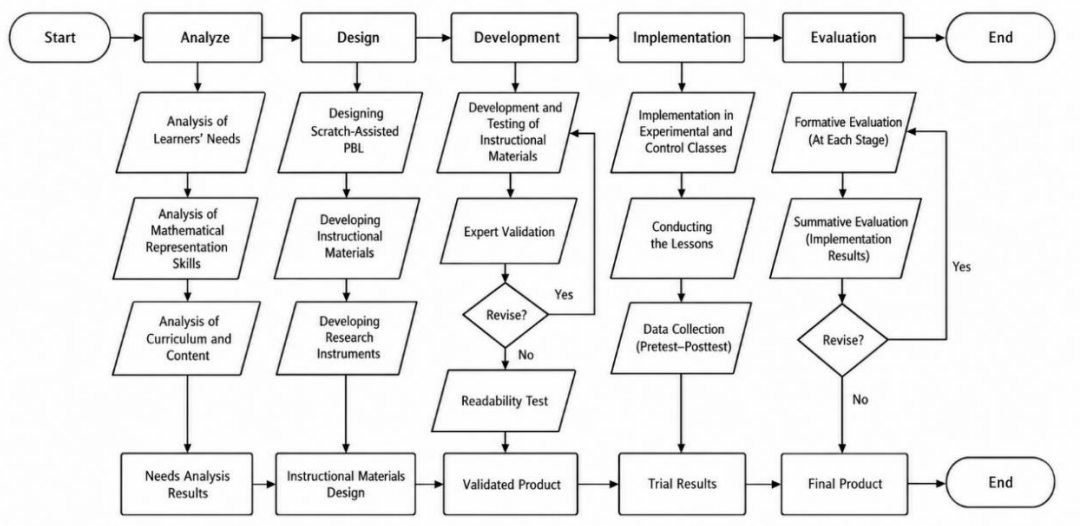


Figure 1. ADDIE Research Process

The primary research instrument was a mathematical representation skills test consisting of 10 essay questions designed to measure three episodes of representational translation [2], [4] across nine indicators. The first episode involved translation between verbal and pictorial representations, including the ability to create relevant sketches or graphs from word problems and revise them when the given information changed. The second episode focused on translation from pictorial to symbolic representations, including the ability to formulate equations based on sketches and explain the relationships between visual elements and mathematical formulas. The third episode involved translation from symbolic to verbal representations, covering the ability to define variables, construct mathematical models from textual information, explain the meaning of formulas in context, modify equations, and express calculation results in concluding statements. Each item was scored using an analytical rubric ranging from 0 to 4 based on the completeness and accuracy of students' solutions, yielding a maximum possible score of 40. Before implementation, the instrument underwent content validation through expert judgment and empirical validity testing using Pearson's product-moment correlation. Reliability was assessed using Cronbach's alpha, with a coefficient greater than 0.70 considered acceptable [29]. In addition to the test, a validation sheet using a five-point Likert scale and a student response questionnaire using the Guttman or Likert scale were employed to assess the feasibility and practicality of the developed learning product.

The research data were analyzed using descriptive and inferential statistical methods. Data from expert validation and practicality assessments were analyzed by calculating percentage scores [26]. To evaluate the effectiveness of the developed product, the posttest data were first examined for the assumptions of normality using the Shapiro–Wilk test and homogeneity of variances using Levene's test. The effectiveness hypothesis was tested in four stages. First, a one-sample t-test was conducted to determine whether the mean posttest score of the experimental class exceeded the Learning Objective Achievement Criteria (Kriteria Ketercapaian Tujuan Pembelajaran, KKTP) of 75. Second, classical mastery was calculated to determine whether at least 75% of students achieved the specified mastery criterion. Third, an independent-samples t-test was used to compare the posttest mean scores of the experimental and control classes. If a significant difference in pretest scores was identified between the two classes, the analysis was adjusted using analysis of covariance (ANCOVA), with pretest scores included as a covariate. Fourth, Cohen's d was calculated to determine the magnitude of the intervention's effect. Improvements in students' mathematical representation skills following instruction were measured using the normalized gain (N-Gain), categorized as high ((g \geq 0.7)), moderate ($0.3 \leq g < 0.7$), or low ($g < 0.3$).

3. RESULTS AND DISCUSSION

This section presents the findings of the development and implementation of a mathematics learning product based on Problem-Based Learning (PBL) assisted by Scratch. The findings cover product validation, readability testing, implementation of the learning process, the effectiveness of the product in improving students' mathematical representation skills, and student responses. Furthermore, the findings are discussed in relation to relevant theoretical perspectives and previous research.

3.1 Research result

The learning products developed in this study consist of instructional materials based on the Problem-Based Learning (PBL) model supported by Scratch for teaching quadratic equations. The products include an instructional module, digital worksheets, Scratch-based interactive media, a mathematical representation skills assessment instrument, a readability questionnaire, a student response questionnaire, and interview guidelines. Before classroom implementation, the developed products underwent validation by one expert lecturer over two rounds of revision and two practicing teachers. The validation process aimed to assess the appropriateness of the content, construct, language, media presentation, and overall suitability of the learning products.

Table 2. Summary of Learning Materials Validation Results

Validator	Percentage (%)	Criteria
Expert 1	91,94%	Highly Suitable
Practitioner 1	86,29%	Highly Suitable
Practitioner 2	87,90%	Highly Suitable
Rata-rata	88,71	Highly Suitable

Based on Table 2, the developed learning materials achieved an average validation score of 88.71%, placing them in the highly suitable category. The expert lecturer assigned a score of 91.94%, while the two practitioner validators assigned scores of 86.29% and 87.90%, respectively. These results indicate that the learning materials met the criteria for alignment with learning outcomes, integration of

the Problem-Based Learning (PBL) syntax, quality of media presentation, language clarity, and alignment of learning activities with the indicators of mathematical representation skills.

During the validation process, the validators provided several suggestions for improving the learning materials. The revisions included simplifying the wording of the digital worksheets, improving the user interface of the Scratch media, refining the workflow of the Algebra Guide feature, and revising several items in the mathematical representation skills assessment instrument. All suggestions were incorporated into the learning materials before they proceeded to the next stage.

After the materials were deemed suitable, a readability test was conducted involving 36 students from Class X-1 to assess the ease of use of the digital worksheets and the Scratch platform. The aspects evaluated included the visual appearance of the platform, language clarity, ease of use, clarity of instructions, and functionality of each feature. The results of the readability test are presented in Figure 2.

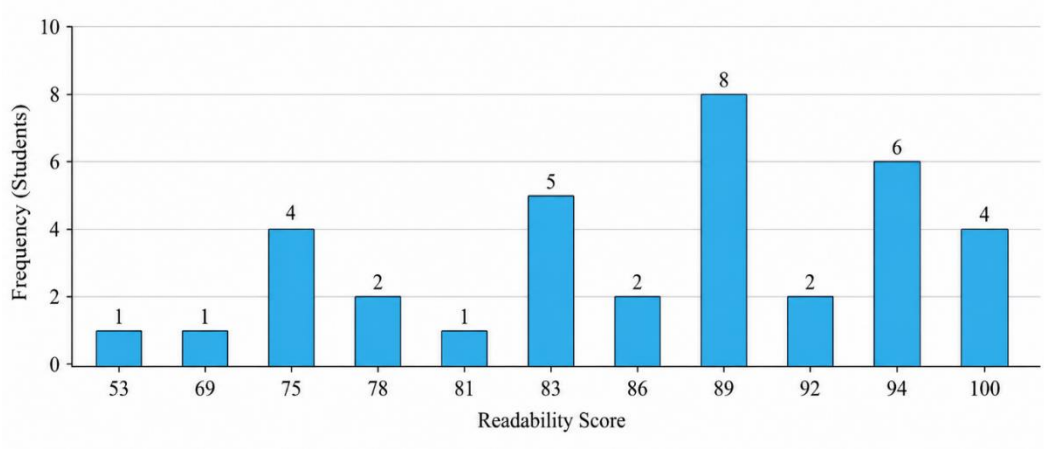


Figure 2. Readability Test Results

Based on Figure 2, the developed learning tool achieved a readability score of 86.47%, which falls into the “very good” category. These results indicate that students generally experienced no significant difficulties in understanding the instructions, accessing the digital worksheets, or using the features available on the Scratch platform. The majority of students obtained readability scores in the higher range, suggesting that the platform’s interface, language, and navigation were appropriate for the students’ needs.

During the readability test, students were able to access and use the platform on their own devices without encountering significant obstacles. The interactive features, including the Sketchboard, Algebra Guide, and Root Calculator, functioned properly and enabled students to follow the learning activities independently. Furthermore, no functional errors (bugs) or technical issues that hindered platform use were identified during testing. These findings indicate that the developed learning tool was sufficiently usable to proceed to the instructional implementation phase.

The next stage involved implementing the learning tool in the experimental class using the Scratch-assisted Problem-Based Learning (PBL) model, while the control class received PBL instruction without Scratch. The intervention was conducted over three sessions covering quadratic equations. The Scratch interface used during the learning process is presented in Figure 3.



Figure 3. *Scratch* Media Interface and Learning Features

The Scratch platform incorporates three main features: the Sketchboard, the Algebra Guide, and the Root Calculator. Students used these features sequentially to support their understanding of contextual problems, develop pictorial representations, construct mathematical models, and verify their solutions. Documentation of the learning activities using the digital worksheets and the Scratch platform is presented in Figure 4.

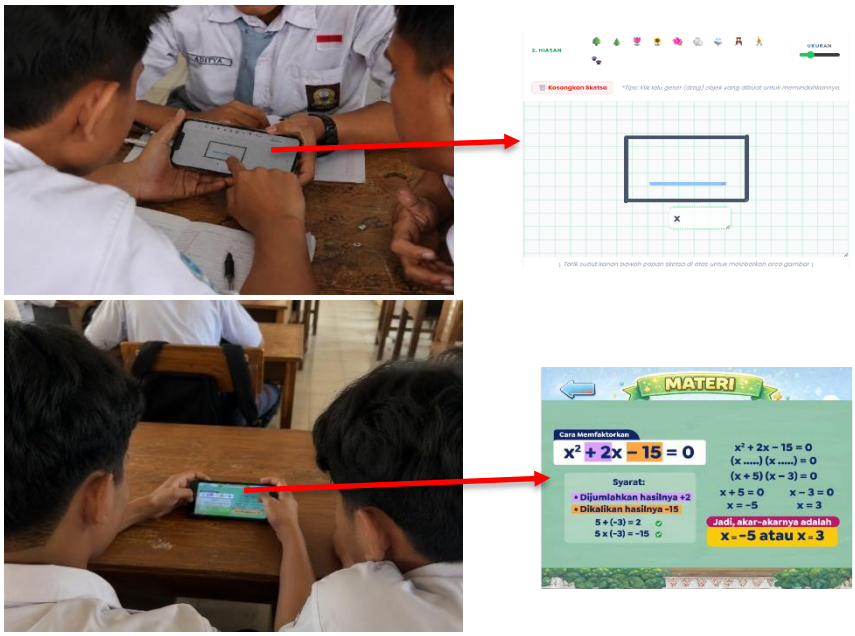


Figure 4. Students Using Digital Worksheets and *Scratch* During Instruction During the learning process

Students worked collaboratively in groups following the stages of Problem-Based Learning (PBL). They identified relevant information in contextual problems, created sketches using the Sketchboard feature, determined variables and constructed mathematical models using the Algebra Guide, and verified their solutions using the Root Calculator. Throughout the learning process, the teacher acted as a facilitator, guiding group discussions and providing assistance when students encountered difficulties.

The effectiveness of the developed learning tools was evaluated using a 10-item mathematical representation skills test administered after the learning intervention (posttest). Improvements in students' skills from before to after instruction were measured using the normalized gain (N-Gain), calculated from the pretest and posttest scores. Descriptive statistics for both the experimental and control classes are presented in Table 3.

Table 3. Descriptive Statistics of Mathematical Representation Skills

Group	***Pretest***	***Posttest***	***N-Gain***
Experimental	43,4	84,72	0,73
Control	39,09	72,5	0,56

Based on Table 3, the experimental class achieved a mean posttest score of 84.72, whereas the control class achieved a mean of 72.50. The experimental class obtained an N-Gain score of 0.73, which falls into the high category ((g \geq 0.7)), while the control class obtained an N-Gain score of 0.56, which falls into the moderate category ((0.3 \leq g < 0.7)). Furthermore, an independent-samples t-test of the N-Gain scores revealed a statistically significant difference in improvement between the two groups ((p < 0.05)).

Subsequently, a one-sample t-test was conducted to determine whether the mean posttest score of the experimental class significantly exceeded the minimum passing criterion of 75, as specified by the Learning Objective Achievement Criteria (KKTP).

Table 4. Results of the *One-Sample t-Test*

Mean	t	df	Sig.
84,72	8,703	35	<0,001

Based on Table 4, the one-sample t-test yielded a p-value of less than 0.001, indicating that the experimental class's mean posttest score was significantly higher than the established minimum criterion of 75. Furthermore, classical mastery was achieved, as 33 out of 36 students (91.67%) in the experimental class attained scores meeting or exceeding the KKTP of 75. This percentage exceeded the minimum target of 75% for classical mastery. It is important to note that the one-sample t-test and classical mastery analysis were used to evaluate the experimental class's achievement against the established criteria, rather than to establish its comparative effectiveness relative to other instructional approaches.

To evaluate the comparative effectiveness of the developed learning tool, the posttest mean scores of the experimental and control classes were compared using an independent-samples t-test, supplemented by an effect size analysis. These analyses were conducted to determine whether the Scratch-assisted Problem-Based Learning model produced greater improvements in students' mathematical representation skills than the conventional PBL model without Scratch. A summary of the results is presented in Table 5.

Table 5. Results of the *Independent-Samples t-Test*

Group	Mean	SD	Mean Diff	t-value	df	p-value	95% CI	Cohen's d
Experimental	84,72	7,35	12,22	6,923	70	<0,001	[8,70; 15,74]	1,63
Control	72,50	7,64	-	-	-	-	-	-

Based on Table 5, the mean posttest score of the experimental class was 12.22 points higher than that of the control class. The independent-samples t-test yielded a statistically significant difference between the two groups, $(t(70) = 6.923), (p < 0.001)$, indicating that the Scratch-assisted Problem-Based Learning approach was more effective than conventional PBL without Scratch in improving students' mathematical representation skills. Furthermore, the effect size analysis yielded a Cohen's (d) value of 1.63. According to the commonly used interpretation criteria, an effect size greater than 0.8 represents a large effect. Thus, the intervention demonstrated a very large effect on students' mathematical representation skills.

After the effectiveness of the developed learning tool was established, its practicality was evaluated based on responses from students in the experimental class. The results of the student response questionnaire are presented in Figure 5.

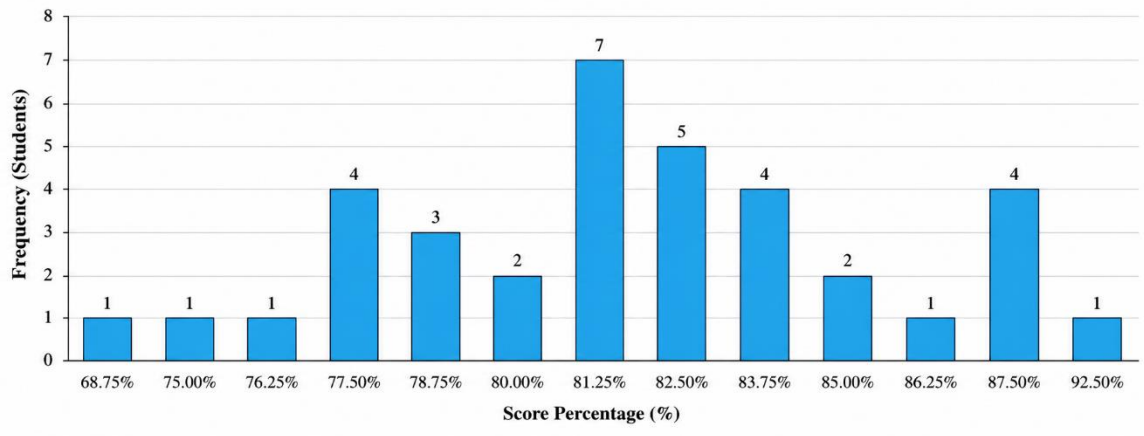


Figure 5. Students' Responses to the Instructional Intervention

Based on Figure 5, the average student response score for the developed learning tool was 88.61%, which falls into the "very positive" category. This result indicates that students responded favorably to

the learning tool, particularly the user-friendly interfaces of the digital worksheets and Scratch-based interactive media [30]. The interview findings further supported these results, indicating that students found the Sketchboard feature helpful in translating verbal representations into pictorial representations, while the Algebra Guide facilitated the translation of pictorial representations into quadratic equations.

The questionnaire results were further supported by interviews with several students. In general, students reported that the Sketchboard feature helped them understand the information presented in word problems before constructing mathematical models. The Algebra Guide also simplified the process of identifying variables and formulating quadratic equations, while the Root Calculator enabled students to verify their solutions. These findings suggest that the integration of the three interactive features supported students throughout the process of translating mathematical representations and solving contextual problems involving quadratic equations.

3.2 Discussion

The findings of this study demonstrate that the Scratch-assisted Problem-Based Learning (PBL) learning tool meets the criteria of validity, practicality, and effectiveness. Expert validation confirmed the suitability of the developed tool as a mathematics learning medium, while the readability test and student responses indicated that the digital worksheets and Scratch-based interactive media were practical for classroom use. The effectiveness results further support these findings. The experimental class achieved a mean posttest score of 84.72, an N-Gain score of 0.73, and a classical mastery rate of 91.67%. The posttest and N-Gain results also demonstrated statistically significant differences in favor of the experimental class compared with the control class. These findings suggest that the success of the intervention was associated with pedagogical mechanisms designed to address students' difficulties in learning quadratic equations [31].

The primary pedagogical mechanism underlying this learning approach is the use of digital worksheets and Scratch simulations as cognitive scaffolding to guide students through different episodes of mathematical representation [32]. Following the PBL framework, the learning process begins with problem orientation, in which students identify relevant information from contextual problems as verbal representations. Rather than proceeding directly to formulas, which may be difficult for students to interpret, the learning process guides them to construct pictorial representations using the Sketchboard feature. Once the pictorial representation has been established, students use the Algebra Guide to identify variables and construct mathematical models as symbolic representations. They then solve the resulting equations and verify their solutions using the Root Calculator before interpreting the results in the context of the original problem. This systematic process aligns with the perspective presented in [2] and the theory discussed in [3], which emphasize that mathematical understanding develops through the ability to translate between different forms of representation rather than relying solely on symbolic memorization [33].

Previous studies have established that Scratch can support students' motivation and the development of basic algorithmic thinking, as reported in [17], [20], and [34]. However, previous research has generally positioned Scratch as a tool for final demonstrations or as a coding environment, which may increase students' cognitive load when they must simultaneously learn programming and mathematical concepts. The contribution of the present study lies in using Scratch as interactive instructional scaffolding without requiring students to write code. By integrating PBL syntax with purposefully designed Scratch features, the developed learning tool supports students throughout the processes of constructing and translating mathematical representations. This integration provides a learning experience centered on contextual problem-solving and offers structured assistance to help students overcome difficulties when solving word problems involving quadratic equations [22].

3.3 Research Limitations

Although the Scratch-assisted Problem-Based Learning (PBL) tool demonstrated a substantial positive effect on students' mathematical representation skills (Cohen's d = 1.63), several limitations should be considered when interpreting the findings. First, the study was conducted at only one educational institution, SMA Negeri 1 Godong, with a relatively small sample of 72 students, which limits the generalizability of the findings to broader student populations. Second, the study focused exclusively on quadratic equations; therefore, the applicability of this integration of PBL and Scratch to other mathematical topics has yet to be established. Third, the instructional intervention was conducted over a relatively short period of three sessions. Furthermore, no long-term follow-up assessment was conducted to determine whether improvements in students' mathematical representation skills were sustained several months after the intervention.

4. CONCLUSION

Based on the research objectives and empirical findings, this study concludes that the development of a mathematics learning tool integrating Problem-Based Learning (PBL), Scratch-based interactive media, and digital worksheets was successful. First, the developed learning tool was considered highly

suitable, achieving an average validation score of 88.71%. Second, the tool demonstrated a high level of practicality, as indicated by a readability score of 86.47%. Third, the tool was effective in improving students' mathematical representation skills, with the experimental class achieving a classical mastery rate of 91.67% and an N-Gain score of 0.73, which falls into the high category. Fourth, the independent-samples t-test revealed a statistically significant difference in posttest scores between the experimental and control classes, with a large effect size (Cohen's $d = 1.63$), indicating that the Scratch-assisted PBL approach was more effective than PBL without Scratch. These findings suggest that integrating PBL, digital worksheets, and Scratch simulations as cognitive scaffolding, particularly through the Sketchboard and Algebra Guide features, offers a promising instructional approach for supporting students' translation of mathematical representations from verbal to pictorial and symbolic forms when solving quadratic equation problems.

5. AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Andi Khol	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
Ary Woro Kurniasih	✓	✓		✓						✓		✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

6. AI Disclosure Statement

During the preparation of this manuscript, the authors used Grammarly to assist with English translation, grammar checking, and academic language editing to improve clarity and readability. The authors carefully reviewed and revised the suggestions provided and take full responsibility for the accuracy, integrity, and content of the manuscript.

REFERENCES

1. National Council of Teachers of Mathematics, *Principles and Standards for School Mathematics*. Reston, VA, USA: NCTM, 2000.
2. G. A. Goldin, "Representation in mathematical learning and problem solving," in *Handbook of International Research in Mathematics Education*, L. D. English, Ed. Mahwah, NJ, USA: Lawrence Erlbaum Associates, 2002.
3. R. Lesh, T. Post, and M. Behr, "Representations and translations among representations in mathematics learning and problem solving," in *Problems of Representation in the Teaching and Learning of Mathematics*, C. Janvier, Ed. Hillsdale, NJ, USA: Lawrence Erlbaum Associates, 1987, pp. 33–40.
4. B. Mainali, "Representation in teaching and learning mathematics," *International Journal of Education in Mathematics, Science and Technology*, vol. 9, no. 1, pp. 1–21, 2021. doi:10.46328/ijemst.1111.
5. Kemendikbudristek, *Keputusan Kepala BSKAP Nomor 033/H/KR/2022 tentang Capaian Pembelajaran pada Kurikulum Merdeka*. Jakarta, Indonesia, 2022.
6. OECD, *PISA 2022 Results Volume I: The State of Learning and Equity in Education*. Paris, France: OECD Publishing, 2023. doi:10.1787/53f23881-en.
7. I. Santia and A. Sutawidjaja, "The analysis of students' mathematical representation in solving word problems," *Journal of Physics: Conference Series*, vol. 1157, no. 4, Art. no. 042079, 2019. doi:10.1088/1742-6596/1157/4/042079.
8. D. Rahmawati, E. Hidayanto, and L. Anwar, "Proses translasi representasi matematis siswa SMP dalam menyelesaikan soal cerita," *Jurnal Pendidikan Matematika dan Sains*, vol. 5, no. 2, pp. 131–140, 2017.
9. D. Kotsopoulos, "Unraveling student challenges with quadratics: A cognitive approach," *Australian Senior Mathematics Journal*, vol. 21, no. 2, pp. 19–24, 2007.
10. C. E. Hmelo-Silver, "Problem-based learning: What and how do students learn?," *Educational Psychology Review*, vol. 16, no. 3, pp. 235–266, 2004. doi:10.1023/B:EDPR.0000034022.16470.f3.
11. E. H. J. Yew and K. Goh, "Problem-based learning: An overview of its process and impact on learning," *Health Professions Education*, vol. 2, no. 2, pp. 75–79, 2016. doi:10.1016/j.hpe.2016.01.004.

12. A. Minarni and E. E. Napitupulu, "Developing instruction materials based on joyful PBL to improve students' mathematical representation ability," *International Education Studies*, vol. 13, no. 9, pp. 89–98, 2020. doi:10.5539/ies.v13n9p89.
13. R. Ramadhani, S. Huda, and K. Umam, "Problem-based learning and cognitive style: Its impact on mathematical representation skills," *Journal of Physics: Conference Series*, vol. 1188, no. 1, Art. no. 012061, 2019. doi:10.1088/1742-6596/1188/1/012061.
14. M. C. P. Sari, Mahmudi, Kristinawati, and H. L. Mampouw, "Peningkatan kemampuan representasi matematis melalui model *Problem Based Learning*," *PTK: Jurnal Tindakan Kelas*, vol. 4, no. 1, pp. 1–17, 2023. doi:10.53624/ptk.v4i1.242.
15. W. Daher, N. Baya'a, O. Jaber, and S. Awawdeh, "Students' learning of mathematics through *Scratch*," *International Journal of Emerging Technologies in Learning*, vol. 15, no. 6, pp. 154–168, 2020. doi:10.3991/ijet.v15i06.12128.
16. H. Montiel and M. G. Gomez-Zermeño, "*Scratch* programming in K–12 education: A systematic review," *Computers & Education*, vol. 168, Art. no. 104192, 2021. doi:10.1016/j.compedu.2021.104192.
17. A. Izza, "Digital didactical design: *Scratch* assisted learning of probability materials in junior high school," *International Journal of Multicultural and Multireligious Understanding*, vol. 11, no. 1, pp. 1–14, 2024.
18. J. Smith, A. Johnson, and M. Lee, "Integrating visual programming in middle school mathematics: A focus on cognitive engagement," *Computers & Education*, vol. 185, p. 104521, 2022. doi:10.1016/j.compedu.2022.104521.
19. P. Nurfauziah et al., "Media pembelajaran *Scratch* untuk meningkatkan kemampuan representasi matematis siswa," *Jurnal Pembelajaran Matematika Inovatif*, vol. 5, no. 4, pp. 1123–1134, 2022.
20. L. Chen and H. Wang, "The impact of *Scratch*-based simulations on students' visual representations in algebra," *Journal of Educational Technology & Society*, vol. 26, no. 3, pp. 45-58, 2023. doi:10.1016/j.jethsoc.2023.03.005.
21. R. Garcia, "Technology-enhanced problem-based learning: Bridging the representational gap in quadratic functions," *International Journal of STEM Education*, vol. 11, no. 1, p. 24, 2024. doi:10.1186/s40594-024-00324-x.
22. D. Kim and S. Park, "Scaffolding mathematical translation through interactive digital environments," *Educational Technology Research and Development*, vol. 73, no. 2, pp. 315-334, 2025. doi:10.1007/s11423-024-10115-2.
23. R. M. Branch, *Instructional Design: The ADDIE Approach*. New York, NY, USA: Springer, 2009. doi:10.1007/978-0-387-09506-6.
24. T. Trust and E. Pektas, "Using the ADDIE model and Universal Design for Learning (UDL) to create instructional tools for educators," *Journal of Educational Technology Systems*, vol. 46, no. 3, pp. 356–374, 2021. doi:10.1177/0047239520977849.
25. J. van den Akker, "Principles and methods of development research," in *Design Approaches and Tools in Education and Training*, J. van den Akker et al., Eds. Dordrecht: Springer, 1999, pp. 1–14.
26. Sugiyono, *Metode Penelitian Pendidikan*. Bandung: Alfabeta, 2021.
27. M. Tessmer, *Planning and Conducting Formative Evaluations*. London, U.K.: Routledge, 1993.
28. N. Nieveen, "Prototyping to reach product quality," in *Design Approaches and Tools in Education and Training*, J. van den Akker et al., Eds. Dordrecht: Springer, 1999, pp. 125–135.
29. T. Plomp, "Educational Design Research: An Introduction," in *Educational Design Research Part A*. Enschede: SLO, 2013, pp. 10–51.
30. D. Harefa and H. T. La'ia, *Media Pembelajaran Matematika*. Medan: Media Sains Indonesia, 2021.
31. A. Woolfolk, *Educational Psychology*, 13th ed. Boston, MA, USA: Pearson, 2016.
32. R. E. Mayer, *Multimedia Learning*, 2nd ed. Cambridge, U.K.: Cambridge University Press, 2009.
33. Munir, *Multimedia: Konsep dan Aplikasi dalam Pendidikan*. Bandung: Alfabeta, 2012.
34. A. N. S. Az-Zahrah, *Pengaruh Penggunaan Media Pembelajaran Scratch terhadap Pemahaman Konsep Matematis Siswa pada Materi Fungsi Kuadrat*. Skripsi, UIN Kiai Haji Achmad Siddiq Jember, 2025.