JURNAL ABSIS
Jurnal Pendidikan Matematika dan Matematika
Vol. 9 No. 2, August 2026

Effectiveness of Scratch-Assisted Problem-Based Learning for Mathematical Conceptual Understanding: A Quasi-Experimental Study

Devi Syafitri Padang[1], *Eyus Sudihartini[2]
[1–2] Universitas Pendidikan Indonesia, West Java, Indonesia
eyus84@upi.edu

Received: July 10, 2026 | **Revised:** July 25, 2026 | **Accepted:** July 27, 2026 | **Published:** July 30, 2026

ABSTRACT This study examined the effectiveness of Scratch-assisted problem-based learning (PBL) in improving eighth-grade students' mathematical conceptual understanding of systems of linear equations in two variables. The study employed a quantitative quasi-experimental approach with a pretest--posttest nonequivalent control group design. Two intact classes were selected through cluster random sampling, comprising 32 students in the experimental group and 30 students in the control group at SMP Negeri 15 Bandung. The intervention was implemented over three sessions. Data were collected using a five-item essay test and analyzed using descriptive statistics, the Shapiro--Wilk test, Levene's test, the Mann--Whitney U test, independent-samples t-tests, normalized gain (N-Gain), and Cohen's d. The experimental group achieved a significantly higher posttest mean than the control group (80.00 vs. 67.50), with a large effect size, $t(60) = 4.883$, $p < 0.001$, $d = 1.241$. The experimental and control groups obtained mean N-Gain scores of 0.591 and 0.362, respectively. This difference was also significant, $t(60) = 4.235$, $p < 0.001$, with a large effect size ($d = 1.076$). These findings indicate that, within the context and duration of this study, Scratch-assisted PBL was more effective than conventional instruction in improving mathematical conceptual understanding.

Keywords: Scratch, problem-based learning, mathematical conceptual understanding, systems of linear equations, quasi-experimental study

INTRODUCTION

Conceptual understanding is a fundamental component of mathematics learning because it enables students to explain concepts, articulate mathematical ideas, establish connections, use multiple representations, and apply knowledge flexibly when solving problems (Sugawara et al., 2026). Students with strong conceptual understanding not only perform procedures but also recognize the mathematical reasoning underlying each solution process (Payadnya et al., 2021). However, developing such understanding remains challenging in many educational contexts, including Indonesia. Studies involving PISA-type tasks indicate that Indonesian students continue to experience difficulty interpreting mathematical information, connecting concepts, and applying knowledge in problem-solving situations (Putra et al., 2025; N. D. Rahmawati et al., 2026). These challenges underscore the need for instructional innovations that promote deeper conceptual learning.

This issue is particularly evident in systems of linear equations in two variables. The topic requires more than algebraic manipulation through elimination, substitution, or graphing; students must also understand relationships between variables, the meaning of a system's solution, and connections between algebraic and graphical representations (Mustafa et al., 2026; L. Rahmawati et al., 2023). In practice, instruction often continues to emphasize teacher explanations and routine procedural exercises (Hadianto et al., 2021). Consequently, students may memorize solution steps without understanding the underlying concepts and may struggle when problems differ from familiar examples (Belue et al., 2017; Fatio et al., 2020; Raudiyah and Suryadi, 2023).

A preliminary study at SMP Negeri 15 Bandung revealed a comparable pattern. Most students could apply elimination or substitution procedures but could not explain why the intersection of two lines represents the solution of a system. They also experienced difficulty connecting algebraic equations with graphical representations and contextual problems. Interviews with mathematics teachers further indicated that students tended to reproduce demonstrated procedures and struggled when problems were modified or situated in real-life contexts. Collectively, these findings confirmed the need for an instructional approach that supports deeper conceptual construction.

Digital technology offers opportunities to create more interactive and meaningful mathematics learning experiences. By visualizing abstract relationships dynamically, technology allows students to explore mathematical objects and receive immediate feedback. Scratch, a block-based visual programming environment, offers this potential (Calder and Taylor, 2010; Maqhfiroh, 2025; Iskandar et al., 2024; Sungur and Ozkan, 2026). In mathematics education, Scratch can support the construction of simulations and interactive representations, making abstract concepts more accessible while encouraging exploration, logical reasoning, and active engagement (Nurhasanah et al., 2025; Pérez-Jorge and Martínez-Murciano, 2022).

However, technology does not automatically improve learning quality; its effectiveness depends on the pedagogical model through which it is used. Problem-based learning (PBL) is relevant in this context because it uses contextual problems as the starting point for learning (Amri et al., 2025; Rahman and Nisa, 2020) and encourages students to construct knowledge through inquiry, collaboration, discussion, and reflection (Cai et al., 2026; Pérez-Jorge and Martínez-Murciano, 2022; N. D. Rahmawati et al., 2026). Integrating Scratch with PBL may therefore combine interactive visualization with a structured problem-solving process, thereby supporting deeper mathematical conceptual understanding (Funa and Prudente, 2021; Merritt et al., 2017; Musna et al., 2021; Smith et al., 2022; L. Zhang and Ma, 2023).

Previous research indicates that digital technology and problem-based or project-based learning can support engagement, higher-order thinking, problem-solving, and learning outcomes (Aminah et al., 2023; Mangiri, 2024; Saad and Zainudin, 2022; Sukkamart et al., 2025; Sungur and Ozkan, 2026; W. Zhang et al., 2024). Research related to Scratch and conceptual learning has also addressed programming, computational thinking, creativity, digital literacy, procedural and conceptual understanding, and science achievement (Addido et al., 2025; Adeniji and Baker, 2022; Edo and Tasik, 2022; Meiliati et al., 2026; Prayitno et al., 2026; Sercenia et al., 2023; Sugawara et al., 2026). These studies suggest that integrating digital tools with student-centered learning can contribute to meaningful twenty-first-century mathematics education (Ayeh, 2025; Lukman and Setiani, 2019; Sercenia et al., 2023).

Even so, much of the existing research has focused on motivation, creativity, computational thinking, programming, or digital literacy rather than mathematical conceptual understanding (Calder, 2018; Nurhasanah et al., 2025; Saad and Zainudin, 2022; Sercenia et al., 2023; Wen et al., 2023). Scratch has also frequently been treated primarily as a learning medium rather than being systematically integrated with a pedagogically grounded learning model (Pérez-Jorge and Martínez-Murciano, 2022; Sulaiman et al., 2021). Although Scratch and PBL have been studied separately, research combining them to strengthen conceptual understanding of systems of linear equations in two variables at the junior high school level remains limited (Aminah et al., 2023; Ayeh, 2025; Belessova et al., 2024; Fitrah et al., 2025; Funa and Prudente, 2021; Lukman and Setiani, 2019; Mediana et al., 2025).

To address this gap, the present study examined the effectiveness of Scratch-assisted PBL in improving junior high school students' mathematical conceptual understanding of systems of linear equations in two variables. Unlike studies that primarily emphasize computational thinking, programming, creativity, motivation, or general learning outcomes, this study treated mathematical conceptual understanding as its principal outcome (Muzana et al., 2021; Purwanto et al., 2022; Purwoko et al., 2023; Sacristán et al., 2024). The findings are expected to provide empirical evidence concerning the integration of Scratch and PBL and to inform the development of more meaningful technology-supported mathematics instruction.

RESEARCH METHOD

Research Design

This study employed a quantitative quasi-experimental approach with a pretest–posttest nonequivalent control group design. Because the school had established intact classes before the study, individual students could not be randomly assigned; consequently, sampling was conducted at the class level. This design enabled the researchers to compare changes in mathematical conceptual understanding over time and to evaluate Scratch-assisted PBL relative to conventional instruction.

Table 1. Pretest--posttest nonequivalent control group design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X_1	O_2
Control	O_1	X_2	O_2

O_1: pretest;
X_1: Scratch-assisted PBL;
X_2: conventional instruction without Scratch;
O_2: posttest.

Research Participants

The study was conducted during the second semester of the 2025/2026 academic year at SMP Negeri 15 Bandung, West Java, Indonesia. The population comprised all eighth-grade students studying systems of linear equations in two variables. Cluster random sampling was used because school policy did not permit individual randomization. All eighth-grade classes followed the same curriculum, instructional time allocation, subject teacher, and teaching materials. The selected sample comprised one experimental class with 32 students and one control class with 30 students, yielding a total of 62 participants.

Research Procedures

The research procedure comprised preparation, implementation, and post-intervention stages. During preparation, the researchers developed teaching modules, student worksheets, Scratch activities, and a mathematical conceptual understanding test. Both groups completed the pretest before instruction. The experimental group subsequently received Scratch-assisted PBL, whereas the control group received conventional instruction without Scratch or the PBL framework.

The same teacher delivered the intervention over three sessions, each lasting 2×40 minutes. Both groups studied equivalent content and followed the same learning objectives and time allocation. Instruction in the experimental group followed five PBL phases: orienting students to the problem, organizing learning, guiding inquiry, developing and presenting results, and analyzing and evaluating the problem-solving process. Scratch was used to visualize systems of equations, manipulate relationships between variables, and connect algebraic, graphical, and contextual representations. By contrast, the control group received teacher explanations, worked examples, question-and-answer activities, and individual exercises. Both conditions followed prepared teaching modules, and implementation was monitored descriptively using an observation sheet during each session.

After the intervention, both groups completed a posttest based on the same assessment framework as the pretest. The resulting data were then analyzed in accordance with the study objectives.

Research Instruments

The research instrument was a five-item essay test designed to assess mathematical conceptual understanding. The indicators were informed by relational understanding and multiple-representation perspectives (Skemp, 2006). Table 2 presents the indicators and their operational descriptions.

Table 2. Indicators of mathematical conceptual understanding

No.	Indicator	Description
1	Restating a concept	Explaining systems of linear equations in two variables using the student's own words and appropriate mathematical symbols.
2	Classifying mathematical objects	Identifying whether an equation or pair of equations satisfies the defining characteristics of a system of linear equations in two variables.
3	Providing examples and non-examples	Constructing examples and distinguishing them from expressions that do not represent the target concept.
4	Representing concepts in multiple forms	Expressing the concept through equations, tables, graphs, and contextual situations.
5	Applying and connecting concepts	Applying and relating concepts to solve contextual mathematical problems accurately.

Instrument Validation

Two mathematics education faculty members evaluated the instrument in terms of content, construction, language, and alignment with the specified indicators. The mean Aiken's V coefficient was 0.90, indicating very high content validity. The instrument was subsequently piloted with 26 students whose characteristics were comparable to those of the research participants. Corrected item–total correlations ranged from 0.835 to 0.956, and Cronbach's alpha was 0.969. The items demonstrated moderate difficulty and very good discrimination, supporting the instrument's use in the study.

Data Analysis

Data were analyzed using IBM SPSS Statistics. Descriptive statistics were first calculated to summarize the data. Distributional assumptions were then examined using the Shapiro–Wilk test, while homogeneity of variance was assessed using Levene's test. Because one pretest distribution was nonnormal, initial group equivalence was evaluated using the Mann–Whitney U test. After the relevant assumptions had been satisfied, posttest and N-Gain differences were examined using independent-samples t-tests. Normalized gain was calculated as

$$g = \frac{\text{posttest} - \text{pretest}}{\text{maximum score} - \text{pretest}}.$$

Cohen's d was used to quantify the practical magnitude of group differences. Statistical significance was evaluated at $\alpha = 0.05$.

FINDINGS AND DISCUSSION

Descriptive Statistics of Conceptual Understanding. Table 3 summarizes pretest and posttest performance. Before the intervention, the experimental group obtained a mean score of 50.63 ($SD = 8.684$), whereas the control group obtained a mean score of 47.50 ($SD = 10.401$). This 3.13-point difference suggested broadly comparable initial performance, which was subsequently examined through inferential analysis.

Table 3. Descriptive statistics of mathematical conceptual understanding

Group	Test	N	Min.	Max.	Mean	Mdn.	SD	Var.
Experimental	Pretest	32	35	70	50.63	50.00	8.684	75.403
Experimental	Posttest	32	55	100	80.00	80.00	9.672	93.548
Control	Pretest	30	25	70	47.50	50.00	10.401	108.190
Control	Posttest	30	50	90	67.50	70.00	10.484	109.914

Following instruction, both groups demonstrated improvement. The experimental group's mean increased by 29.37 points to 80.00, whereas the control group's mean increased by 20.00 points to 67.50. This larger descriptive gain provided initial evidence that Scratch-assisted PBL may have supported stronger conceptual development.

Normality Test. The Shapiro–Wilk results are presented in Table 4. The experimental pretest scores were nonnormal ($p = 0.005$), while the control pretest scores were normal ($p = 0.435$). Both posttest distributions and both N-Gain distributions satisfied the normality criterion.

Table 4. Shapiro--Wilk normality test

Variable	Group	W	p-value	Decision
Pretest	Experimental	0.895	0.005	Nonnormal
Pretest	Control	0.966	0.435	Normal
Posttest	Experimental	0.955	0.203	Normal
Posttest	Control	0.942	0.110	Normal
N-Gain	Experimental	0.936	0.058	Normal
N-Gain	Control	0.968	0.478	Normal

Equivalence of Initial Ability. Because the experimental pretest distribution was nonnormal, initial group equivalence was evaluated using the Mann–Whitney U test. Table 5 shows no significant difference between the groups, $U = 421.500$, $Z = -0.840$, $p = 0.401$. The experimental and control mean ranks were 33.33 and 29.55, respectively. Thus, the groups had statistically comparable initial mathematical conceptual understanding.

Table 5. Mann--Whitney U test for pretest scores

Statistic	Value
Mann--Whitney U	421.500
Z	-0.840
p-value	0.401

Homogeneity Test. Levene's test indicated that the posttest variances were homogeneous, $F = 0.622$, $p = 0.434$ (Table 6). The N-Gain variances were also homogeneous, $F = 0.267$, $p = 0.607$. Consequently, independent-samples t-tests were appropriate for comparing the posttest and N-Gain scores.

Table 6. Levene's homogeneity tests

Variable	F	p-value	Interpretation
Posttest	0.622	0.434	Homogeneous variances
N-Gain	0.267	0.607	Homogeneous variances

Comparison of Posttest Performance. The independent-samples t-test showed a significant posttest difference between the experimental and control groups, $t(60) = 4.883$, $p < 0.001$. The mean difference was 12.50 points, and the 95% confidence interval ranged from 7.38 to 17.62. Cohen's $d = 1.241$ indicated a large effect. Thus, students who received Scratch-assisted PBL demonstrated substantially higher post-intervention conceptual understanding than those who received conventional instruction.

Table 7. Independent-samples t-test for posttest scores

Experimental Mean	Control Mean	Mean Difference	$t(60)$	p	95% CI	Cohen's d
80.00	67.50	12.50	4.883	< 0.001	7.38--17.62	1.241

Normalized Gain Analysis. Table 8 shows that the experimental group obtained a mean N-Gain of 0.591, compared with 0.362 for the control group. Both means were in the moderate category, but improvement was greater in the experimental group.

Table 8. Improvement based on N-Gain scores

Group	N	Mean	SD	Category
Experimental	32	0.591	0.211	Moderate
Control	30	0.362	0.222	Moderate

The N-Gain difference was statistically significant, $t(60) = 4.235$, $p < 0.001$. The mean difference of 0.229 and Cohen's $d = 1.076$ indicated a large practical effect. Scratch-assisted PBL therefore produced greater normalized improvement than conventional instruction in this sample.

Table 9. Independent-samples t-test for N-Gain scores

Mean Difference	t	df	p	Cohen's d
0.229	4.235	60	< 0.001	1.076

Taken together, the findings indicate that Scratch-assisted PBL improved students' mathematical conceptual understanding more effectively than conventional instruction. The significant posttest difference, higher N-Gain, and large effect sizes demonstrate that the intervention produced both statistically significant and practically meaningful gains. This finding is consistent with research suggesting that Scratch can facilitate mathematical exploration and that PBL can promote active knowledge construction (Calder, 2018; Merritt et al., 2017; Smith et al., 2022).

The effectiveness of the intervention cannot be attributed to Scratch as a presentation medium alone. In the experimental class, Scratch enabled students to manipulate relationships between variables, observe corresponding changes in graphs, and compare multiple solution representations. Simultaneously, the PBL framework gave these activities a clear instructional purpose: students began with contextual problems, formulated strategies, discussed alternatives, and evaluated their solutions. Thus, the combination of dynamic representation and structured inquiry supported connections among symbolic, graphical, and contextual forms.

This combined mechanism is especially relevant to systems of linear equations in two variables. Students often learn elimination and substitution as isolated procedures and may not recognize that an algebraic solution corresponds to the intersection of two lines. Through Scratch-based visualizations, changes in coefficients and variables could be linked immediately to changes in graphical representations. As a result, the relationship between equations and their solutions became more concrete, reducing students' reliance on memorized procedures.

Nevertheless, the large effect sizes should be interpreted in relation to the study design. The intervention involved only two intact classes from one school and lasted three sessions. The findings establish a strong difference within this sample, but they do not demonstrate long-term retention or generalizability to other schools, teachers, topics, or student populations. Moreover, implementation fidelity was monitored descriptively but was not analyzed as a formal outcome. These limitations should therefore be considered before the intervention is adopted on a wider scale.

CONCLUSIONS AND RECOMMENDATIONS

Scratch-assisted PBL was more effective than conventional instruction in improving eighth-grade students' mathematical conceptual understanding of systems of linear equations in two variables. The experimental group achieved both a higher posttest mean and a higher mean N-Gain than the control group. The posttest comparison produced $t(60) = 4.883$, $p < 0.001$, and $d = 1.241$, whereas the N-Gain comparison produced $t(60) = 4.235$, $p < 0.001$, and $d = 1.076$. These results suggest that integrating dynamic Scratch visualizations with problem-based inquiry can support conceptual connections, mathematical exploration, and collaborative problem-solving.

The conclusions are limited to two classes at one school and a three-session intervention. Future studies should involve more schools, longer interventions, and delayed posttests to evaluate retention. Researchers should also analyze implementation fidelity systematically and examine whether the approach supports other outcomes, including mathematical reasoning, problem-solving, critical thinking, and transfer to other topics. Classroom implementation should ensure that Scratch activities remain focused on mathematical meaning rather than programming complexity.

Artificial Intelligence Statement: The authors used ChatGPT (OpenAI) and DeepL for grammar and style checking, translation, and brainstorming or idea development during manuscript preparation. All AI-assisted outputs were critically reviewed, verified, and revised by the authors. The authors remain fully responsible for the accuracy, originality, interpretation, and integrity of the final manuscript.

Author Contribution Statement: DSP: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. ES: Methodology, Software, Validation, Formal analysis, Resources, Writing – review & editing, Supervision, Project administration.

Funding Statement: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interest Statement: The authors declare no conflict of interest

REFERENCES

Addido, J., Borowczak, A. C. B., & Slater, T. F. (2025). Impact of conceptual understanding, teaching experience, and parental education on science achievement: TIMSS data analysis. *European Journal of Science and Mathematics Education, 14*(1), 28--46. https://doi.org/10.30935/scimath/17622

Adeniji, S. M., & Baker, P. (2022). Worked-examples instruction versus Van Hiele teaching phases: A demonstration of students' procedural and conceptual understanding. *Journal on Mathematics Education, 13*(2), 337--356. https://doi.org/10.22342/jme.v13i2.pp337-356

Aminah, N., Sukestiyarno, Y. L., Cahyono, A. N., & Maat, S. M. (2023). Student activities in solving mathematics problems with a computational thinking using Scratch. *International Journal of Evaluation and Research in Education, 12*(2), 613--621. https://doi.org/10.11591/ijere.v12i2.23308

Amri, R. A., Gunowibowo, P., & Wijaya, A. P. (2025). The effect of the guided discovery learning model on students' mathematical reasoning ability. *Jurnal Absis: Jurnal Pendidikan Matematika Dan Matematika, 8*(2), 321--329. https://doi.org/10.30606/absis.v8i2.3249

Ayeh, I. G. (2025). Students' mathematics conceptual challenges: Exploring students' thinking, understanding, and misconceptions in functions and graphs. *European Journal of Science and Mathematics Education, 13*(3), 191--206. https://doi.org/10.30935/scimath/16596

Belessova, D., Ibashova, A., Zhidebayeva, A., Shaimerdenova, G., & Nakhipova, V. (2024). The impact of Scratch on student engagement and academic performance in primary schools. *Open Education Studies, 6*(1), Article 20220228. https://doi.org/10.1515/edu-2022-0228

Belue, P. T., Cavey, L. O., & Kinzel, M. T. (2017). An exploration of a quantitative reasoning instructional approach to linear equations in two variables with community college students. *School Science and Mathematics, 117*(5), 183--193. https://doi.org/10.1111/ssm.12223

Cai, J., Ding, M., & Hwang, S. (2026). Fostering students' mathematical understanding: Toward a theoretical framework. *Asian Journal for Mathematics Education, 5*(2), 117--137. https://doi.org/10.1177/27527263261442721

Calder, N. (2018). Using Scratch to facilitate mathematical thinking. *Waikato Journal of Education, 23*(2), 43--58. https://doi.org/10.15663/wje.v23i2.654

Calder, N., & Taylor, M. (2010). Scratching below the surface: Mathematics through an alternative digital lens? In L. Sparrow, B. Kissane, & C. Hurst (Eds.), *Shaping the future of mathematics education: Proceedings of the 33rd annual conference of the Mathematics Education Research Group of Australasia* (pp. 117--124). MERGA. https://files.eric.ed.gov/fulltext/ED520871.pdf

Edo, S. I., & Tasik, W. F. (2022). Investigation of students' algebraic conceptual understanding and the ability to solve PISA-like mathematics problems in a modeling task. *Mathematics Teaching Research Journal, 14*(2), 44--60. https://eric.ed.gov/?id=EJ1350638

Fatio, N. A., Fatimah, S., & Rosjanuardi, R. (2020). The analysis of students' learning difficulties on system of linear equation in two variables topic. *Journal of Physics: Conference Series, 1521*(3), 032062. https://doi.org/10.1088/1742-6596/1521/3/032062

Fitrah, M., Sofroniou, A., Setiawan, C., Widihastuti, W., Yarmanetti, N., Jaya, M. P. S., Panuntun, J. G., Arfaton, A., Beteno, S., & Susianti, I. (2025). The Impact of Integrated Project-Based Learning and Flipped Classroom on Students' Computational Thinking Skills: Embedded Mixed Methods. *Education Sciences, 15*(4), 448. https://doi.org/10.3390/educsci15040448

Funa, A. A., & Prudente, M. S. (2021). Effectiveness of Problem-Based Learning on Secondary Students' Achievement in Science: A Meta-Analysis. *International Journal of Instruction, 14*(4), 69--84. https://doi.org/10.29333/iji.2021.1445a

Hadianto, D., Damaianti, V. S., Mulyati, Y., & Sastromiharjo, A. (2021). Does reading comprehension competence determine level of solving mathematical word problems competence? *Journal of Physics: Conference Series, 1806*(1), 012049. https://doi.org/10.1088/1742-6596/1806/1/012049

Lukman, H. S., & Setiani, A. (2019). Teaching materials design based on project learning to improve the students' mathematical understanding. *Journal of Physics: Conference Series, 1315*(1), 012026. https://doi.org/10.1088/1742-6596/1315/1/012026

Mangiri, G. R. P., & Prabawanto, S. (2024). Exploring computational thinking in learning mathematics: A systematic literature review from 2017--2024. *Jurnal Pendidikan MIPA, 25*(1), 34--52. https://doi.org/10.23960/jpmipa/v25i1.pp34-52

Maqhfiroh, H., & Maharani, H. R. (2025). Effectiveness of Scratch-based interactive learning media on students' mathematical problem-solving. *Union: Jurnal Ilmiah Pendidikan Matematika, 13*(3), 665--680. https://doi.org/10.30738/union.v13i3.19673

Mediana, N., Funa, A., & Dio, R. (2025). Effectiveness of Inquiry-based Learning (IbL) on Improving Students' Conceptual Understanding in Science and Mathematics: A Meta-Analysis. *International Journal of Education in Mathematics, Science and Technology, 13*(2), 532--552. https://doi.org/10.46328/ijemst.4769

Meiliati, R., Djodding, I. M., Aswin, Salido, A., Husain, D. S., Tahir, & Hidayati, U. (2026). Exploration problem-based learning in mathematics learning in higher education: A bibliometric review. *Social Sciences & Humanities Open, 13*(August 2025), 102345. https://doi.org/10.1016/j.ssaho.2025.102345

Merritt, J., Lee, M. Y., Rillero, P., & Kinach, B. M. (2017). Problem-Based Learning in K--8 Mathematics and Science Education: A Literature Review. *Interdisciplinary Journal of Problem-Based Learning, 11*(2), 5--17. https://doi.org/10.7771/1541-5015.1674

Musna, R. R., Juandi, D., & Jupri, A. (2021). A meta-analysis study of the effect of Problem-Based Learning model on students' mathematical problem solving skills. *Journal of Physics: Conference Series, 1882*(1), 012090. https://doi.org/10.1088/1742-6596/1882/1/012090

Mustafa, V., Jusufi Zenku, T., Iseni, E., & Rexhepi, S. (2026). Comparison of solving systems of linear equations with two variables with classic methods and application software. *International Electronic Journal of Mathematics Education, 21*(1), em0867. https://doi.org/10.29333/iejme/17836

Muzana, S. R., Jumadi, Wilujeng, I., Yanto, B. E., & Mustamin, A. A. (2021). E-STEM project-based learning in teaching science to increase ICT literacy and problem solving. *International Journal of Evaluation and Research in Education, 10*(4), 1386--1394. https://doi.org/10.11591/IJERE.V10I4.21942

Nurhasanah, A., Handoyo, E., Widiyatmoko, A., & Rusdarti, R. (2025). Digital-based learning media innovation: Improving motivation and science learning outcomes. *International Journal on Social and Education Sciences, 7*(2), 185--194. https://doi.org/10.46328/ijonses.723

Payadnya, I. P. A. A., Suwija, I. K., & Wibawa, K. A. (2021). Analysis of Students' Abilities in Solving Realistic Mathematics Problems Using ``what-If''-Ethnomathematics Instruments. *Mathematics Teaching-Research Journal, 13*(4), 131--149. https://eric.ed.gov/?id=EJ1332339

Pérez-Jorge, D., & Martínez-Murciano, M. C. (2022). Gamification with Scratch or App Inventor in Higher Education: A Systematic Review. *Future Internet, 14*(12), 374. https://doi.org/10.3390/fi14120374

Prayitno, B. A., Widoretno, S., Sugiharto, B., & Oetomo, D. (2026). Can Scientific-Based Learning Close the Gap in Understanding Science Concepts Between Underachiever and High-Achiever Students? *Journal of Teaching and Learning, 20*(1), 280--296. https://doi.org/10.22329/jtl.v19i2.8763

Purwanto, W. R., Zaenuri, Z., Wardono, W., & Junaedi, I. (2022). A meta-analysis on the effect of ethnomathematics on students' ability in geometry. *Proceedings of the International Conference on Science, Education, and Technology, 8*(1), 114--122. https://proceeding.unnes.ac.id/ISET/article/view/1737

Purwoko, R. Y., Supriyono, Nuryadi, Kusumaningrum, B., & Setiana, D. S. (2023). Developing e-module based on ethnomathematics to improve students' creative thinking skill. In *Proceedings of the International Conference on Information Technology and Education (ICITE 2023)* (pp. 44--48). Atlantis Press. https://doi.org/10.2991/978-94-6463-338-2_7

Putra, B. Y. G., Yaniawati, P., Fitri, N., Sharif, S., Supianti, I. I., & Mudrikah, A. (2025). Analyzing student errors in PISA ``Change and Relationship'' tasks using the AVAEM framework. *Infinity Journal, 14*(4), 1105--1128. https://doi.org/10.22460/infinity.v14i4.p1105-1128

Rahman, T., & Nisa, F. (2020). Pengaruh Model Problem Based Learning Dengan Strategi Everyone Is A Teacher Here Terhadap Kemampuan Komunikasi Matematis Dan Self-Confidence Siswa SMP. *Jurnal Absis: Jurnal Pendidikan Matematika Dan Matematika, 2*(2), 148--159. https://doi.org/10.30606/absis.v2i2.336

Rahmawati, L., Zaenuri, & Hidayah, I. (2023). Pembelajaran bernuansa etnomatematika sebagai upaya menumbuhkan karakter cinta budaya dan kemampuan pemecahan masalah matematis. *Journal of Authentic Research on Mathematics Education, 5*(1), 25--32. https://doi.org/10.37058/jarme.v5i1.5984

Rahmawati, N. D., Wardono, W., Wijayanti, K., & Dewi, N. R. (2026). Mathematical Literacy with Technology-Assisted Scaffolding in Indonesia: Camper and Quitter Students in Solving PISA Problems. *Educational Process International Journal, 20*(1). https://doi.org/10.22521/edupij.2026.20.10

Raudiyah, R. R., & Suryadi, D. (2023). Junior High School Student's Learning Obstacle Related to Mathematical Communication Ability on Systems of Linear Equations in Two Variables. *AIP Conference Proceedings, 2734*, 90011. https://doi.org/10.1063/5.0156250

Saad, A., & Zainudin, S. (2022). A review of Project-Based Learning (PBL) and Computational Thinking (CT) in teaching and learning. *Learning and Motivation, 78*(December 2021), 101802. https://doi.org/10.1016/j.lmot.2022.101802

Sacristán, A. I., Faggiano, E., Santacruz-Rodríguez, M., & Rocha, H. (2024). Policies and implementations for technology integration in mathematics education: Perspectives from around the world. In B. Pepin, G. Gueudet, & J. Choppin (Eds.), *Handbook of digital resources in mathematics education* (pp. 1263--1305). Springer. https://doi.org/10.1007/978-3-031-45667-1_52

Iskandar, R. S. F., Darhim, Dahlan, J. A., Jupri, A., & Supriyadi, E. (2024). How to analyze objects in the context of realistic mathematics education (RME) using Scratch programming? *Journal of Engineering Science and Technology, 19*(5), 10--17. https://jestec.taylors.edu.my/Special%20Issue%20ISCoE%202023_3/ISCoE%202023%203_02.pdf

Sercenia, J. C., Ibañez, E. D., & Pentang, J. T. (2023). Thinking Beyond Thinking: Junior High School Students' Metacognitive Awareness and Conceptual Understanding of Integers. *Mathematics Teaching-Research Journal, 15*(1), 4--24. https://files.eric.ed.gov/fulltext/EJ1391473.pdf

Skemp, R. R. (2006). Relational Understanding and Instrumental Understanding. *Mathematics Teaching in the Middle School, 12*(2), 88--95. https://doi.org/10.5951/MTMS.12.2.0088

Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., Mansfield, J., Ellerton, P., & Smith, T. (2022). Principles of Problem-Based Learning (PBL) in STEM Education: Using Expert Wisdom and Research to Frame Educational Practice. *Education Sciences, 12*(10), 728. https://doi.org/10.3390/educsci12100728

Sugawara, M., Sekao, D., & Sibiya, M. R. (2026). Investigating learners' misconceptions on division of whole numbers to identify a goal of research lesson -- a case of lesson study. *International Electronic Journal of Mathematics Education, 21*(1), em0863. https://doi.org/10.29333/iejme/17700

Sukkamart, A., Chachiyo, W., Chachiyo, M., Pimdee, P., Moto, S., & Tansiri, P. (2025). Enhancing computational thinking skills in Thai middle school students through problem-based blended learning approaches. *Cogent Education, 12*(1). https://doi.org/10.1080/2331186X.2024.2445951

Sulaiman, T., Abdul Rahim, S. S., Wong, K., & Wan Jaafar, W. M. (2021). The Use of ``Scratch and Challenge Board'' as an Alternative Assessment Tool to Enhance University Students' Skills. *Asian Journal of University Education, 17*(3), 85. https://doi.org/10.24191/ajue.v17i3.14506

Sungur, S., & Ozkan, G. (2026). Coding Science: The Role of Block-Based Programming Activities in Enhancing Computational Thinking and Science Achievement. *Journal of Science Education and Technology*. https://doi.org/10.1007/s10956-026-10317-5

Wen, F.-H., Wu, T., & Hsu, W.-C. (2023). Toward improving student motivation and performance in introductory programming learning by Scratch: The role of achievement emotions. *Science Progress, 106*(4), 1--21. https://doi.org/10.1177/00368504231205985

Zhang, L., & Ma, Y. (2023). A study of the impact of project-based learning on student learning effects: a meta-analysis study. *Frontiers in Psychology, 14*(July), 1--14. https://doi.org/10.3389/fpsyg.2023.1202728

Zhang, W., Guan, Y., & Hu, Z. (2024). The efficacy of project-based learning in enhancing computational thinking among students: A meta-analysis of 31 experiments and quasi-experiments. *Education and Information Technologies, 29*(11), 14513--14545. https://doi.org/10.1007/s10639-023-12392-2