Interval: Indonesian Journal of Mathematical Education
Vol. 3, No. 2, December 2025, pp. 159~168
ISSN: 3021-7857, DOI: 10.37251/ijome.v3i2.2519

From Problems to Progress: Improving Mathematics Learning Outcomes through Problem-Solving Instruction

Minh Tuấn Nguyễn[1], and Bernard Alorgbey[2]
[1]Department of Mathematics, Vietnam National University, Hanoi, Vietnam
[2]Department of Mathematics, University of Education, Winneba, Ghana

Article Info

Article history:

Received Sep 15, 2025
Revised Oct 27, 2025
Accepted Nov 25, 2025
Online First Dec 27, 2025

Keywords:

Classroom Action Research
Student Engagement
Mathematics Education
Learning Outcomes
Problem-Solving

ABSTRACT

Purpose of the study: The aim of this research is to improve students' learning outcomes in Mathematics by using the Problem Solving method.

Methodology: The research conducted used Classroom Action Research. Data were obtained from qualitative and quantitative data. Data collection techniques included observation, testing, documentation, and interviews. The data analysis method used both qualitative and quantitative data.

Main Findings: Based on the results of data analysis, it is known that, after using the Problem Solving method, student learning outcomes have increased. This can be seen from the results of the pre-test and post-test given to students, which always increased in each cycle. The increase in student learning outcomes in cycle 1 was 71.88% and in cycle II 87.10%. There was an increase in the completeness of student learning outcomes by 5.31%.

Novelty/Originality of this study: This study introduces a structured problem-solving instructional model implemented through classroom action research to regularly improve students' mathematics learning outcomes. Unlike previous studies, it integrates iterative reflection cycles with authentic classroom problems, providing practical evidence on how problem-solving instruction directly enhances students' engagement, conceptual understanding, and achievement.

Corresponding Author:
Minh Tuấn Nguyễn,
Department of Mathematics, Vietnam National University, Hanoi, 144 Xuan Thuy Street, Cau Giay District
Hanoi 10000 Red River Delta, Vietnam
Email: mtnguyenntuan@gmail.com

1. INTRODUCTION

Mathematics education at the elementary school level plays a crucial role in building students' foundational numeracy, reasoning skills, and problem-solving abilities [1]-[3]. Early experiences in learning mathematics strongly influence students' attitudes and achievement in later educational stages [4]-[6]. Therefore, improving mathematics learning outcomes in elementary schools remains a global priority, particularly in developing countries striving to enhance the quality of basic education.

In many elementary classrooms in developing contexts, including Vietnam in Southeast Asia and Ghana in Sub-Saharan Africa, students often encounter difficulties in understanding basic mathematical concepts [7], [8]. These difficulties are frequently associated with instructional practices that emphasize procedural routines and teacher-centered explanations rather than active student participation [9]-[11]. Consequently, elementary students tend to struggle with applying mathematical knowledge to problem situations, which negatively affects their learning outcomes.

Several international and regional studies have emphasized the importance of problem-solving instruction as an effective approach in elementary mathematics learning [12]-[14]. Problem-solving-based instruction encourages students to explore mathematical ideas, reason logically, and construct solutions collaboratively [15], [16]. In elementary school settings, this approach is particularly valuable as it supports the development of conceptual understanding while fostering positive learning attitudes from an early age [17], [18].

Although problem-solving instruction has been widely discussed in the literature, its classroom implementation in elementary schools within developing countries remains underexplored [19], [20]. In Vietnam and Ghana, contextual challenges such as large class sizes, limited instructional resources, and diverse student abilities require adaptive teaching strategies [21], [22]. Many previous studies have not sufficiently addressed how problem-solving instruction can be continuously improved through reflective classroom practices.

Classroom action research offers a practical and systematic framework for implementing and refining instructional strategies in real classroom contexts [23], [24]. By engaging teachers in iterative cycles of planning, action, observation, and reflection, this approach allows instructional adjustments based on students' learning responses [25], [26]. However, empirical studies that integrate classroom action research with problem-solving instruction at the elementary level are still limited, particularly in cross-regional educational contexts [27], [28].

A collaborative perspective involving researchers from Vietnam and Ghana provides valuable insights into shared instructional challenges and effective pedagogical practices in elementary mathematics education [7], [29]. Despite differences in cultural and curricular backgrounds, both countries face similar issues related to students' low problem-solving abilities and learning outcomes in mathematics [30], [31]. Cross-context collaboration strengthens the generalizability and relevance of instructional findings.

The novelty of this research lies in the systematic integration of problem-solving instruction and a classroom action research approach in the context of elementary schools in developing countries. Unlike previous research, which generally examines the effectiveness of problem-solving experimentally or descriptively, this study emphasizes the process of continuous learning improvement through a detailed, documented reflective cycle. Furthermore, this study presents a cross-country collaborative perspective (Vietnam and Ghana) rarely explored in classroom action research, thus providing a new empirical contribution to how problem-solving instruction can be adapted and optimized in real-world classroom contexts with limited resources.

The urgency of this research is based on the persistently low mathematics learning outcomes and problem-solving abilities of elementary school students in various developing countries, including Vietnam and Ghana. This situation demands learning strategies that are not only theoretically effective but also applicable and sustainable in daily classroom practice. Without appropriate pedagogical interventions, difficulties in learning mathematics at an early level have the potential to persist into higher education. Therefore, this research is important because it offers practical evidence on how teachers can reflectively improve the quality of mathematics learning through problem-solving instruction, while also providing a learning model relevant to the elementary school context in educational environments with similar challenges.

Therefore, this study aims to improve elementary school students' mathematics learning outcomes through the implementation of problem-solving instruction using a classroom action research approach. By documenting instructional cycles and student progress, this study seeks to contribute practical evidence and pedagogical insights that can inform elementary mathematics teaching practices in Vietnam, Ghana, and other developing educational contexts.

2. RESEARCH METHOD

2.1. Research Subjects

The subjects of this study were third-grade elementary school students from a public elementary school in Vietnam, conducted in collaboration with researchers affiliated with institutions in Vietnam and Ghana. The class consisted of 32 students, comprising 20 male students and 12 female students. A total sampling technique was applied, in which all students in the class were included as research subjects, as the study employed a classroom action research design focused on improving mathematics instruction within a single classroom context [32], [33].

2.2. Research Procedures

This study employed a classroom action research design following the model proposed by Kemmis and McTaggart, which is widely used in international educational research [34], [35]. The research was conducted through two action cycles, with each cycle consisting of two instructional meetings. Each meeting lasted approximately 70 minutes, following the regular elementary school timetable. The intervention focused on the implementation of problem-solving instruction in mathematics. The research was conducted collaboratively, involving close cooperation between the researcher and the elementary mathematics teacher [36], [37]. Through this collaboration, instructional plans were discussed, implemented, and evaluated to improve the effectiveness of mathematics teaching and learning.

Each cycle followed four interconnected stages: planning, action, observation, and reflection. During the planning stage, lesson plans and problem-solving activities were designed. The action stage involved implementing the planned instruction in the classroom. Observation was conducted to collect data on students' learning activities and responses, while reflection was used to evaluate the outcomes of each cycle and determine necessary improvements for the subsequent cycle [38], [39]. This cyclical and reflective process allowed continuous refinement of instructional practices, ensuring that problem-solving instruction was systematically improved based on classroom evidence. The use of this internationally recognized action research model strengthens the methodological rigor and relevance of the study for broader educational contexts, including elementary schools in Vietnam, Ghana, and other developing countries. The research procedure can be seen in the following image:

Figure 1. Research Procedures

2.3. Data Collection Techniques

This study employed both qualitative and quantitative data to obtain a comprehensive understanding of the learning process and outcomes [40], [41]. Qualitative data were used to describe students' learning activities and classroom interactions, while quantitative data were used to measure students' mathematics learning outcomes. Observation was conducted to collect qualitative data related to students' participation, engagement, and problem-solving behaviors during mathematics lessons. Structured observation sheets were used to systematically record students' activities and the teacher's instructional practices throughout the implementation of problem-solving instruction.

Achievement tests were administered to collect quantitative data on students' mathematics learning outcomes. The tests consisted of problem-solving-based items designed to assess students' understanding and application of mathematical concepts. Students' performance was evaluated based on predetermined learning achievement criteria aligned with the school's mathematics standards. Document analysis was used to support and validate the collected data. Relevant documents included lesson plans, instructional materials, students' worksheets, attendance records, and samples of students' work. These documents provided additional evidence regarding the implementation process and students' learning progress. Interviews were conducted to gain deeper insights into the learning process and instructional challenges. Semi-structured interviews with the classroom teacher were used to explore perceptions of problem-solving instruction, students' responses, and obstacles encountered during implementation [42], [43]. Interview data complemented observational findings and contributed to the reflective stages of the action research cycles.

2.4. Research Instruments

The research instruments were designed to collect data aligned with the study objectives and to measure students' learning progress during the implementation of problem-solving instruction. Students' mathematics learning outcomes were assessed using a written achievement test consisting of five open-ended problem-solving items administered at the end of each action cycle [44], [45]. In Cycle I, the test focused on perimeter concepts of squares and rectangles, including calculation, strategy explanation, and figure construction. In Cycle II, the test emphasized area concepts, covering formula understanding, calculation, and comparison of areas. Each item was scored on a 0–20 scale, resulting in a maximum score of 100.

Observation instruments were used to collect qualitative data on students' learning activities and the teacher's instructional practices during mathematics lessons. A structured observation checklist was employed to document students' engagement, participation, and problem-solving behaviors, as well as the implementation of problem-solving instruction. These observation data supported the reflective analysis and informed instructional improvements across the action research cycles.

2.5. Data Analysis Techniques

Students' mathematics learning outcomes were analyzed using data obtained from achievement tests administered at the end of each action cycle. Both qualitative and quantitative data analysis techniques were employed to provide a comprehensive evaluation of the learning process and outcomes [40], [46]. Qualitative data analysis was used to examine students' learning activities during the implementation of problem-solving instruction. Observation data collected through structured observation sheets were analyzed descriptively to identify patterns of student engagement, participation, and problem-solving behavior. The results were summarized in the form of percentages to illustrate improvements in students' learning activities across cycles. Quantitative data analysis was conducted to evaluate students' mathematics learning outcomes. Students' test scores were analyzed by calculating descriptive statistics, including the mean score and the percentage of students achieving the expected learning criteria. These quantitative results were used to compare students' performance between cycles and to determine the effectiveness of problem-solving instruction in improving mathematics learning outcomes.

3. RESULTS AND DISCUSSION

This study employed a classroom action research design aimed at improving third-grade elementary school students' mathematics learning outcomes through the implementation of problem-solving instruction. The research was conducted in a public elementary school in Vietnam in collaboration with researchers from Vietnam and Ghana. The study was carried out in two action cycles, each consisting of two instructional meetings, with each meeting lasting approximately 70 minutes.

3.1. Results of Cycle I

Cycle I was conducted in two instructional meetings. The implementation of problem-solving instruction began with introductory activities to prepare students for learning, including reviewing prior knowledge and explaining the learning objectives. These activities helped students understand the focus of the lesson and created a structured learning environment. During the core learning activities, students were organized into small groups of four to engage in problem-solving tasks. The teacher presented mathematical problems related to calculating the perimeter of squares and rectangles and facilitated group discussions through guiding questions. Concrete learning materials, such as rulers, cardboard, and simple manipulatives, were used to support students' understanding of abstract concepts. Each group discussed possible solutions, and representatives presented their results to the class, followed by collective discussion and clarification. Individual worksheets were then assigned to assess students' understanding.

The closing activities focused on reflection and consolidation of learning. The teacher and students jointly reviewed the problem-solving process and summarized the key concepts learned. Feedback was provided to reinforce students' efforts and address misconceptions identified during the lesson [47], [48]. Observation results indicated that most students showed increased enthusiasm and engagement during problem-solving activities. Students were able to follow instructions and actively participate in group discussions. However, some students remained passive, were hesitant to ask questions, and lacked confidence in expressing their ideas. These findings were used as a basis for reflection, leading to instructional adjustments aimed at increasing student participation and confidence in the subsequent cycle.

The second meeting of Cycle I focused on strengthening students' problem-solving skills through more intensive collaborative learning. The lesson began with introductory activities, including a brief review of previous material and clarification of the learning objectives to ensure students' readiness for learning. During the core activities, students worked in pairs to solve mathematical problems related to drawing and constructing plane figures with a specified perimeter. This modification in group structure aimed to increase individual participation and encourage students to express their ideas more confidently. The teacher guided learning through probing questions and presented problem situations that required students to apply perimeter concepts. Students shared their solutions through class presentations, followed by joint evaluation and formulation of conclusions. Individual worksheets were then assigned to assess students' understanding.

The closing activities emphasized reflection and consolidation of learning. Feedback was provided to reinforce students' efforts and address remaining difficulties. Observation results indicated an improvement in students' engagement and confidence compared to the first meeting. Students were more active in discussions, more willing to ask questions, and more confident in presenting their solutions. However, a small number of students did not use the allotted time effectively and showed limited focus during presentations. At the end of Cycle I, a post-test was administered to evaluate students' learning outcomes following the implementation of problem-solving instruction. Assessment of student learning outcomes can be seen based on cycle I, by looking at the average scores from the pre-test and post-test given by the teacher to 32 third-grade students. Student learning outcome data can be seen in the table below:

Table 1. Student Learning Outcomes in Cycle I

No.	Indicator	Test Score	
		Pre-Test	Post-Test
1.	Average	60.31	73.44
2.	Lowest Score	41.00	58.00
3.	Highest Score	82.00	92.00
4.	Level of Completion	46.88%	75.00%

Based on Table 1, the results show an improvement in students' mathematics learning outcomes after the implementation of problem-solving instruction in Cycle I. The percentage of students achieving the learning completion criteria increased from 46.88% in the pre-test to 75.00% in the post-test. However, this result had not yet met the expected success indicator of 80%, indicating the need for further instructional improvement. Therefore, Cycle II was conducted to address the remaining learning difficulties and to optimize the effectiveness of the problem-solving approach.

Based on classroom observations in Cycle I, several challenges were identified. Some students were still passive during learning activities, showing limited participation in asking questions, expressing ideas, and engaging in problem-solving tasks. A few students demonstrated low collaboration during group discussions and did not use the allocated time effectively. In addition, off-task behavior was occasionally observed, and some students lacked confidence when presenting their group work. As a result, the level of learning completion had not yet reached the targeted criterion of 80%.

In response to these findings, several improvements were planned for Cycle II. Instructional explanations would be more closely connected to students' everyday experiences to enhance understanding and relevance. The teacher would provide stronger motivation and guidance, particularly to less active students, while improving classroom and time management. More intensive support would be given to discussion groups experiencing difficulties, and positive reinforcement, such as rewards and verbal encouragement, would be used to increase students' confidence and participation during problem-solving activities.

3.2. Results of Cycle II

Following the reflection of Cycle I, Cycle II was implemented using the same classroom action research framework, consisting of planning, action, observation, and reflection stages. This cycle was designed to address the challenges identified in the previous cycle and to optimize the implementation of problem-solving instruction. During the planning stage, instructional improvements were formulated based on the reflection results from Cycle I. These included strengthening the connection between mathematical concepts and real-life contexts, increasing student motivation and participation, and improving classroom and time management strategies.

The action stage focused on implementing these improvements in the classroom. The teacher provided more contextual explanations, actively encouraged less-participative students, and offered targeted guidance during group discussions, particularly for students experiencing difficulties in problem-solving tasks. Positive reinforcement, such as rewards and verbal encouragement, was used to enhance students' confidence and engagement. Cycle II was conducted in two instructional meetings, with a pre-test administered before the first meeting and a post-test administered after the second meeting to measure students' mathematics learning outcomes following the refined problem-solving instruction.

The first meeting of Cycle II was conducted to strengthen students' understanding of area concepts through refined problem-solving instruction. The lesson began with introductory activities aimed at preparing students for learning, including a review of prior knowledge and clarification of learning objectives. During the core learning activities, students worked collaboratively in small groups to solve problems related to understanding formulas and calculating the area of squares and rectangles. The teacher facilitated learning through guiding questions and the use of simple learning materials, such as grid paper and rulers, to support students' conceptual understanding. Group discussions were followed by class presentations, collective evaluation of solutions, and formulation of conclusions. Individual worksheets were then used to assess students' understanding.

The closing activities emphasized reflection and reinforcement of key concepts. Observation results showed that students demonstrated higher enthusiasm, confidence, and active participation compared to the previous cycle. Students were more willing to ask questions, express their ideas, and collaborate effectively in solving problems. The problem-solving approach helped students better understand how to identify, determine, and calculate the area of squares and rectangles.

The second meeting of Cycle II focused on enhancing students' abilities to compare and order the areas of squares and rectangles through problem-solving instruction. The lesson began with a brief review of previous material and clarification of learning objectives to ensure students' readiness for learning. During the core activities, students worked collaboratively in small groups to solve problems involving the comparison and ordering of areas. The teacher guided learning through probing questions and facilitated group discussions to encourage students to explain their reasoning. Students presented their solutions to the class, followed by collective evaluation and formulation of conclusions. Individual worksheets were then administered to assess students' understanding.

The closing activities emphasized reflection and reinforcement of key concepts. Observation results indicated that students demonstrated higher levels of active participation, confidence, and independence in problem-solving. Students were more willing to express ideas, respond to questions, and apply mathematical concepts effectively. At the end of the second meeting, a post-test was administered to evaluate improvements in students' mathematics learning outcomes following the implementation of problem-solving instruction. Student learning outcomes can be assessed based on cycle II, by looking at the average pre-test and post-test scores given by the teacher to 32 third-grade students. Student learning outcome data can be seen in the table below.

Table 2. Student Learning Outcomes in Cycle II

No.	Indicator	Test Score	
		Pre-Test	Post-Test
1.	Average	63.12	81.56
2.	Lowest Score	38.00	65.00
3.	Highest Score	85.00	95.00
4.	Level of Completion	68.75%	90.63%

Based on Table 2, students' mathematics learning outcomes showed a substantial improvement after the implementation of problem-solving instruction in Cycle II. The percentage of students achieving the learning completion criteria increased from 68.75% in the pre-test to 90.63% in the post-test. This result exceeded the targeted success indicator of 80%, indicating that the learning objectives had been achieved and the instructional improvements implemented in Cycle II were effective in enhancing students' mathematics learning outcomes.

Based on the results of the implementation of the actions in Cycle II, the application of the Problem Solving method was proven to significantly improve students' mathematics learning outcomes compared to Cycle I. Students demonstrated a better understanding of determining, calculating, and drawing the perimeter and area of squares and rectangles. Furthermore, student engagement in the learning process increased, as evidenced by active participation in discussions, expressing opinions, and solving the assigned problems.

The application of the Problem Solving method also encouraged students to be more creative in developing ideas and problem-solving strategies [49], [50]. Student learning outcomes at the end of Cycle II met and exceeded the established mastery targets. Therefore, it is recommended that teachers consistently link learning materials to everyday life contexts to maintain and improve the quality of mathematics learning in the classroom.

The application of problem-solving-based learning in this study demonstrated that this approach can create a more meaningful learning environment for elementary school students [51], [52]. Learning activities that position students as problem solvers encourage active thinking processes, where students not only receive information but also construct understanding through discussion, exploration, and reflection. The use of contextual problems and concrete media helps bridge abstract mathematical concepts with students' real-life experiences, facilitating the internalization of the concepts of perimeter and area of geometric shapes.

Improvements in learning strategies in Cycle II demonstrated that successful problem-solving is significantly influenced by the quality of teacher facilitation. Increased motivation, more effective time management, and more intensive guidance for students experiencing difficulties contributed to increased student participation and confidence. Changes in learning grouping and the provision of positive reinforcement also played a crucial role in creating a more conducive, collaborative, and inclusive learning environment, allowing students to feel safe expressing ideas and exploring various problem-solving strategies.

In addition to impacting cognitive aspects, problem-solving learning also positively contributes to the development of students' attitudes and social skills. Students become more active, creative, and independent in addressing mathematical problems, and demonstrate improved collaboration and communication skills [53], [54]. These findings confirm that mathematics learning is not solely oriented toward achieving final results, but also toward developing thinking processes and learning attitudes. Therefore, integrating problem-solving learning with everyday contexts is recommended as an effective strategy for improving the quality of mathematics learning in elementary schools.

Improved mathematics learning outcomes are not solely driven by the use of problem-solving methods, but also by the quality of the reflection process and continuous learning improvement through classroom action research. Each cycle provides teachers with the opportunity to analyze student responses, identify learning barriers, and adapt learning strategies contextually. These findings align with the view that effective learning at the elementary school level requires pedagogical flexibility and responsiveness to student learning needs, particularly in developing mathematical problem-solving skills.

From a constructivist perspective, the results of this study reinforce the assumption that mathematical knowledge is actively constructed by students through interactions with problems, peers, and the learning environment [55], [56]. Group discussions, presentations of problem-solving results, and collaborative reflection encourage students to construct meaningful conceptual understanding, rather than simply memorizing procedures. This supports previous research findings that problem-based learning can improve elementary school students' conceptual understanding and higher-order thinking skills.

In addition to cognitive aspects, problem-solving learning in this study also positively impacted students' affective and social aspects. Increased self-confidence, courage to express opinions, and the ability to work collaboratively in groups demonstrate that a student-centered mathematics learning process can create a more inclusive and participatory classroom climate [57], [58]. This condition is crucial in the context of elementary education, as a positive attitude toward mathematics in the early stages plays a significant role in learning success at subsequent levels.

Improved learning strategies in Cycle II confirmed that the teacher's role as a facilitator is crucial to the success of problem-solving instruction. Motivation, positive reinforcement, more effective time management, and the use of everyday contexts have been shown to help students connect mathematical concepts to real-life experiences. These findings confirm that problem-solving learning is inseparable from the quality of scaffolding provided by teachers, especially for students who still experience learning difficulties.

In the context of developing countries such as Vietnam and Ghana, the results of this study have important practical implications. Limited learning facilities and infrastructure are not a major obstacle as long as teachers are able to design problem-solving activities that are relevant, simple, and contextual. Therefore, this study strengthens the argument that pedagogical innovation based on classroom reflection can be a realistic and sustainable solution to improve the quality of mathematics learning in elementary schools.

Overall, this discussion demonstrates that the integration of problem-solving instruction and classroom action research is not only effective in improving mathematics learning outcomes but also contributes to the development of students' thinking processes, learning attitudes, and social skills [59], [60]. Thus, this approach is worth recommending as an adaptive and contextual mathematics learning strategy, especially at the elementary education level in educational environments with similar challenges.

This research has practical and theoretical implications for the development of mathematics learning in elementary schools. Practically, the research findings demonstrate that the application of problem-solving instruction combined with classroom action research can be an effective, adaptive, and easily implemented learning model by teachers in real classroom contexts. This model helps teachers not only improve student learning outcomes but also improve the quality of the learning process through continuous reflection. Theoretically, this research strengthens the foundation of constructivism in mathematics education by demonstrating that students' active involvement in problem-solving, discussion, and reflection directly contributes to their conceptual understanding, positive attitudes, and thinking skills. Furthermore, the cross-national collaborative perspective (Vietnam–Ghana) broadens the relevance of the findings and opens up opportunities for adopting similar approaches in other developing country elementary education contexts.

This study has several limitations, including the fact that it involved only one class with a limited number of subjects and the relatively short duration of the study, which means it cannot yet describe the long-term impact of implementing problem-solving learning. Furthermore, the study did not analyze in-depth differences in individual student characteristics that could potentially influence learning outcomes.

4. CONCLUSION

Based on the results of the classroom action research conducted, it can be concluded that the application of the Problem Solving method can improve student learning outcomes in Mathematics. Through problem-centered learning, students become more active in the learning process, better understand the mathematical concepts they are learning, and are able to apply this knowledge to solve problems. The improvement in student learning outcomes was evident after continuous learning improvements were implemented through two action cycles. The Problem Solving method not only improves cognitive learning outcomes but also encourages student engagement, self-confidence, and critical thinking skills in Mathematics learning. Thus, the research objective of improving student Mathematics learning outcomes through the use of the Problem Solving method has been achieved.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the principal, teachers, and third-grade students of the public elementary school in Vietnam who willingly participated in this study. Their cooperation and enthusiasm greatly contributed to the successful implementation of this classroom action research. Special appreciation is also extended to fellow researchers and academic colleagues from Vietnam and Ghana for their valuable collaboration, guidance, and constructive feedback throughout the research process. Finally, the authors would like to thank all parties who provided support, assistance, and encouragement, both directly and indirectly, in completing this study. Future research is recommended to apply classroom action research-based problem-solving learning to a wider range of school contexts, levels, and subjects to increase the generalizability of the findings. Furthermore, future research could explore the long-term impact of this approach on higher-order thinking skills, attitudes toward mathematics, and differences in individual student characteristics.

REFERENCES

[1] W. Chen, "Problem-Solving Skills, Memory Power, and Early Childhood Mathematics: Understanding the Significance of the Early Childhood Mathematics in an Individual's Life," *J. Knowl. Econ.*, vol. 16, no. 1, pp. 1–25, Jan. 2024, doi: 10.1007/s13132-023-01557-6.

[2] R. C. Torres-Peña, D. Peña-González, J. L. Lara-Orozco, E. A. Ariza, and D. Vergara, "Enhancing Numerical Thinking Through Problem Solving: A Teaching Experience for Third-Grade Mathematics," *Educ. Sci.*, vol. 15, no. 6, pp. 1–27, 2025, doi: 10.3390/educsci15060667.
[3] H. S. Iswara, F. Ahmadi, and D. Da Ary, "Numeracy Literacy Skills of Elementary School Students through Ethnomathematics-Based Problem Solving," *Interdiscip. Soc. Stud.*, vol. 2, no. 2, pp. 1604–1616, 2022, doi: 10.55324/iss.v2i2.316.
[4] S. Hwang and T. Son, "Students' attitude toward mathematics and its relationship with mathematics achievement," *J. Educ. e-Learning Res.*, vol. 8, no. 3, pp. 272–280, 2021, doi: 10.20448/JOURNAL.509.2021.83.272.280.
[5] R. Wen and A. K. Dubé, "A Systematic Review of Secondary Students' Attitudes Towards Mathematics and its Relations With Mathematics Achievement," *J. Numer. Cogn.*, vol. 8, no. 2, pp. 295–325, 2022, doi: 10.5964/jnc.7937.
[6] I. Chang, "Early numeracy and literacy skills and their influences on fourth-grade mathematics achievement: a moderated mediation model," *Large-Scale Assessments Educ.*, vol. 11, no. 1, pp. 1–22, 2023, doi: 10.1186/s40536-023-00168-6.
[7] B. C. Agbata, S. Abraham, A.-M. F, P. A. Kwabi, S. O. Okpako, and S. S. Arivi, "Advancing Mathematics Education Challenges , Strategies , and Prospects in Africa :," *Sci. World J.*, vol. 19, no. 3, pp. 808–818, 2024.
[8] J. Dadzie, R. Keziah Anaan-Brew, E. Danso, and A. Strzelecki, "Gamification in Ghanaian mathematics classrooms: Examining the roles of teacher knowledge, motivation, and self-Efficacy on student engagement," *Am. J. STEM Educ.*, vol. 15, pp. 45–86, 2025, [Online]. Available: https://ojed.org/STEM/article/view/8164
[9] L. Zhang, J. D. Basham, R. A. Carter, and J. Zhang, "Exploring Factors associated with the implementation of student-centered instructional practices in U.S. classroomss," *Teach. Teach. Educ.*, vol. 99, p. 103273, 2021, doi: 10.1016/j.tate.2020.103273.
[10] N. Ramos-Vallecillo, V. Murillo-Ligorred, and R. Lozano-Blasco, "University Students' Achievement of Meaningful Learning through Participation in Thinking Routines," *Eur. J. Investig. Heal. Psychol. Educ.*, vol. 14, no. 4, pp. 1012–1027, 2024, doi: 10.3390/ejihpe14040066.
[11] M. Treve, "Comparative analysis of teacher-centered and student-centered learning in the context of higher education: A co-word analysis," *Iberoam. J. Sci. Meas. Commun.*, vol. 4, no. 2, pp. 1–12, 2024, doi: 10.47909/ijsmc.117.
[12] E. Susanti, "Enhancing Problem-Solving Skills in Elemtary Students Through Realistic mathematics Education," *Sci. J. Inov. Pendidik. Mat. dan IPA*, vol. 5, no. 1, pp. 48–59, 2025.
[13] M. Suseelan, C. M. Chew, and H. Chin, "Research on Mathematics Problem Solving in Elementary Education Conducted from 1969 to 2021: A Bibliometric Review," *Int. J. Educ. Math. Sci. Technol.*, vol. 10, no. 4, pp. 1003–1029, Aug. 2022, doi: 10.46328/ijemst.2198.
[14] J. L. Piñeiro, E. Castro-Rodríguez, and E. Castro, "What problem-solving knowledge is required in mathematical teaching? A curricular approach," *Curric. Perspect.*, vol. 42, no. 1, pp. 1–12, Apr. 2022, doi: 10.1007/s41297-021-00152-6.
[15] J. Park, "Pre-Service Teachers' Project-Based Instruction with Mathematics Problem-Solving," *Educ. Sci.*, vol. 12, no. 8, pp. 1–12, 2022, doi: 10.3390/educsci12080526.
[16] E. Ampadu, M. Narh-Kert, and R. Yeboah, "Teachers', Researchers', and Educators' Partnerships: The Effect of Co-Creation on Pupils' Problem-Solving Performance in Mathematics," *Educ. Sci.*, vol. 14, no. 12, p. 1328, Dec. 2024, doi: 10.3390/educsci14121328.
[17] S. Prediger, J. Dröse, R. Stahnke, and C. Ademmer, "Teacher expertise for fostering at-risk students' understanding of basic concepts: conceptual model and evidence for growth," *J. Math. Teach. Educ.*, vol. 26, no. 4, pp. 481–508, Aug. 2023, doi: 10.1007/s10857-022-09538-3.
[18] J. Su and W. Yang, "AI literacy curriculum and its relation to children's perceptions of robots and attitudes towards engineering and science: An intervention study in early childhood education," *J. Comput. Assist. Learn.*, vol. 40, no. 1, pp. 241–253, Feb. 2024, doi: 10.1111/jcal.12867.
[19] F. I. L. Pinar, A. A. E. Panergayo, R. R. Sagcal, D. P. Acut, L. S. Roleda, and M. S. Prudente, "Fostering scientific creativity in science education through scientific problem-solving approaches and STEM contexts: a meta-analysis," *Discip. Interdiscip. Sci. Educ. Res.*, vol. 7, no. 1, pp. 1–17, 2025, doi: 10.1186/s43031-025-00137-9.
[20] E. Gradini, F. B. Firmansyah B, J. Noviani, and K. Ulya, "Fostering Higher-Order Thinking Skills in Mathematics Education: Strategies, Challenges, and Classroom Practices," *Prism. Sains J. Pengkaj. Ilmu dan Pembelajaran Mat. dan IPA IKIP Mataram*, vol. 13, no. 2, pp. 135–163, 2025, doi: 10.33394/j-ps.v13i2.15099.
[21] T. T. H. Duong, T. T. H. Nguyen, and T. M. Hoang, "Exploring Teachers' Perspectives on Adaptive Learning in Undergraduate Programs, Vietnam National University, Hanoi," *Int. J. TESOL Educ.*, vol. 4, no. 3, pp. 110–129, Aug. 2024, doi: 10.54855/ijte.24437.
[22] Y. Ofosu-Asare, "Developing classroom ICT teaching techniques, principles and practice for teachers in rural Ghana without access to computers or internet: a framework based on literature review," *Int. J. Inf. Learn. Technol.*, vol. 41, no. 3, pp. 262–279, Jun. 2024, doi: 10.1108/IJILT-04-2023-0045.
[23] S. Darwin and M. Barahona, "Making research (more) real for future teachers: a classroom-based research model for initial teacher education," *Educ. Action Res.*, vol. 31, no. 4, pp. 745–761, Aug. 2023, doi: 10.1080/09650792.2021.1980073.
[24] O. V. Barna, O. H. Kuzminska, and S. O. Semerikov, "Enhancing digital competence through STEM-integrated universal design for learning: a pedagogical framework for computer science education in Ukrainian secondary schools," *Discov. Educ.*, vol. 4, no. 1, p. 357, Sep. 2025, doi: 10.1007/s44217-025-00821-y.
[25] T. Rabgay and G. Kidman, "Multiple iterations and messiness in the implementation of action research by Bhutanese secondary science teachers," *Discov. Educ.*, vol. 2, no. 1, pp. 1–12, 2023, doi: 10.1007/s44217-023-00077-4.
[26] M. Muslimin, "Enhancing Teachers' Competence in Developing Lesson Plans through Continuous Guidance: A School Action Research," *Didakt. J. Kependidikan*, vol. 17, no. 1, pp. 83–98, Aug. 2023, doi: 10.30863/didaktika.v17i1.5099.
[27] M. G. R. Lugo, "Enhancing technology research capacity in technical-vocational education: a participatory action

research study of faculty development in Davao Oriental, Philippines," *Discov. Educ.*, vol. 4, no. 1, p. 509, Nov. 2025, doi: 10.1007/s44217-025-00959-9.

[28] T. Musengimana, L. L. Yadav, J. Uwamahoro, and G. Nizeyimana, "Instructional strategies for enhancing students' problem-solving skills in physics: a systematic review," *Discov. Educ.*, vol. 4, no. 1, p. 380, Sep. 2025, doi: 10.1007/s44217-025-00733-x.

[29] T. T. Le, T. T. Pham, and T. T. Tran, "Exploring the Impact of Lesson Study in Vietnamese Primary Education: Perspectives of EFL Lecturers," *J. Innov. Res. Prim. Educ.*, vol. 3, no. 1, pp. 21–30, Mar. 2024, doi: 10.56916/jirpe.v3i1.583.

[30] D. Olivares, J. L. Lupiáñez, and I. Segovia, "Roles and characteristics of problem solving in the mathematics curriculum: a review," *Int. J. Math. Educ. Sci. Technol.*, vol. 52, no. 7, pp. 1079–1096, Aug. 2021, doi: 10.1080/0020739X.2020.1738579.

[31] F. Borgonovi, S. W. Han, and S. Greiff, "Gender differences in collaborative problem-solving skills in a cross-country perspective.," *J. Educ. Psychol.*, vol. 115, no. 5, pp. 747–766, Jul. 2023, doi: 10.1037/edu0000788.

[32] M. A. Adeoye, "Review of Sampling Techniques for Education," *ASEAN J. Sci. Educ.*, vol. 2, no. 2, pp. 87–94, 2023, [Online]. Available: https://ejournal.bumipublikasinusantara.id/index.php/ajsed

[33] F. Mulisa, "Sampling techniques involving human subjects: Applications, pitfalls, and suggestions for further studies," *Int. J. Acad. Res. Educ.*, vol. 8, no. 1, pp. 74–83, Dec. 2022, doi: 10.17985/ijare.1225214.

[34] A. Yundayani and F. Alghadari, "Reframing multifaceted roles of teachers through developing educational research method design: design-based classroom action research," *Int. J. Math. Sci. Educ.*, vol. 2, no. 2, pp. 60–81, Dec. 2024, doi: 10.59965/ijmsed.v2i2.134.

[35] K. Ahmed, A. Sharif, S. Perween, and A. Akram, "Implementing Improvisation Techniques to Teach Spoken English at Undergraduate Level: A Classroom Action Research," *Int. J. Linguist. Cult.*, vol. 4, no. 2, pp. 347–362, Jan. 2024, doi: 10.52700/ijlc.v4i2.209.

[36] C. Qi, C. Cao, and R. Huang, "Teacher Learning Through Collaboration Between Teachers and Researchers: a Case Study in China," *Int. J. Sci. Math. Educ.*, vol. 21, no. 1, pp. 93–112, Jan. 2023, doi: 10.1007/s10763-021-10241-7.

[37] O. A. Saka, "Can Teacher Collaboration Improve Students' Academic Achievement in Junior Secondary Mathematics?," *Asian J. Univ. Educ.*, vol. 17, no. 1, pp. 33–46, Mar. 2021, doi: 10.24191/ajue.v17i1.8727.

[38] E. Evendi and N. N. S. P. Verawati, "Evaluation of Student Learning Outcomes in Problem-Based Learning: Study of Its Implementation and Reflection of Successful Factors," *J. Penelit. Pendidik. IPA*, vol. 7, no. SpecialIssue, pp. 69–76, Nov. 2021, doi: 10.29303/jppipa.v7iSpecialIssue.1099.

[39] I. Azizah and D. Mardiana, "Learning Transformation: Increasing Student Achievement through Discovery Learning," *Dirasah Int. J. Islam. Stud.*, vol. 2, no. 2, pp. 155–166, Oct. 2024, doi: 10.59373/drs.v2i2.42.

[40] P. Rana, M. K. Dubey, L. R. Gupta, and A. K. Thakur, "A model to combine qualitative and quantitative measures in education for better assessment of learning outcomes," *Interact. Learn. Environ.*, vol. 32, no. 10, pp. 5947–5977, Nov. 2024, doi: 10.1080/10494820.2023.2243291.

[41] D. Harefa, M. Sarumaha, K. Telaumbanua, T. Telaumbanua, B. Laia, and F. Hulu, "Relationship Student Learning Interest To The Learning Outcomes Of Natural Sciences," *Int. J. Educ. Res. Soc. Sci.*, vol. 4, no. 2, pp. 240–246, 2023, doi: 10.51601/ijersc.v4i2.614.

[42] A. K. Melaku, A. Y. Ali, and T. M. Tesfaye, "Teachers' and students' perception, practices, and challenges of active learning strategy utilization in primary schools of North Wollo Zone, Ethiopia," *Smart Learn. Environ.*, vol. 12, no. 1, p. 51, Aug. 2025, doi: 10.1186/s40561-025-00391-4.

[43] S. Feng and D. Yang, "Teachers' Perceived Value, Challenges, and Advice for Implementing Computational Thinking in Elementary Classrooms," *J. Technol. Teach. Educ.*, vol. 30, no. 3, pp. 293–320, 2022, doi: 10.70725/048319epkkuu.

[44] G. C. Bayarcal and D. A. Tan, "Students' Achievement and Problem-Solving Skills in Mathematics through Open-Ended Approach," *Am. J. Educ. Res. Vol. 11, 2023, Pages 183-190*, vol. 11, no. 4, pp. 183–190, 2023, doi: 10.12691/education-11-4-2.

[45] S. Rahayuningsih, S. Sirajuddin, and M. Ikram, "Using Open-ended Problem-solving Tests to Identify Students' Mathematical Creative Thinking Ability," *Particip. Educ. Res.*, vol. 8, no. 3, pp. 285–299, Aug. 2021, doi: 10.17275/per.21.66.8.3.

[46] A. Alam, "Mapping a Sustainable Future Through Conceptualization of Transformative Learning Framework, Education for Sustainable Development, Critical Reflection, and Responsible Citizenship: An Exploration of Pedagogies for Twenty-First Century Learning," *ECS Trans.*, vol. 107, no. 1, pp. 9827–9840, Apr. 2022, doi: 10.1149/10701.9827ecst.

[47] M. Qorib, "Analysis the Impact of Differentiated Instruction on Critical Diversity Literacy in Inclusive Education," *Aksaqila Int. Humanit. Soc. Sci. [AIHSS] J.*, vol. 3, no. 1, pp. 1–19, 2024, doi: 10.30596/aihss.v3i1.502.

[48] F. Almasri, "Exploring the Impact of Artificial Intelligence in Teaching and Learning of Science: A Systematic Review of Empirical Research," *Res. Sci. Educ.*, vol. 54, no. 5, pp. 977–997, Oct. 2024, doi: 10.1007/s11165-024-10176-3.

[49] M. P. Simanjuntak, J. Hutahaean, N. Marpaung, and D. Ramadhani, "Effectiveness of problem-based learning combined with computer simulation on students' problem-solving and creative thinking skills," *Int. J. Instr.*, vol. 14, no. 3, pp. 519–534, 2021, doi: 10.29333/iji.2021.14330a.

[50] J. Nilimaa, "New Examination Approach for Real-World Creativity and Problem-Solving Skills in Mathematics," *Trends High. Educ.*, vol. 2, no. 3, pp. 477–495, 2023, doi: 10.3390/higheredu2030028.

[51] S. Salwi, A. Wahid, and J. N, "Effectiveness Of Problem Solving Based Learning Model In The 21st Century In Improving Creativity and Science Learning Outcomes Of Grade IV Students," *ALENA J. Elem. Educ.*, vol. 3, no. 2, pp. 245–256, Jul. 2025, doi: 10.59638/jee.v3i2.414.

[52] M. Mukhlisin, M. S. Alayubi, Bintang Zein Al-Hazmi, and A. Hayani, "Increasing Cognitive Abilities Through Problem Solving-Based Learning," *Akhlaqul Karimah J. Pendidik. Agama Islam*, vol. 3, no. 01, pp. 13–18, Apr. 2024, doi: 10.58353/jak.v3i01.153.

[53] M. Masjudin, “Strengthening 21st Century Skills Through an Independent Curriculum in Mathematics Education in Indonesia: Challenges, Potential, And Strategies,” *Int. J. Appl. Sci. Sustain. Dev.*, vol. 6, no. 2, pp. 92–113, Oct. 2024, doi: 10.36733/ijassd.v6i2.9087.

[54] D. Mariani, M. Mustaji, and U. Dewi, “Literature Study: The Effect of The Problem-Based Learning Model Assisted by The Flipped Classroom on Mathematical Creative Thinking Ability,” *J. Pendidik. Indones.*, vol. 6, no. 1, Jan. 2025, doi: 10.59141/japendi.v6i1.6668.

[55] Y. Zhu, A. Nankhantee, and N. Jantharajit, “An Experimental Study on Improving First-Grade Students’ Mathematical Learning Achievement and Social Awareness Through an Instructional Approach Based on Constructivist Theory and Collaborative Learning,” *High. Educ. Stud.*, vol. 14, no. 3, p. 1, 2024, doi: 10.5539/hes.v14n3p1.

[56] E. Oppong-Gyebi, E. Bonyah, and L. J. Clark, “Constructive instructional teaching and learning approaches and their mathematical classroom teaching practices: A junior high school perspective,” *Contemp. Math. Sci. Educ.*, vol. 4, no. 1, p. ep23002, Jan. 2023, doi: 10.30935/conmaths/12541.

[57] N. Che Mat and K. A. Jamaludin, “Effectiveness of Practices and Applications of Student-Centered Teaching and Learning in Primary Schools: A Systematic Literature Review,” *Int. J. Acad. Res. Progress. Educ. Dev.*, vol. 13, no. 3, Jun. 2024, doi: 10.6007/IJARPED/v13-i3/21733.

[58] M. Arafah, S. Rijal, S. Sumarni, S. Satar, and B. Sulfiana, “The Study of Constructivistic Learning Experience, Democratic Attitude, Learning Independence & Learning Motivation of Senior High School Students at Wajo Regency South Sulawesi,” *J. Iqra’ Kaji. Ilmu Pendidik.*, vol. 10, no. 1, pp. 213–227, May 2025, doi: 10.25217/ji.v10i1.4905.

[59] C. Choirudin, M. Lubis, and M. A. Masuwd, “Enhancing High School Students’ Mathematical Problem-Solving Skills through Interactive Media: A Classroom Action Research Approach,” *J. Teach. Learn. Math.*, vol. 2, no. 2, pp. 104–121, Jan. 2025, doi: 10.22219/jtlm.v2i2.31685.

[60] S. Dolapcioglu and A. Doğanay, “Development of critical thinking in mathematics classes via authentic learning: an action research,” *Int. J. Math. Educ. Sci. Technol.*, vol. 53, no. 6, pp. 1363–1386, Jun. 2022, doi: 10.1080/0020739X.2020.1819573.