Improve Problem-Solving Ability through Implementation of Problem-Based Learning Based on Self-Regulation

Helfra Durasa[1*)], Ni Made Sri Mertasari[2], I Gusti Ngurah Pujawan[3]
[1,2,3] Universitas Pendidikan Ganesha
*) helfradurasa920@gmail.com

Abstract
This research is motivated by the crucial role of mathematics in human development and the significant challenges faced in mathematics education. The research problem is the low quality of mathematics learning outcomes and the need to improve PSA and self-regulation among students. The study aimed to improve students' Problem-Solving Ability (PSA) by implementing Problem-Based Learning (PBL) based on their level of self-regulation. The research design is quantitative quasi-experimental research using a 2 x 2 factorial-level design. The population is 430 seventh-grade students from 1st State High School 1 Langke Rembong. Data analysis using a two-way ANOVA. The results showed that PBL had a positive impact on PSA. In addition, the interaction between learning models and self-regulation significantly affects PSA. These findings have implications for classroom practice, proving the importance of applying PBL to improve PSA and the need to develop student self-regulation. The research also highlights the importance of collaboration between PBL and conventional teaching to improve student learning outcomes in mathematics.
Keywords: problem-based learning, problem-solving, self-regulation, math education

Introduction

Mathematics plays a vital part in human development (Yadav, 2019). Mathematics is a scientific discipline that forms logical and critical thinking, abstract thinking skills, and the ability to count (Cresswell & Speelman, 2020). Thanheiser explains the meaning of mathematics in three frames, namely: 1) mathematics as abstract knowledge or ideas organized into systems and structures and a set of methods for reasoning; 2) mathematics as contextual knowledge for understanding the world; and 3) mathematics as a human action, part of a self-identity (Thanheiser, 2023). Therefore, mathematics learning aims to enable humans to understand mathematical concepts, think logically, analytically, and creatively in finding solutions to mathematical problems, and communicate mathematical concepts, methods, and reasoning to others (NCTM, 2000). Polya presents four problem-solving phases: understanding the problem, creating strategies, implementing strategies, and drawing conclusions (Polya, 1973).

In addition, self-regulation affects problem-solving. Self-regulation is a person's effort to manage learning goals, improve strategies, achieve learning goals, and increase learning motivation (Zimmerman & Kitsantas, 2014). Self-regulation can improve students' motivation and metacognition and help them find new ideas to achieve academic achievement (Hidajat, 2023). Self-regulation also plays an active role in unstructured problem-solving in PBL (Ge et al., 2016). The application of PBL is based on its ability to enhance cognitive abilities, stimulate cognitive independence, increase motivation for independent learning, and promote interdisciplinary connections, fostering a more profound understanding and application of practical knowledge (Garanina, 2020). In addition, applying PBL encourages students to enhance higher-order thinking, active engagement, real-world connections, and interdisciplinary learning by being based on unstructured problems (Rehmat et al., 2022). Thus, the successful application of PBL is determined mainly by the student's responsibility for the learning task by maintaining motivation, setting goals, monitoring progress, and actively engaging in self-evaluation (English & Kitsantas, 2013).

However, the quality of learning outcomes is still inferior, and significant effort is required until most learning outcomes can achieve internationally accepted best practices (Schoepp, 2019), especially in problem-solving. Students experience difficulties solving math problems due to an inability to understand basic mathematics (Karimah et al., 2018), (Amalina & Vidákovich, 2023). Students' low mathematical PSA tends to lead to cognitive problems, such as computation (calculation), fact retrieval, number notions (quantity processing, quantity-number linkages, numerical relationships, and visual-spatial short-term storage (Haberstroh & Schulte-Körne, 2022). Students experience difficulties in solving math problems caused by several factors, including students' innate cognitive abilities, processes and procedures used to solve math problems, and external factors such as teacher intervention and contextual material (Waswa & Al-kassab, 2023; Chirimbana et al., 2022). Ineffective problem-solving is also caused by factors (Plotnik & Kouyoumdjian, 2010), such as: 1) students tend to make decisions in problem-solving without looking at the overall complexity of the problem; 2) students tend to be satisfied with existing problem-solving solutions or get stuck in a routine without thinking of other, more optimal solutions; 3) Students tend to make decisions in problem-solving based on explanations that come first in their minds (direct answers) without making confirming, careful analysis of situations beyond direct responses. Therefore, students should develop alternative ideas rather than utilizing the first idea as a solution; 4) Students tend to be unable to see problems from new angles. The initial perception in structuring a problem often determines the approach students use to solve the problem. Incorrect structuring of the problem is a major cause of the inability to resolve the problem correctly; 5) Students tend to solve problems based on personal beliefs, without looking at a problem objectively with all accurate information and using objective reasoning to reach a reasonable decision.

Some researchers have previously examined various problem-solving improvement strategies, such as reducing mathematical anxiety (Samuel & Warner, 2021), the application of Learning Cycle 7E, and self-regulation (Mulyono & Noor, 2016), included in online learning (Hendarwati et al., 2021). Applying an inquiry learning model combined with an advanced organizer can improve problem-solving skills (Gunawan et al., 2020). Various analyses of PSA have been examined, such as in integer matter (Sipayung & Anzelina, 2019) and trigonometry in terms of self-regulation (Fahrudin et al., 2019).

Departing from the above problems, researchers try implementing a PBL model and self-regulation in learning. In PBL, students become the center of learning by finding solutions to real problems (Wulandari & Shofiyah, 2018). Therefore, teacher competence determines the quality of learning (Yang & Kaiser, 2022) so that students can understand mathematical material and improve their study skills (Septian et al., 2021). Implementation Experiments using syntax-type PBL It is divided into the following five stages: 1) organizing students into problem-solving scenarios; 2) organizing students into collaborative learning groups; 3) facilitating independent and group inquiry; 4) creating and presenting projects; and 5) assessing the analysis and evaluation of the problem-solving process (Arends, 2008). Implementing experiments using this syntax is based on previous findings that the ability to understand Mathematics concepts is positively influenced by using PBL tools (Boye & Agyei, 2023).

This study has substantial differences from previous studies. This research focuses on how the application of PBL improves mathematical problem-solving skills based on student learning independence with a focus on quadrilateral and triangular material. This research is essential because the PBL model involves student activeness in solving problems and requires robust self-regulation to support student activeness in developing the skills needed for lifelong learning. This study also compared differences in PSA caused by treatment in each self-regulation and did not compare high and low levels in each group of learning models because they were rated high and low, which is not worth appealing. This study aims to improve students' PSA by applying PBL models based on their level of self-regulation.

Method

This study is a quasi-experimental quantitative research type with a factorial design at level 2 x 2. The study was a posttest-only control group design (Candiasa, 2019).

Table 1. Matrix treatment by level 2x2

B	(A)	
	A_1	A_2
B_1	A_1B_1	A_2B_1
B_2	A_1B_2	A_2B_2

Information:
A : Learning Models
B : Self-Regulation
A1 : PBL class
A2 : Conventional Class
B1 : High Self-Regulation
B2 : Low Self-Regulation
A1B1 : group of students with high self-regulation in PBL classes
A1B2 : group of students with low self-regulation in PBL classes
A2B1 : group of students with high self-regulation in conventional classes
A2B2 : group of students with low self-regulation in conventional classes

This study involved 430 grade VII students at 1st State High School 1 Langke Rembong, Manggarai Regency, East Nusa Tenggara spread across 12 classes and had class equality based on one-way ANOVA analysis. Determination of research samples from the treatment group using random sampling techniques. As a result, two classes were designated as experimental groups, namely class VIIA (36 students) and class VIIC (35 students); while two classes in the control group, namely class VIID (36 students) and class VIIE (35 students), so that a total of 71 students were obtained in each group. Each treatment group is divided into two more groups of students: high self-regulation as the upper group and low self-regulation as the lower group. The determination of this category sample departs from Roscoe's thinking that experimental research samples are needed to take a sample of 15-30 respondents per group (Borg et al., 2007). On that basis, the determination of the upper group is carried out by taking 33% of all students based on the order of grades from the largest. In comparison, the bottom group is determined by taking 33% of all students based on the order of grades from the smallest. The results were obtained by 24 students in each treatment group.

This research procedure uses the following stages: 1) Initial activities, including selection of research populations, data collection of general mathematics test results for odd semesters of the 2021-2022 academic year, testing equality of ability between classes, determining treatment classes, preparing research instruments, such as math PSA description questions, self-regulation questionnaires, preparing lesson implementation plans, student worksheets and evaluation rubrics, and tests. Experiment with research instruments, apply instrument validation, and discuss with the experimental teacher. 2) Experimental activities and data collection: Experiments are conducted by local mathematics subject teachers, test conduct, and research data collection. 3) The final stage includes checking the result sheet, tabulating data, conducting prerequisite tests, testing research hypotheses, and making research reports.

The experiment procedure uses the PBL model in the experimental class and continues to use the earlier learning model in the control class. The meeting time allocation is 12 meetings with details of line and angle material meetings for 6 lesson hours and quadrilateral and triangular material for six lessons adjusted to mathematics lesson hours. Implementing this experiment controls the changes in students' attitudes very tightly. Internal validity control like this can be done by the way the researcher does not directly go into the field to supply learning in the classroom but gives mathematics teachers in the school concerned to carry out learning.

Validity and reliability testing is carried out on problem-solving instruments and self-regulation instruments. The problem-solving instrument uses a description test with a total of six questions. The self-regulation instrument is in the form of a questionnaire with a total of 40 statements. The items of this instrument have passed content validity tests by experts, internal consistency tests of the grains, and reliability tests. Content validity testing is analyzed using the Aiken formula. Internal consistency testing of items uses the product moment correlation formula, while reliability measurement is performed using Cronbach's alpha formula.

The test results show that the six items of the PSA instrument are classified as valid in terms of content validity, and the results of internal consistency testing items are classified as reliable. Meanwhile, in the instrument statement items, 40 statements are valid from the aspect of content validity, and only 30 statements are classified as valid from the aspect of testing the internal consistency of the items. The reliability test results show that this instrument is classified as reliable.

Table 2. Results of reliability statistics

	Cronbach's Alpha	N of Items
Self-Regulation	.829	30
PSA	.733	6

Data analysis using descriptive analysis, normality prerequisite testing (Kolmogorov-Smirnov test), and homogeneity testing of variance between data groups (Levene Statistic test). Hypothesis testing using Two-way ANOVA (α:0.05).

Results and Discussion

The results of the descriptive analysis of research data are attached to Table 3.

Table 3. Description of the PSA data

		A_1	A_1B_1	A_1B_2	A_2	A_2B_1	A_2B_2
N	Valid	48	24	24	48	24	24
Mean		79,58	90,42	68,75	72,81	68,54	77,08
Median		80,00	90,00	70,00	70,00	70,00	75,00
Mode		100	100	70	70	70	55[a]
Std. Deviation		15,534	8,836	13,043	14,025	12,290	14,590
Range		55	30	45	55	55	45
Minimum		45	70	45	45	45	55
Maximum		100	100	90	100	100	100
Mean Category		Extremely high	High	Enough	High	Enough	High

Data on PSA obtained a score range of 0 - 100, an ideal average of 50, and an ideal standard deviation of 16.67. based on the ideal standard deviation and ideal average, the average PSA of the PBL student group is 79.58 and is classified in the high PSA category. The average PSA of the conventional student group is 72.81, which is classified as high PSA. The average PSA of students with high self-regulation in PBL classes was 90.42 and classified as PSA was extremely high. The average PSA of students with low self-regulation in PBL classes was 68.75 and classified as sufficient PSA. The average PSA of students with high self-regulation in conventional classes was 68.54 and classified as sufficient PSA. The average PSA of students with low self-regulation in conventional classes was 77.08, classified as high PSA.

The results of the Kolmogorov-Smirnov test and Levene's test can be presented in Table 4 and Table 5.

Table 4. Results of tests of normality kolmogorov-smirnov

Learning Models		Statistics	df	Sig.
Residual for PSA	Problem-Based Learning	,110	48	,196
	Conventional Learning	,080	48	,200*
	High Self-Regulation	,098	48	,200*
	Less Self-Regulation	,086	48	,200*

Table 4 presents the > α sig values for all data groups, meaning problem-solving capability data is typically distributed within each data group.

Table 5. Results of group variance homogeneity of variance analysis

F	df_1	df_2	Sig.
1,930	3	92	,130

Table 5 presents the significant Levene, a statistic value of 0.130 (p>α), which means all data groups have homogeneous variance. Based on the fulfillment of the prerequisite test, the hypothesis test of the main effect and interaction was conducted. The research hypothesis was analyzed with a two-way ANOVA analysis. The results of the statistical analysis can be presented in Table 6.

Table 6. Results of a Two-Way ANOVA

Difference Test			
Influence	Mean Difference	F_{value}	Sig.
Learning Models	6,771*	7,190	,009
Learning Models*Self-Regulation		35,781	,000
Advanced Test with Tukey Test			
Learning models in students with high self-regulation	21,875*	46,587	,000
Learning models in students with less self-regulation	8,333*	4,352	,043

The two-way ANOVA main effect analysis results obtained a value of F = 7.190, p = 0.009 ($p < 0.05$), with a mean difference of 6.771*. These results prove that the application of PBL models influences PSA. The results of the interaction effect analysis obtained a value of F = 35.781, p = 0.000 ($p < 0.05$). These results prove that the interaction between learning models and self-regulation influences PSA. More explicitly, the interaction model of the two independent variables is depicted in the following model interaction profile.

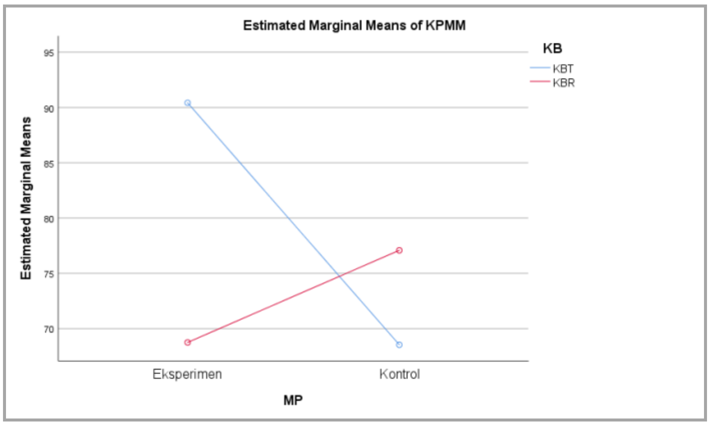

Figure 1. Model interaction profile

A simple effect test was conducted to determine the interaction between independent variables. The simple main effect analysis results on very independent students obtained a value of F = 46.587, *p* = 0.000, with a mean difference of 21.875*. These results prove that students who learn through PBL models can solve problems better than those who learn through conventional classroom learning. Conversely, the simple main effect analysis results on less independent students obtained a value of F = 4.352, p = 0.043, with a mean difference of 8.333*. These results prove that students who learn through PBL models are less able to solve problems than students who learn through conventional classroom learning.

The results of the main-effect analysis show that the application of the model of PBL influences students' ability to solve problems. Theoretically, influence is more likely due to PBL, which integrates contextual problems into learning so students can find solutions to complex and unstructured real-life problems (Seibert, 2021). This result is one of the reasons why students are delighted and motivated to understand and internalize their knowledge (Hung & Tsai, 2020). In the environment of PBL, students learn to shape their knowledge meaningfully through questioning, active learning, sharing, and reflection (English & Kitsantas, 2013). Therefore, students are expected to actively seek out and understand the learning material themselves with the support of the facilitator. The teacher provides direction and guidance throughout the learning process and remains the leading player in learning (Kladchuen & Srisomphan, 2021). Things differ in applying the jigsaw-type cooperative learning model, where students share knowledge and information in groups for all students to become experts in a particular part of the material (Sudin et al., 2021).

Empirically, the implementation of the model of PBL, which can strengthen student motivation (Khatimah & Sugiman, 2019), has an impact on improving learning outcomes when compared to learning outcomes with previous approaches (Hendriana et al., 2018; Duchi et al., 2023), especially on problem-solving capabilities (Nasution, 2018; Sani & Malau, 2017). Intervention with PBL models affects improving mathematics learning outcomes (Hidajat, 2023). Professional knowledge, learning engagement, and reflective abilities are enhanced through the use of PBL methods (Erdogan & Senemoglu, 2017).

The results of the interaction effect analysis show that the interaction of learning models and self-regulation influences PSA. Theoretically, this interaction is caused by the characteristics of self-regulation that affect the effectiveness of the application of learning models because the role of teachers in learning is only as a designer, organizer, and facilitator (Supriatna et al., 2019). Students are more able to interpret problems and identify problem-solving strategies to increase self-regulation (Nurlaily et al., 2019). Independent students can manage their learning patterns creatively and form thinking patterns to solve problems (Zimmerman & Campillo, 2003). Positive self-regulation builds students' sense of responsibility to learn independently. This sense of responsibility gives confidence to the student and motivates him to solve problems (Abdillah et al., 2023). Self-regulation can grow and develop when students have (1) a capacity component (i.e., the ability to demonstrate self-regulation), (2) a goal representation component (i.e., maintaining goals to strive for), and (3) a motivational component (i.e., sufficient motivation to strive for this goal) (Gunzenhauser & Saalbach, 2020). Self-regulation can increase student motivation (Tanti et al., 2020), thus impacting problem-solving capabilities.

This interaction reinforces previous findings that the PBL model has the best impact on increasing competence, self-regulation, and problem-solving (Perels et al., 2005). PSA has good stability over time, and there is an increase in self-regulation when applied to PBL models. PBL positively affects student independence by building knowledge and developing PSA (Ali et al., 2023).

The analysis of the simple main effect on students who are very independent shows that students who learn with PBL models are better able to solve problems than students who learn with conventional learning. In theory, the characteristics of the PBL model affect the development of self-regulation. Some of the fundamental reasons include: 1) PBL models encourage students to explore alone or in groups in problem-solving (Duchi et al., 2023); 2) the PBL model can develop students' metacognitive skills and gain a higher awareness of their self-regulation (Zimmerman, 2002); 3) engagement of relevant and contextual issues keeps students motivated to learn (Yew & Goh, 2016). Empirically, the PBL model positively affects self-regulation (Tjalla & Sofiah, 2015). Thus, students who learn through PBL models can solve problems better than those who learn through conventional classroom learning.

The analysis results of the simple main effect on less independent students are that Students who learn through PBL models are less able to solve problems than students who learn through conventional classroom learning. Theoretically, the cause of this difference is that PBL models require higher-order thinking skills (Anggraeni et al., 2023). Less independent students tend to be less skilled at honing critical thinking skills (Sani & Malau, 2017). Empirically, self-regulation can improve PSA. However, increased self-regulation did not have an overall impact on all students after treatment. Students have difficulty adapting to PBL as they are less independent (Sahyar Sahyar et al., 2017). Students have difficulty finding the intent of the case (problem), and students' self-regulation skills have not been sufficiently practiced for independent concept discovery. PBL learners are apprehensive about the new learning format and worried about succeeding (Seibert, 2021).

Conclusion and Suggestion

The results of this study have presented significant findings in mathematics learning. PBL has a positive impact on PSA. In addition, the interaction between learning models and self-regulation significantly affects PSA. Highly independent students show better PSA when learning through PBL, while less independent students show lower PSA.

These findings have important implications for classroom instructional practices. Teachers can consider using PBL models as an effective learning strategy in improving students' PSA. In addition, it is essential to develop student self-regulation through a supportive approach and supply additional support for students. This research also illustrates the importance of collaboration in applying PBL models and conventional learning to improve student learning outcomes. This research can be a foundation for further research and application of best practices in mathematics learning in the future.

References

Abdillah, M. H., Tentama, F., Wcidiana, H. S., & Zurqoni. (2023). Self-regulation, self-evaluation, and self-efficacy: How does its impact on employability? *International*

Journal of Evaluation and Research in Education, *12*(3), 1165–1173. https://doi.org/10.11591/ijere.v12i3.25076

Ali, K., Daud, A., Ba Hattab, R., Philip, N., Matoug-Elwerfelli, M., Anweigi, L., Al Khabuli, J., & Du, X. (2023). Development of self-regulation amongst dental students in problem-based learning curricula: A qualitative study. *European Journal of Dental Education*, *27*(2), 388–395. https://doi.org/10.1111/eje.12820

Amalina, I. K., & Vidákovich, T. (2023). Cognitive and socioeconomic factors that influence the mathematical problem-solving skills of students. *Heliyon*, *9*(9), e19539. https://doi.org/10.1016/j.heliyon.2023.e19539

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, *49*, 101334. https://doi.org/10.1016/j.tsc.2023.101334

Arends. (2008). *Learning To Teach*. New York: McGraw-Hill.

Borg, W. R., Meredith D, G., & Gall., J. P. (2007). *Education Research*. New York: Pearson Education, Inc.

Boye, E. S., & Agyei, D. D. (2023). Effectiveness of problem-based learning strategy in improving teaching and learning of mathematics for pre-service teachers in Ghana. *Social Sciences & Humanities Open*, *7*(1), 100453. https://doi.org/10.1016/j.ssaho.2023.100453

Candiasa, I. M. (2019). *Analisis Data dengan Statistik Univariat dan Bivariat*. Singaraja: Undiksha Press.

Chirimbana, M., Nghipandulwa, L. T., & Kamati, F. N. (2022). An Investigation of the Factors That Contribute to Poor Problem-Solving Skills in Grade 8 Mathematics Learners in Namibia. *Open Journal of Social Sciences*, *10*(12), 614–628. https://doi.org/10.4236/jss.2022.1012042

Clark, C. E. (2006). Problem-based learning: How do the outcomes compare with traditional teaching? *British Journal of General Practice*, *56*(530), 722–723.

Cresswell, C., & Speelman, C. P. (2020). Does mathematics training lead to better logical thinking and reasoning? A cross-sectional assessment from students to professors. *PLoS ONE*, *15*(7 July), 1–21. https://doi.org/10.1371/journal.pone.0236153

Duchi, L., Servant-Miklos, V., Kooij, L., & Noordegraaf-Eelens, L. (2023). The "Sweet Spot" for Reflection in Problem-oriented Education: Insights From Phenomenographic Action-research. *Journal of Problem Based Learning in Higher Education*, *11*(1), 1–35. https://doi.org/10.54337/ojs.jpblhe.v11i1.7370

English, M. C., & Kitsantas, A. (2013). Supporting Student Self-Regulated Learning in Problem- and Project-Based Learning. *Interdisciplinary Journal of Problem-Based Learning*, *7*(2), 127–150. https://doi.org/10.7771/1541-5015.1339

Erdogan, T., & Senemoglu, N. (2017). PBL in teacher education: its effects on achievement and self-regulation. *Higher Education Research and Development*, *36*(6), 1152–1165. https://doi.org/10.1080/07294360.2017.1303458

Fahrudin, D., Mardiyana, & Pramudya, I. (2019). The analysis of mathematic problem solving ability by polya steps on material trigonometric reviewed from self-regulated learning. *Journal of Physics: Conference Series*, *1254*(1), 012076. https://doi.org/10.1088/1742-6596/1254/1/012076

Garanina, R. M. (2020). Problem-based learning as a means of chemistry education effectiveness improvement at a medical university. *Samara Journal of Science*, *9*(4), 282–289. https://doi.org/10.17816/snv202094303

Ge, X., Law, V., & Huang, K. (2016). Detangling the interrelationships between self-regulation and ill-structured problem solving in problem-based learning. *Interdisciplinary Journal of Problem-Based Learning*, *10*(2). https://doi.org/10.7771/1541-5015.1622

Gunawan, G., Harjono, A., Nisyah, M., Kusdiastuti, M., & Herayanti, L. (2020). Improving Students' Problem-Solving Skills Using Inquiry Learning Model Combined with Advance Organizer. *International Journal of Instruction*, *13*(4), 427–442. https://doi.org/10.29333/iji.2020.13427a

Gunzenhauser, C., & Saalbach, H. (2020). Domain-specific self-regulation contributes to concurrent but not later mathematics performance in elementary students. *Learning and Individual Differences*, *78*(2), 101845. https://doi.org/10.1016/j.lindif.2020.101845

Haberstroh, S., & Schulte-Körne, G. (2022). The Cognitive Profile of Math Difficulties: A Meta-Analysis Based on Clinical Criteria. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.842391

Hendarwati, E., Nurlaela, L., Bachri, B. S., & Sa'ida, N. (2021). Collaborative Problem Based Learning Integrated with Online Learning. *International Journal of Emerging Technologies in Learning*, *16*(13), 29–39. https://doi.org/10.3991/ijet.v16i13.24159

Hendriana, H., Johanto, T., & Sumarmo, U. (2018). The Role of Problem-Based Learning to Improve Students' Mathematical Problem-Solving Ability and Self Confidence. *Journal on Mathematics Education*, *9*(2), 291–299. https://doi.org/10.22342/jme.9.2.5394.291-300

Hidajat, F. A. (2023). A comparison between problem-based conventional learning and creative problem-based learning on self-regulation skills: Experimental study. *Heliyon*, *9*(9), e19512. https://doi.org/10.1016/j.heliyon.2023.e19512

Hung, M.-L., & Tsai, C.-W. (2020). Problem-based learning in teacher education. *Higher Education Research & Development*, *39*(5), 1070–1072. https://doi.org/10.1080/07294360.2019.1675946

Karimah, R. K. N., Kusmayadi, T. A., & Pramudya, I. (2018). Analysis of difficulties in mathematics learning on students with deictic gesture type in problem-solving HOTS algebra test. *Journal of Physics: Conference Series*, *1108*(1). https://doi.org/10.1088/1742-6596/1108/1/012074

Khatimah, H., & Sugiman, S. (2019). The effect of problem solving approach to mathematics problem solving ability in fifth grade. *Journal of Physics: Conference Series*, *1157*(4). https://doi.org/10.1088/1742-6596/1157/4/042104

Kladchuen, R., & Srisomphan, J. (2021). The Synthesis of a Model of Problem-Based Learning With the Gamification Concept to Enhance the ProblemSolving Skills for High Vocational Certificate. *International Journal of Emerging Technologies in Learning*, *16*(4), 4–21. https://doi.org/10.3991/ijet.v16i14.20439

Mulyono, M., & Noor, N. L. (2016). Self-Regulation and Problem Solving Ability in 7E-Learning Cycle Based Goal Orientation. *Journal of Physics: Conference Series*, *755*, 011001. https://doi.org/10.1088/1742-6596/755/1/011001

Nasution, M. L. (2018). Students' Mathematical Problem-Solving Abilities Through The Application of Learning Models Problem Based Learning. *INA-Rxiv Papers*. https://doi.org/10.31227/osf.io/ajtyb

NCTM. (2000). *Principles Standards and for School Mathematics*. Reston, VA: The National Council of Teachers of Mathematics, Inc.

Nurlaily, V. A., Soegiyanto, H., & Usodo, B. (2019). Elementary school teacher's obstacles in the implementation of problem-based learning model in mathematics learning. *Journal on Mathematics Education*, *10*(2), 229–238.

https://doi.org/10.22342/jme.10.2.5386.229-238

Perels, F., Gürtler, T., & Schmitz, B. (2005). Training of self-regulatory and problem-solving competence. *Learning and Instruction*, *15*(2), 123–139. https://doi.org/10.1016/J.LEARNINSTRUC.2005.04.010

Plotnik, R., & Kouyoumdjian, H. (2010). *Handbook on Problem-solving Skills*. Wadsworth Publishing.

Polya, G. (1973). *How To Solve it: A New Aspect of Mathematical Method*. United States of America: Princeton University Press.

Rehmat, A. P., Glazewski, K., & Hmelo-Silver, C. E. (2022). Contextualizing Problem-Based Learning. In *The Oxford Handbook of Educational Psychology*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199841332.013.24

Sahyar Sahyar, S., Sani, R., Sani, R. A., & Malau, T. (2017). The Effect of Problem Based Learning (PBL) Model and Self Regulated Learning (SRL) toward Physics Problem Solving Ability (PSA) of Students at Senior High School Teaching and Learning View project The Effect of Problem Based Learning (PBL) Model and Self . *American Journal of Educational Research*, *5*(3), 279–283. https://doi.org/10.12691/education-5-3-8

Samuel, T. S., & Warner, J. (2021). "I Can Math!": Reducing Math Anxiety and Increasing Math Self-Efficacy Using a Mindfulness and Growth Mindset-Based Intervention in First-Year Students. *Community College Journal of Research and Practice*, *45*(3), 205–222. https://doi.org/10.1080/10668926.2019.1666063

Sani, R. A., & Malau, T. (2017). The Effect of Problem Based Learning (PBL) Model and Self Regulated Learning (SRL) toward Physics Problem Solving Ability (PSA) of Students at Senior High School. *American Journal of Educational Research*, *5*(3), 279–283. https://doi.org/10.12691/education-5-3-8

Schoepp, K. (2019). The state of course learning outcomes at leading universities. *Studies in Higher Education*, *44*(4), 615–627. https://doi.org/10.1080/03075079.2017.1392500

Seibert, S. A. (2021). Problem-based learning: A strategy to foster generation Z's critical thinking and perseverance. *Teaching and Learning in Nursing*, *16*(1), 85–88. https://doi.org/10.1016/j.teln.2020.09.002

Septian, A., Ramadhanty, C. L., Darhim, D., & Prabawanto, S. (2021). Mathematical Problem Solving Ability And Student Interest In Learning Using Google Classroom. *International Conference on Education of Suryakancana (IConnects Proceedings)*, *1*, 155–161. https://doi.org/10.35194/CP.V0I0.1331

Sipayung, T. N., & Anzelina, D. (2019). An analysis of students problem solving skills using a realistic mathematics approach on integers materials. *Journal of Physics: Conference Series*, *1211*, 012083. https://doi.org/10.1088/1742-6596/1211/1/012083

Sudin, M., Hermawan, C., Rosfiani, O., Ristiawati, W., & Hasanah, S. (2021). Improve Mathematics Pedagogical Content Knowledge and Verbal Communication Skills through Cooperative Learning Type Jigsaw. *Journal of Physics: Conference Series*, *1764*(1), 1–6. https://doi.org/10.1088/1742-6596/1764/1/012094

Supriatna, I., Asmahasanah, S., Rachmadtullah, R., Khair Asdar, A., Fahrudin, & Rasmitadila. (2019). The effect of learning methods and self regulation on problem-solving ability of mathematics in elementary school. *Journal of Physics: Conference Series*, *1175*(1). https://doi.org/10.1088/1742-6596/1175/1/012139

Tanti, Maison, Syefrinando, B., Daryanto, M., & Salma, H. (2020). Students' self-regulation and motivation in learning science. *International Journal of Evaluation and Research in Education*, *9*(4), 865–873. https://doi.org/10.11591/ijere.v9i4.20657

Thanheiser, E. (2023). What is the Mathematics in Mathematics Education? *Journal of Mathematical Behavior*, *70*(March 2022), 1–13. https://doi.org/10.1016/j.jmathb.2023.101033

Tjalla, A., & Sofiah, E. (2015). Effect of Methods of Learning and Self-Regulated Learning toward Outcomes of Learning Social Studies. *Journal of Education and Practice*, *6*(23), 15–20.

Waswa, D. W., & Al-kassab, M. M. (2023). *Mathematics Learning Challenges and Difficulties: A Students' Perspective* (pp. 311–323). https://doi.org/10.1007/978-981-99-0447-1_27

Widyatiningtyas, R., Kusumah, Y. S., Sumarmo, U., & Sabandar, J. (2015). The impact of problem-based learning approach tosenior high school students' mathematics critical thinking ability. *Journal on Mathematics Education*, *6*(2), 30–38. https://doi.org/10.22342/jme.6.2.2165.107-116

Wulandari, F. E., & Shofiyah, N. (2018). Problem-based learning: effects on student's scientific reasoning skills in science. *Journal of Physics: Conference Series*, *1006*(1), 012029. https://doi.org/10.1088/1742-6596/1006/1/012029

Yadav, S. (2019). Role of Mathematics in the. *International Journal of Research and Analytical Reviews (IJRAR)*, *6*(4), 295–298.

Yang, X., & Kaiser, G. (2022). The impact of mathematics teachers' professional competence on instructional quality and students' mathematics learning outcomes. *Current Opinion in Behavioral Sciences*, *48*, 1–8. https://doi.org/10.1016/j.cobeha.2022.101225

Yew, E. H. J., & Goh, K. (2016). Problem-Based Learning: An Overview of its Process and Impact on Learning. *Health Professions Education*, *2*(2), 75–79. https://doi.org/10.1016/j.hpe.2016.01.004

Zimmerman, B. J. (2002). Becoming a Self-Regulated Learner: An Overview. *Theory Into Practice*, *41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2

Zimmerman, B. J., & Campillo, M. (2003). Motivating Self-Regulated Problem Solvers. In *The Psychology of Problem Solving* (pp. 233–262). Cambridge University Press. https://doi.org/10.1017/CBO9780511615771.009

Zimmerman, B. J., & Kitsantas, A. (2014). Comparing students' self-discipline and self-regulation measures and their prediction of academic achievement. *Contemporary Educational Psychology*, *39*(2), 145–155. https://doi.org/10.1016/j.cedpsych.2014.03.004