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The Impact of Problem-Based Learning Intervention and Students' Pre-existing Motivation Level on Solving HOTS Mathematics Problems

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Abstract

Most Indonesian students encounter difficulties when solving high-order thinking skills (HOTS) type of mathematics problems which require students to analyze and synthesize prior knowledge and relate it to new situations. This study aims to evaluate the effectiveness of problem-based learning (PBL) in solving HOTS mathematics problems among high school students. We also examined whether students' level of motivation influence the ability of problem-solving skill as well as any interaction between learning models and study motivation on HOTS math type. A class intervention was conducted in one private Madrasa (Islamic High School) Mojokerto, Indonesia. A total of 59 students were divided into the intervention (PBL, $n = 29$) and control (conventional learning, $n = 30$) groups. Both groups had a similar topic on the linear system with three variables. The lessons were delivered by the same teacher twice a week, with a duration of 90 minutes per session within three weeks for each group. A two-way analysis of variance was performed to evaluate the data with the independent variables consisting of two models (PBL and non-PBL) and three levels of motivation (low, medium, and high). The dependent variable is the HOTS mathematics score. The ANOVA results showed that students in the PBL classroom (Mean = 82.78) obtained significantly higher math scores ($p<0.001$), compared to students in the non-PBL classroom (Mean=78.18). There was also a significant effect on motivation level (F (2, 53) = 16.30, $p<0.001$). Moreover, the significant interaction effect between models and motivation level F (2, 53) = 3.45, p = 0.04) indicated that students with high levels of motivation performed better in the PBL classroom while those with low levels of motivation in the same class did not. These findings suggest the urgency of implementing a mathematics education PBL-based model in secondary schools because of their benefits in boosting problem-solving skills for HOTS problems.

Keywords: HOTS, Mathematics, Problem-based Learning, PBL, Problem Solving, Motivation

Introduction

The triennial 2018 OECD Program for International Student Assessment (PISA) report shows that Indonesian students score among the lowest in mathematics, ranked 72 out of 79 countries (OECD, 2018). Indonesian students encounter difficulties to understand and apply the concept of mathematics in a real-world context which relies heavily on the ability to analyze, synthesize, and evaluate or high-order thinking skills (HOTS) (Suparman et al., 2021). The inability to identify and solve real-world problems will negatively impact students' future professional life. One of the main causal factors is didactic learning which is centered on the teacher and focused on implementing lower-order thinking skills (LOTS) (Abdullah et al., 2017; Seman et al., 2017). Accordingly, there is a need to introduce a new strategy to enhance mathematical proficiency by shifting from a major emphasis on sequential memorizing LOTS to higher-order thinking skills (HOTS). HOTS will improve students' abilities in analyzing, synthesizing, evaluating, and generating new ideas through their Factual, Conceptual, Procedural, and Metacognitive (FCPM) thinking capacities (Hermayawati, 2020).

The Indonesia Minister of Education and Culture advocated for the integration of Higher Order Thinking Skills (HOTS) in mathematics and science with the launch of Curriculum 2013. One of the learning models covered in C-13 which is considered effective to foster HOTS in mathematics education is the problem-based learning (PBL) approach. PBL is a student-oriented approach that allows students to solve problems by doing research, combining theory and practice, finding practical solutions as well working collaboratively (Loyens et al., 2008). It fosters learning and the development of 21st competencies and skills through problem-solving and knowledge transfer to real-life applications (Merritt et al., 2017; Shanta & Wells, 2022). Meanwhile, the success of PBL implementation depended on some attitude factors such as students' self-efficacy and motivations (Harun et al., 2012; Manganelli et al., 2019; Schukajlow et al., 2017) because it emphasizes self-learning than a more traditional (didactic) setting (Wijnen et al., 2018). However, as highlighted by Schukajlow et al., (2017), studies on motivation in educational research have generally declined during the past two decades.

Based on the aforementioned reasons, this study aims to evaluate the effectiveness of PBL-classroom implementation, compared to the conventional or non-PBL classroom, in solving HOTS mathematics problems among 10th-grade students. We also examine whether any differences in students' motivation levels and the interaction effect between classroom models and their motivation levels. The hypotheses are then formulated as follows:

1. Students in the PBL classroom will obtain higher HOTS-type mathematics scores than those in the non-PBL classroom
2. Students with higher motivation levels will obtain higher HOTS-type mathematics scores than those with medium and low motivation levels
3. There is an interaction effect between models and motivation levels in HOTS-type mathematics scores.

Theory and literature review

Higher Order Thinking Skill in Mathematics

One of the main priorities in mathematics learning is gaining creative and critical thinking skills as well as problem-solving abilities which play important roles when applied in everyday life (Shanta & Wells, 2022; Suparman et al., 2021). Such essential skills are developed through higher order thinking skills (HOTS), thinking levels that manage a broad domain of information and knowledge with the use of meta-cognition into a unified structure to solve unfamiliar problems. HOTS is also characterized by several descriptions, such as the ability to formulate nonalgorithmic, complex, and multiple solutions; make various decisions and interpretations; and many other criteria involving uncertainty, effort, and self-regulation (Sun et al., 2022). Students will gain some abilities through HOTS which cover creative thinking, critical thinking, and problem-solving (Suparman et al., 2021). In the Indonesia education system, three dimensions are used as indicators of HOTS assessment: analysis (C4), evaluation (C5), and creating ideas (C6). Educators should design HOTS questions level in such a way that facilitates students to comprehend the questions slowly. There are four levels of the HOTS problem which combine the Trends in International Mathematics and Science Study (TIMSS) cognitive level and the revised dimension cognitive process of Bloom's taxonomy (Ariyanto et al., 2020)

- HOTS level 1 questions relate to the ability to analyze and make a reasoning.
- HOTS level 2 problems are directed to the student's ability to evaluate and do reasoning.
- HOTS level 3 questions are a combination of reasoning and creation
- HOTS level 4 problems are a combination of reasoning with a minimum of two levels of analysis,

evaluation, or creation

Problem-Based Learning

Problem-based learning (PBL) is a pedagogical technique that facilitates the learning process through collaborative group work and open-ended problem-solving. It was first introduced by the medical school of McMaster University in the mid-1960s to the usage of "problems" that represented actual medical problems. This approach was later adopted by other disciplines (Loyens et al., 2008). The tenet of PBL is built based on social constructivism theory in which students construct their knowledge through social interaction. Students are encouraged to work collaboratively with peer review in small group discussions which promote higher order thinking and shared knowledge construction. The teachers facilitate learning by acknowledging the students' efforts, ideas, and prior knowledge.

Loyens et al., (2008) list five main goals of PBL implementation for students which include broad and flexible knowledge, effective collaboration, intrinsic motivation for learning, effective problem-solving, and self-directed learning skills. Moreover, Wijnen et al., (2018) summarize the delivery of PBL in three phases: the initial discussion, the self-study, and the reporting phase. In the initial discussion, students start the learning process by working collaboratively with peers, and discussing a realistic problem. Students attempt to explain the problem using common sense and past knowledge. In the second phase, students work individually in searching for and studying relevant literature sources to find solutions to the learning problems. Students who have completed self-study then return to their peer group to review the readings and work together to address the learning problems (i.e., the reporting phase). An instructor is present during the initial discussion and reporting phase, for instance, by directing the students when they spent more time on irrelevant issues. She or he needs to ensure that students elaborate on the course material, rather than offer them factual knowledge.

In the mathematics discipline, the benefits of PBL in improving mathematics performance over traditional lecture-based instruction have been reported (Kwangmuang et al., 2021; Makmuri et al., 2021; Suparman et al., 2021). This approach is considered one of the best strategies to enhance critical thinking, creative thinking, and problem-solving which helps students to develop their HOTS (Bosica et al., 2021). On the opposite, some scholars reported insignificant effects, even negative, on the effectiveness of PBL on critical thinking, creative, and problem-solving skills (Ahdhianto et al., 2020; Nahdi, 2018). These inconclusive findings provide unclear information about the effect of PBL implementation on students' HOTS, thus there is still needed research to examine its effectiveness.

Motivation

In education systems, it has long been considered that students have different learning capacities and skills (Demirel & Dağyar, 2016). Research showed motivation is a significant factor in successful learning across disciplines or subjects (Manganelli et al., 2019; Schukajlow et al., 2017). According to self-determination theory (SDT) (Deci & Ryan, 2000), humans have three innated psychological needs: autonomy, competence, and social relatedness. In the education context, fulfilling these needs enable a person to be more intrinsically motivated to learn and attain a more in-depth understanding of learning content and subsequently achieve better academic performance. As PBL focuses on active learning, studies have reported successful PBL in fostering affective domains such as interest and intrinsic motivation (Argaw et al., 2017; Harun et al., 2012; Khairani et al., 2020).

Meanwhile, Asrafil et al., (2020) have presented four main difficulties encountered by students when solving HOTS problems: 1) insufficient prior knowledge, 2) Poorly trained and unfamiliar with HOTS questions, 3) Negative perception about HOTS, 4) Errors triggered by high cognitive load. Students who perceived HOTS negatively are more likely to be less motivated or interested in HOTS problem which in turn lead to their lack of self-confidence to solve HOTS problems. Also, research within self-regulation learning has indicated the main role of motivational factors, particularly autonomous motivation, on students' use of cognitive and learning strategies (Manganelli et al., 2019). Therefore, it is important to study to what extent the pre-existing motivation level influences cognitive or academic achievement which is still less studied.

Methodology

Participants and Study Design

The participants were tenth-grade students from a private Islamic high school in Mojokerto, East Java, Indonesia. The sample selection was carried out using a purposive sampling technique based on prior knowledge of the population and the specific study objectives (Fraenkel et al., 2012). There are two groups: PBL or intervention group (*n* = 29) and non-PBL (*n* = 30) as the control group.

Instrument

In this research, a standardized and constructed questionnaire developed by Uno (Uno, 2016) was used to evaluate students' motivation levels. It consists of 40 questions that reflect six main indicators: 1) desires to succeed; 2) encouragement and learning needs; 3) goals of the future; 4) rewards in learning; 5) interesting activities, and 6) supportive learning environment. This scale has been widely used in Indonesian education research and has good psychometric properties. Participants were asked to rate their perceived motivation levels on a Likert scale of 1 – 4 (1: strongly disagree to 4 = strongly agree). A higher final score represents a higher level of motivation. The Pearson correlation was performed to evaluate the item validity based on the criteria that the value of r_{count} has to be > r_{table} (Aspelmeier, 2005). At the significance level α = 0.05 and degree of freedom 58 (*N*= 59), an item was categorized as valid if its value is above the value of r_{table} = 0.367. Table 1 shows that seven questions (denotes by *, numbers 5, 11, 13, 14, 18, and 33) were excluded from further analysis because their Pearson's coefficient was below 0.367. The internal consistency (Cronbach's alpha) of this scale was 0.74 or good.

Table 1. Pearson correlation value of motivation scale

Item	*r*-value	Item	*r*-value	Item	*r*-value	Item	*r*-value
1	0.371	11*	0.151	21	0.541	31	0.599
2	0.418	12	0.376	22	0.405	32	0.697
3	0.395	13*	0.003	23	0.519	33*	0.348
4	0.439	14*	0.083	24	0.544	34	0.497
5	-0.169*	15	0.325	25	0.657	35	0.515
6	0.355	16	0.443	26	0.659	36	0.149
7	0.422	17	0.554	27	0.617	37	0.382
8	0.608	18*	0.023	28	0.484	38	0.584
9	0.620	19	0.582	29	0.758	39	0.758
10	0.464	20	0.582	30	0.673	40	0.565

The instrument used to evaluate students' problem-solving related to the HOTS consisted of five open-ended questions on linear systems with three variables. Each question has a score range of 0-5 and the total scores were then multiplied by four to obtain the final scores (maximum 100). Scores were given based on a holistic rubric for grading (Sesanti, N.R & Ferdiani, 2017). HOTS Problems were extracted from the mathematics national examination. The cognitive and knowledge process dimensions of HOTS evaluated are shown in Table 2. Similar to the inter-item validity test in the self-motivation assessment, the validity result of the mathematic instrument test is displayed in Table 2. The Cronbach alpha value of this test was 0.687 or acceptable.

Procedure

The intervention was conducted from July – August 2022 (first semester year 2022-2023). PBL classroom consisted of 30 students while the non-PBL 29 students. The current PBL classroom was composed of the following steps: 1) present the problem related to a linear system with three variables topic to students in a group which consists of 4-5 persons, 2) manage the group to conduct research, 3) assist group to solve a problem first individually, then using group, 4) facilitate the group to present workgroup 5) facilitate the group to analyze and evaluate the process during problem-solving execution. The same teacher delivered a 90-minute session twice a week for three weeks on the topic linear system with three variables.

Table 2**.** Pearson coefficient and cognitive & knowledge process dimensions evaluated for each HOTS question

Item	*r*	Cognitive & knowledge process dimension
1	0.612	C6 (create), conceptual & procedural
2	0.593	C4 (analyze), conceptual & procedural
3	0.807	C5 (evaluate) procedural & metacognitive
4	0.529	C5 (evaluate), metacognitive
5	0.787	C5 (evaluate), procedural & metacognitive

Data Analysis

A two-way analysis of variance (ANOVA) was employed to answer research hypotheses. Data were checked for normality with the Kolmogorov-Smirnov test and homogeneity assumptions using the Levene tests. An independent *t*-test was also conducted to evaluate the baseline performance of both classes. Since there is no significant difference at pre-intervention (t (57) = 0.904, p-value = 0.37) then we could assume the differences post was caused by the intervention. If the main effect was found significantly, a post-hoc comparison test using Tukey was performed and Bonferroni correction was applied. All analysis was conducted using SPSS 23.0 at a significance level α of <0.05.

Findings

The result of Kolmogorov Smirnov test showed that HOTS scores data met the normality distribution assumptions (statistics =0.070, df = 59, p = 0.02). Moreover, the homogeneity test using the Levene test showed non-significant which indicated the scores in both groups were homogenous (F (5, 53) = 1.249, p =.0.300).

The overall mean motivation level for all students was 91.2 (SD = 14.19) which then was converted into three groups using the following formula:

$$\text{Low: Scores} < (\bar{x} - S)$$
$$\text{Medium: } (\bar{x} - S) \leq \text{Scores} \leq (\bar{x} + S)$$
$$\text{High: Scores} > (\bar{x} + S)$$

where:
$\bar{x}$ = average of raw scores of motivation level for all students (i = 1, 2, …, 59)
S = standard deviation of motivation level

Those who obtained scores below 78 were categorized as the low group, the range of 78 up to less than equal to 106 was medium, and beyond 106 was high. Based on this criterion, the distribution of math test scores based on students' motivation levels in both groups is displayed in Table 3.

Table 4 summarized a two ANOVA result which shows the significance effects of models (F (1,53) = 27.24, p<0.001) and motivation level (F (2,53) = 16.30, p<0.001). Post-hoc multiple comparisons was then performed using estimated marginal means with Bonferroni adjusted correction. We found that there were significant differences in mathematics scores between all pairwise comparisons (all p < 0.001). The interaction effect between models and level of motivation was also found significant (F (2,53) = 3.46, p = 0.04). This indicated that two variables (models and motivation levels) had simultaneous effects on their mathematics performance. Students who had a higher level of motivation achieved greater final mathematics scores.

Table 3. Distribution of Math scores across three levels of motivation

Motivation Level	Total	PBL			Non-PBL		
		N	Mean	SD	N	Mean	SD
		29	83.4	6.74	30	73.3	9.99
	Low	5	79.0	4.18	8	62.5	9.10
	Medium	16	80.6	6.29	13	75.8	6.92
	High	11	88.7	4.67	6	81.2	6.21

Table 4. Summary of two-way ANOVA

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
Intercept	303045.898	1	303045.898	7122.296	.000
Motivation	1387.237	2	693.618	16.302	.000
Models	1158.884	1	1158.884	27.237	.000
Motivation * Models	293.259	2	146.629	3.446	.039
Error	2255.092	53	42.549		
Total	367130.000	59			
R^2 = 0.603 (Adjusted R^2 = 0.565)					

Discussion

In general, we found that the PBL classroom model was more effective in improving students' abilities to solve mathematics HOTS problems compared to those in the conventional classroom in 10th-grade secondary school. This is in line with previous reviews which showed the benefits of PBL in various subjects in secondary education (Ahamad et al., 2018; Kwangmuang et al., 2021; Merritt et al., 2017). The process of learning activities in the PBL classroom encouraged students to shift from passive listeners to actively engaged in learning activities both individually and collaboratively when solving complex mathematics problems. PBL students acquired new knowledge through interaction with others and develop their high-level cognitive skills (Demirel & Dağyar, 2016). These skills play important roles in solving HOTS problems which require clearly defining and well-structured problems, formulating a hypothesis, assessing, analyzing, synthesizing data from different sources, revising the initial hypothesis as the data collected, and justifying solutions based on evidence and reasoning (Ali et al., 2010)

Moreover, a higher pre-existing motivation level was associated with higher mathematics achievement which supported a prior study (Manganelli et al., 2019). Schukajlow et al., (2017) emphasized that motivation is an important prerequisite and outcome of learning and achievement. Since there is a significant interaction between two factors (i.e., models and level of motivation), we should interpret the main effect of each factor considering the interaction effect.

Students with a higher level of motivation would gain more benefit from the PBL approach than those with lower motivation levels. This explains that despite in the same PBL classroom, students with low motivation levels remained facing difficulties to understand the concept and they lacked the motivation to seek help although the teacher has already served as a facilitator. Thus, they became less collaborative and found the PBL approach was not interesting. It seems that the transition from the traditional teaching method to PBL led to a negative perception of PBL among those who were less motivated.

In contrast, students with high pre-existing motivation levels found such a learning model allowed them to explore their learning behaviors. This finding is in accordance with autonomous motivation in the SDT theoretical framework (Deci & Ryan, 2000). Prior research also has shown that autonomously motivated students feel a sense of psychological freedom which motivates them to engage in the learning process by applying various cognitive and metacognitive strategies (Manganelli et al., 2019). They are more likely tend to achieve better academic results by using deep-level cognitive or critical thinking, a major skill used in solving HOTS problems. On the opposite, it seems that low motivation levels students were driven by controlled motivation. They relied on surface-level cognitive strategies which are associated with their lower achievement.

Meanwhile, a successful PBL can be measured by not only cognitive but also affective dimensions such as motivation, self-efficacy, and other-related attitudes. Research has demonstrated that students instructed under the PBL model will develop intrinsic motivation, become more independent learners, experience higher levels of self-efficacies, and have better-developed meta-cognitive skills than students in the traditional classroom (Ali et al., 2010; Crowley, 2015). Therefore, further studies are needed to formulate the teaching-learning process in PBL models which can increase students' motivation and engagement in learning particular subjects. level. It can be achieved by connecting PBL with other interactive learning models, for example, blended learning (Phungsuk et al., 2017) or equipping teachers to design more innovative Science Technology Engineering and Mathematics (STEM) lesson activities (Bosica et al., 2021; Chai et al., 2020).

Conclusion and further research

To sum, students in the PBL classroom performed better in mathematics performance when solving HOTS mathematics problems, compared to those in the conventional or non-PBL classroom. Besides, students with high levels of motivation also obtained greater mathematics scores than those with medium and low motivation levels. A significant interaction effect between models and motivation level suggests that students in the PBL classroom would obtain higher mathematics scores if they already had high motivation levels. Despite the study limitations, our study provides insights into the wide implementation of PBL models, even in a relatively short period, in improving HOTS mathematics problem skills in secondary schools.

Notwithstanding the significant findings, the results cannot be generalized to other populations and subjects because our sample is limited to Indonesia's private high schools. We also did not assess to what extent the PBL model influences the affective outcomes such as motivation before and after its implementation. Further research needs to explore more diverse outcomes such as behavioral (e.g., retention rates) and affective (e.g., satisfaction, engagement) domains. Lastly, the results of this study may not generalize to other types of mathematics abilities or levels of education

References

Abdullah, A. H., Mokhtar, M., Halim, N. D. A., Ali, D. F., Tahir, L. M., & Kohar, U. H. A. (2017). Mathematics teachers' level of knowledge and practice on the implementation of higher-order thinking skills (HOTS). Eurasia Journal of Mathematics, Science and Technology Education, 13(1), 3–17. https://doi.org/10.12973/eurasia.2017.00601a

Ahamad, S. N. S. H., Li, H. C., Shahrill, M., & Prahmana, R. C. I. (2018). Implementation of problem-based learning in geometry lessons. Journal of Physics: Conference Series, 943(1). https://doi.org/10.1088/1742-6596/943/1/012008

Ahdhianto, E., Marsigit, Haryanto, & Nurfauzi, Y. (2020). Improving fifth-grade students' mathematical problem-solving and critical thinking skills using problem-based learning. Universal Journal of Educational Research, 8(5), 2012–2021. https://doi.org/10.13189/ujer.2020.080539

Ali, R., Hukamdad, D., Akhter, A., & Khan, A. (2010). Effect of Using Problem Solving Method in Teaching Mathematics on the Achievement of Mathematics Students. Asian Social Science, 6(2). https://doi.org/10.5539/ass.v6n2p67

Argaw, A. S., Haile, B. B., Ayalew, B. T., & Kuma, S. G. (2017). The effect of problem based learning (PBL) instruction on students' motivation and problem solving skills of physics. Eurasia Journal of Mathematics, Science and Technology Education, 13(3), 857–871. https://doi.org/10.12973/eurasia.2017.00647a

Ariyanto, R. O., Mardiyana, & Siswanto. (2020). Characteristics of mathematics high order thinking skill problems levels. Journal of Physics: Conference Series, 1470(1), 0–10. https://doi.org/10.1088/1742-6596/1470/1/012012

Aspelmeier. (2005). Table of critical values for Pearson's r. https://www.real-statistics.com/statistics-tables/pearsons-correlation-table/

Asrafil, A., Retnawati, H., & Retnowati, E. (2020). The difficulties of students when solving HOTS problem and the description of students cognitive load after given worked example as a feedback. Journal of Physics: Conference Series, 1511(1). https://doi.org/10.1088/1742-6596/1511/1/012092

Bosica, J., Pyper, J. S., & MacGregor, S. (2021). Incorporating problem-based learning in a secondary school mathematics preservice teacher education course. Teaching and Teacher Education, 102, 103335. https://doi.org/10.1016/j.tate.2021.103335

Chai, C. S., Rahmawati, Y., & Jong, M. S. Y. (2020). Indonesian science, mathematics, and engineering preservice teachers' experiences in stem-tpack design-based learning. Sustainability (Switzerland), 12(21), 1–14. https://doi.org/10.3390/su12219050

Crowley, B. M. (2015). The Effects of Problem-Based Learning on Mathematics Achievement of Elementary Students Across Time [Western Kentucky University]. http://digitalcommons.wku.edu/theses/1446

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. Psychological Inquiry, 11(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Demirel, M., & Dağyar, M. (2016). Effects of Problem-Based Learning on Attitude: A Meta-analysis Study. Eurasia Journal of Mathematics, Science and Technology Education, 12(8), 2115–2137. https://doi.org/10.12973/eurasia.2016.1293a

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). How to Design Research in Education and Evaluate Research in Education (8th ed.). McGraw-Hills.

Harun, N. F., Yusof, K. M., Jamaludin, M. Z., & Hassan, S. A. H. S. (2012). Motivation in Problem-based Learning Implementation. Procedia - Social and Behavioral Sciences, 56(Ictlhe), 233–242. https://doi.org/10.1016/j.sbspro.2012.09.650

Hermayawati. (2020). Teachers' efforts in understanding the factual, conceptual, procedural and metacognitive assessment using the revised 2013 curriculum. International Journal of Learning, Teaching and Educational Research, 19(5), 186–199. https://doi.org/10.26803/ijlter.19.5.11

Khairani, S., Suyanti, R. D., & Saragi, D. (2020). The Influence of Problem Based Learning (PBL) Model Collaborative and Learning Motivation Based on Students' Critical Thinking Ability Science Subjects in Class V State Elementary School 105390 Island Image. Budapest International Research and Critics in Linguistics and Education (BirLE) Journal, 3(3), 1581–1590. https://doi.org/10.33258/birle.v3i3.1247

Kwangmuang, P., Jarutkamolpong, S., Sangboonraung, W., & Daungtod, S. (2021). The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools. Heliyon, 7(6), e07309. https://doi.org/10.1016/j.heliyon.2021.e07309

Loyens, S. M. M., Magda, J., & Rikers, R. M. J. P. (2008). Self-directed learning in problem-based learning and its relationships with self-regulated learning. Educational Psychology Review, 20(4), 411–427. https://doi.org/10.1007/s10648-008-9082-7

Makmuri, Aziz, T. A., & Kharis, S. A. A. (2021). Characteristics of problems for developing higher-order thinking skills in mathematics. Journal of Physics: Conference Series, 1882(1), 0–7. https://doi.org/10.1088/1742-6596/1882/1/012074

Manganelli, S., Cavicchiolo, E., Mallia, L., Biasi, V., Lucidi, F., & Alivernini, F. (2019). The interplay between self-determined motivation, self-regulated cognitive strategies, and prior achievement in predicting academic performance. Educational Psychology, 39(4), 470–488. https://doi.org/10.1080/01443410.2019.1572104

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

Nahdi, D. S. (2018). Eksperimentasi Model Problem Based Learning dan Guided Discovery Learning terhadap Kemampuan Pemecahan Masalah Matematis Ditinjau dari Self-Efficacy Siswa. Jurnal Cakrawala Pendas, 4(1), 50–56.

OECD. (2018). PISA 2018 Results. https://www.oecd.org/pisa/publications/pisa-2018-results.htm

Phungsuk, R., Viriyavejakul, C., & Ratanaolarn, T. (2017). Development of a problem-based learning model via a virtual learning environment. Kasetsart Journal of Social Sciences, 38(3), 297–306. https://doi.org/10.1016/j.kjss.2017.01.001

Schukajlow, S., Rakoczy, K., & Pekrun, R. (2017). Emotions and motivation in mathematics education: theoretical considerations and empirical contributions. ZDM - The International Journal of Mathematics Education, 49(3), 307–322. https://doi.org/10.1007/s11858-017-0864-6

Seman, S. C., Yusoff, W. M. W., & Embong, R. (2017). Teachers Challenges in Teaching and Learning for Higher Order Thinking Skills (HOTS) in Primary School. International Journal of Asian Social Science, 7(7), 534–545. https://doi.org/10.18488/journal.1.2017.77.534.545

Sesanti, N.R & Ferdiani, R. D. (2017). Assesment Pembelajaran Matematika (Cetakan 1). Yayasan Edelweis. ISBN: 978-602-14916-4-5.

Shanta, S., & Wells, J. G. (2022). T/E design based learning: assessing student critical thinking and problem solving abilities. International Journal of Technology and Design Education, 32(1), 267–285. https://doi.org/10.1007/s10798-020-09608-8

Sun, H., Xie, Y., & Lavonen, J. (2022). Exploring the structure of students' scientific higher order thinking in science education. Thinking Skills and Creativity, 43, 100999. https://doi.org/10.1016/j.tsc.2022.100999

Suparman, S., Juandi, D., & Tamur, M. (2021). Does Problem-Based Learning Enhance Students' Higher Order Thinking Skills in Mathematics Learning? A Systematic Review and Meta-Analysis. ACM International Conference Proceeding Series, 44–51. https://doi.org/10.1145/3451400.3451408

Uno, H. B. (2016). Teori Motivasi dan Pengukurannya: Analisis di Bidang Pendidikan (14th ed.). Bumi Aksara.

Wijnen, M., Loyens, S. M. M., Wijnia, L., Smeets, G., Kroeze, M. J., & Van der Molen, H. T. (2018). Is problem-based learning associated with students' motivation? A quantitative and qualitative study. Learning Environments Research, 21(2), 173–193. https://doi.org/10.1007/s10984-017-9246-9