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Problem-Based Learning to Metacognition in Physics Learning in Indonesia: Literature Review

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Abstract

Physics learning encountered a hurdle due to students' insufficient metacognitive abilities, emphasizing the need to improve their understanding of learning and problem-solving procedures. This literature review aimed to explain the results of applying Problem-Based Learning (PBL) to metacognition in physics learning in Indonesia. This literature review was sourced from scholarly articles published between 2013-2023, retrieved via Google Scholar using tools like Publish or Perish and Open Knowledge Map. The search utilized keywords such as "*Pembelajaran Berbasis Masalah*" or "Problem-Based Learning" and "Metacogni*" and "physics". These criteria included relevance to PBL in physics learning, metacognitive, publication in reputable journals, and full-text availability. From the initial pool of 214 articles, a selection process was applied based on the literature review criteria, including 11 national and one international article. Based on the findings of the literature review analysis, it was discovered that there was limited research on the application of PBL to metacognition in physics education in Indonesia, indicating a need for further exploration. Of the 12 articles examined, only 2 (16.7%) focused on developing PBL tools to facilitate metacognition, ensuring validity, practicality, and effectiveness in enhancing learner metacognition. Additionally, 6 of the 12 articles (50.0%) suggested that implementing the PBL model in physics education improved metacognitive abilities. However, 4 of the 12 articles (33.3%) reported no significant impact on enhancing metacognition through PBL learning methodologies. The results of this study indicated a complex correlation between PBL and the advancement of metacognitive skills in physics education. This underscored the significance of further research to pinpoint the factors influencing these outcomes and to refine PBL instructional approaches.

Keywords: metacognition; physics; problem-based learning

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INTRODUCTION

The problem that is often encountered in physics learning is the difficulty of students understanding physics principles and abstract concepts. Students find it difficult to understand physics problems, especially those that require high levels of cognitive reasoning (Chasanah et al., 2019; Sawitri et al., 2016; Yusuf & Widyaningsih, 2017). Learners need to have the ability to evaluate their understanding of these concepts and to identify areas that require instruction that fosters higher cognitive reasoning abilities. The capacity to understand, organize, and exercise control over one's cognitive processes is called metacognition. Metacognitive refers to the learner's ability to consciously monitor their learning process (Mahdavi, 2014; Setiawan & Supiandi, 2019). Metacognition is related to understanding and regulating individual awareness regarding their cognitive processes (Özsoy & Ataman, 2009; Wass et al., 2023). This requires individuals to understand their thought processes, learning mechanisms, and problem-solving approaches (Sugiarti et al., 2023). Metacognitive abilities are high-level cognitive abilities required for knowledge management (Richmond et al., 2017). Students are expected to establish personal learning objectives and devise suitable learning approaches to accomplish them (Haryani et al., 2018; Hidayah et al., 2016). The metacognitive function in the learning and problem-solving process is very important.

The results of the study indicate that more than 80% of the students demonstrate inadequate metacognitive skills, as indicated by difficulties in comprehending prior knowledge, identifying appropriate times and methods to utilize strategies, failing to regulate the effectiveness of strategies, and restricted application of acquired knowledge (Sari et al., 2022). Metacognition is the capacity to regulate and monitor one's learning process to determine the most efficient learning strategies. By using metacognition, students have the potential to develop a deeper understanding of the subject matter. Metacognition facilitates individual growth into more professional learners, independent individuals, and critical thinkers. This applies to personal development, problem-solving, education, and other aspects of life. Metacognition is a crucial tool in assisting students in overcoming challenging obstacles encountered in physics learning.

Effective physics learning requires teaching methods that can stimulate students' metacognitive abilities. One of the factors causing low metacognitive abilities is learning activities that are designed in the form of learner-centered activities and activities that emphasize the knowledge aspect alone. Therefore, it is necessary to implement learner-centered learning that requires them to be active and develop their metacognitive abilities. According to constructivism theory, problem-based learning (PBL) provides students greater opportunities to build their knowledge, construct meaning, and actively seek and process information (Danial, 2010; Munawaroh, 2020). PBL is an instructional approach characterized by its learner-centered nature, wherein students are encouraged to tackle and resolve real-world challenges.

PBL is a learning method that can develop students' metacognitive abilities (Danial, 2010; Lidia et al., 2018; Reigeluth & Carr-Chellman, 2009; Sutarto et al., 2022). PBL is a learning strategy that prioritizes solving complex scenarios or practical challenges through the active participation of learners (Chen et al., 2021; Zabit, 2010). Learners are encouraged to develop creative, problem-solving, and critical thinking skills through PBL (Amin et al., 2021; Maskur et al., 2020). This ability contributes to metacognitive growth by offering insight into an individual's cognitive process. One of the advantages of PBL is its ability to improve students' metacognitive and constructive thinking (Ayunda et al., 2022; Irmawati et al., 2023). PBL also allows students to work together in groups or pairs to solve problems (Ahdiani & Burhan, 2022; Kusumaningtias et al., 2013). While using PBL is not a novel concept in education, there has been limited research in Indonesia exploring the practical or applied aspects of PBL to enhance students' metacognitive skills in physics subjects.

It is necessary to conduct an in-depth study on how to apply PBL learning to improve metacognition, especially in physics subjects in Indonesia. The influence of PBL on Indonesian students' metacognitive development related to physics learning remains to be investigated. Hence, researchers are motivated to conduct a literature review focusing on the intersection of PBL and metacognitive learning in Indonesia's physics education context. This literature review aims to assess existing research in this domain and offer a comprehensive understanding of how PBL influences Indonesian students' metacognitive growth in their physics studies.

METHOD

This research employed a literature review method, which was conducted based on relevant previous research in the field. A literature review is an activity that focuses on a specific topic of interest to critically analyze the contents of the manuscript being studied (Newman & Gough, 2020; Wahyuni, 2022). This literature review employed literature from the past decade, encompassing publications from 2013-2023, available in full-text PDF format through platforms like Google Scholar and Open Knowledge Map. These criteria included relevance to PBL in physics learning, metacognition, publication in reputable journals, and full-text availability. The journals examined adhered to specific criteria, comprising research journal articles in Indonesian and English, centered around the theme of Problem-Based Learning and Metacognition in physics learning in Indonesia. The literature search targeted keywords such as "*Pembelajaran Berbasis Masalah*" or "Problem Based Learning" and "Metacogni*" and "physics", resulting in the identification of 11 national articles and one international article that aligned with the aim of the literature review. This literature review was presented using a narrative method by grouping similar analysis data according to the results measured to answer the objectives. The research journals relevant to the theme were gathered, and a summary was created for each, encompassing the research title, author and year, type of research, and research findings.

RESULT AND DISCUSSION

The literature review compiled critical data from multiple sources concerning the utilization of PBL in physics education in Indonesia, with an emphasis on metacognitive aspects. The findings are presented in Table 1.

Table 1 Articles about PBL and metacognition in physics learning in Indonesia

No	Research Title	Article Author	Types of Research	Research Result
1	Improving Physics Metacognitive Abilities Through the PBL Model at SMK Pancasila 1	(Wicaksono et al., 2013)	Classroom Action Research	The application of PBL could improve physics metacognitive abilities.

No	Research Title	Article Author	Types of Research	Research Result
	Kutoarjo			
2	The Influence of the PBL Model on Learning Motivation given the Metacognition of Grade XI Science Students at SMAN 9 Pinrang	(Jusriana, 2016)	Quasi-experimental	There was no interaction between the PBL learning model and metacognition (high and low) in the achievement of learning motivation.
3	Physics Learning-Based on PBL Using Experimental and Demonstration Methods Judging from Critical Thinking Ability on Learning Achievement and Metacognitive Skills	(Sawitri et al., 2016)	Quasi-experimental	There was an interaction effect between the PBL model and critical thinking skills on metacognitive skills. There was no influence of the PBL model using experimental and demonstration methods on students' metacognitive skills in the material of straight motion kinematics (significance 0.162).
4	Physics Learning Using a PBL Approach Through Experimental Methods and Guided Problem Inquiry Judging from Students' Metacognitive Skills and Critical Thinking Abilities	(Prastyaninda et al., 2018)	Quasi-experimental	There was no interaction between PBL and metacognitive skills on learning outcomes. However, there was an interaction between PBL, metacognition, and critical thinking skills on learning outcomes.
5	The Influence of the Module-Assisted PBL Model on Students' Metacognitive Abilities	(Lidia et al., 2018)	True Experimental	This research showed that implementing PBL on metacognition was not ideal because there were no significant differences between the experimental and control classes. However, PBL had positive implications for cognitive learning outcomes.
6	Validity of PBL Tools with A Cognitive Conflict Approach for Teaching Metacognitive Skills	(Nur et al., 2020)	RnD	PBL instruments were valid for teaching metacognition skills.
7	Analysis of Students' Conceptual, Procedural, and Metacognitive Knowledge Through Integrated Learning of Flipped Classroom and PBL	(Bintang et al., 2020)	Quasi-experimental	Students with PBL had better conceptual, procedural, and metacognitive knowledge abilities. This was because, during learning, students experienced independent learning, guidance, and deepening based on contextual and challenging problems, which resulted in authentic learning experiences.

No	Research Title	Article Author	Types of Research	Research Result
8	Comparison of PBL Assisted by Animated Video and Non-Assisted by Animated Video Against Metacognitive Abilities of High School Students	(Astra et al., 2021)	Quasi-experimental	The metacognitive abilities of students taught with PBL assisted by animated videos were higher than those of students taught with problem-based learning strategies without the assistance of animated videos.
9	The Effectiveness of the PBL Model on Students' Metacognition Skills	(Sari et al., 2022)	Pre-experimental	The PBL model was effective in improving students' metacognitive skills.
10	PBL Can Improve High School Students' Metacognitive Abilities	(Ekasari et al., 2022)	Mixed Methods	The metacognitive abilities of students who were taught using PBL increased in the indicators of declarative knowledge, procedural knowledge, contextual knowledge and information, planning, monitoring, evaluation, and debugging.
11	Development of A PBL Module to Increase Students' Metacognitive Knowledge of Temperature and Heat Material	(Al Farizi et al., 2023)	RnD	The PBL module that had been developed was valid, practical, and effective for increasing metacognitive knowledge.
12	The Influence of Metacognitive Skills on Motivation and Learning Outcomes Through the PBL Model	(Mustaqim et al., 2013)	Quasi-experimental	There was an influence of metacognitive skills on learning outcomes through the PBL model of 27%, which was included in the medium category.

Twelve articles met the criteria for full reading, aligning with the objectives of the conducted literature review. Three articles employed development research methods, as indicated in Table 1. Additionally, six articles utilized quasi-experimental methods, one employed true experiment, one used pre-experiment, one employed mixed method, and one conducted Classroom Action Research (PTK). Overall, quasi-experimental, true experimental, pre-experimental, mixed method, and PTK research positioned PBL as the independent variable to assess whether it significantly affected the dependent variable, namely metacognition.

Development of PBL Tools to Facilitate Metacognition

The results from the research conducted by (Nur et al., 2020) (article number 6), which investigated the validity of PBL-based learning tools employing a cognitive conflict approach for teaching metacognitive skills, concluded that PBL-based learning tools were valid for teaching metacognitive skills. Similarly, the outcomes of the developmental research conducted by (Al Farizi et al., 2023) (article number 11), entitled "Developing a Problem-Based Learning Module to Increase Students' Metacognitive Knowledge on Temperature and Heat Material" demonstrated that the PBL tools developed were valid, practical, and effective for enhancing metacognition.

PBL contributed to Metacognitive Improvement

The earliest study on the application of PBL to improve metacognitive skills in physics lessons in Indonesia was published by (Wicaksono et al., 2013) (article number 1) entitled "Improving Physics Metacognitive Abilities Through the Problem-Based Learning Model at SMK Pancasila 1 Kutoarjo". This research showed that applying PBL could improve the physics metacognitive abilities of grade X students at SMK Pancasila 1 Kutoarjo. The observations of students' metacognitive physics abilities indicated an average percentage of 46.04% during the pre-cycle, which then increased to 63.41% in cycle I and further to 74.46% in cycle II (Wicaksono et al., 2013).

The results from the research conducted by (Bintang et al., 2020) (article number 7) entitled "Analysis of Students' Conceptual, Procedural, and Metacognitive Knowledge Through Integrated Learning in Flipped Classroom and PBL" showed that students with PBL learning had better conceptual, procedural, and metacognitive knowledge abilities. This was because, during learning, students experienced independent learning, guidance, and deepening based on contextual and challenging problems, resulting in authentic learning experiences.

Another research result from (Astra et al., 2021) (article number 8) entitled "Comparison of Problem-Based Learning Strategies Assisted by Animated Video and Non-Assisted by Animated Video Against Metacognitive Abilities of High School Students" showed that the metacognitive abilities of students who were taught with a problem-based learning strategy assisted by animated videos were higher than the metacognitive abilities of students who were taught with problem-based learning strategies without the assistance of animated videos.

Similar research conducted by (Sari et al., 2022) (article number 9) entitled "The Effectiveness of the Problem-Based Learning (PBL) Model on Students' Metacognition Skills" found that the PBL model was effective on students' metacognitive skills. Similarly, the findings from the research conducted by (Ekasari et al., 2022) (article number 10) entitled "Problem-Based Learning Can Improve High School Students' Metacognitive Abilities" showed that the metacognitive abilities of students who were taught using PBL increased. Students experienced an increase in the indicator stages of declarative knowledge, procedural knowledge, conditional knowledge and information, planning, monitoring, evaluation, and debugging.

PBL did not contribute to Metacognitive Improvement

Several research articles showed that PBL had no significant effect on improving students' metacognitive skills. Research conducted by (Jusriana, 2016) (article number 2) examined the Influence of the Problem-Based Learning Model on Learning Motivation from the Perspective of Metacognition among Grade XI Science Students at SMAN 9 Pinrang. This research used a quasi-experimental research method. The results indicated no interaction between the PBL and metacognitive learning models (high and low) in influencing students' learning motivation. Upon closer examination of this research, it became apparent that the data analysis conducted remained descriptive, primarily in percentages, while hypothesis testing analysis to assess the impact was not undertaken. The assessment results revealed that students' metacognitive abilities were categorized into low and high categories. At the same time, motivation outcomes were found to be in the high category for both the experimental and control classes. The author in the article concluded that there was no interaction between learning methods (PBL and conventional) and metacognitive (high and low) in achieving students' learning motivation. Consequently, additional measurements were necessary using suitable analytical techniques to determine whether such influence was absent.

Further research conducted by (Sawitri et al., 2016) (article number 3) concluded that physics learning based on Problem-Based Learning (PBL) used experimental and demonstration methods in terms of critical thinking abilities on learning achievement and metacognitive skills. The research showed an interaction effect between the PBL model and critical thinking skills on metacognitive skills. However, there was no influence of the PBL model using experimental and demonstration methods on students' metacognitive skills in the material of rectilinear motion kinematics (significance 0.162).

Further research by (Prastyaninda et al., 2018) (article number 4) entitled "Physics Learning Using a Problem-Based Learning Approach Through Experimental and Guided Inquiry Methods given Students' Metacognitive Skills and Critical Thinking Abilities" showed that there was no interaction between PBL-based physics learning and metacognitive skills on student learning outcomes. However, there was an interaction between PBL-based physics learning, metacognitive skills, and critical thinking abilities on student learning outcomes. No evident interaction was noted between the methods used and students' metacognitive skills regarding their learning outcomes. This was because, during the learning process, students with both high and low levels of metacognitive skills in both the experimental and guided inquiry classes actively participated in the learning process. Despite the possibility of some students not being visibly active during implementation, most students were actively engaged. Metacognition was also influenced by various factors, namely the existence of a learning community that worked together to solve problems in learning (Siegesmund, 2016).

The results of other research by (Lidia et al., 2018) (article number 5) entitled "The Effect of Module-Assisted Problem-Based Learning Models on Students' Metacognitive Abilities" showed that the outcomes of implementing PBL on metacognitive abilities were not optimal, as there were no significant differences observed between the experimental and control classes. However, PBL had positive implications for students' cognitive learning outcomes. The resulting correlation coefficient between metacognitive abilities and cognitive learning outcomes in this research was significant, 0.668. In the discussion of article 5, the author stated that the results of this research analysis were not as perfect as those of previous studies. PBL strategies ideally had the advantage of developing metacognitive skills. PBL provided students greater freedom to utilize various learning media and expanded their opportunities to seek information from diverse learning sources.

Analysis of Findings

Two articles (6, 11) related to developing PBL tools to facilitate metacognition in the categories of valid, practical, and effective for facilitating metacognitive abilities. Five articles (1, 7, 8, 9, 10, 12) showed that applying the PBL model in physics learning could improve metacognitive abilities. Four articles (2, 3, 4, 5) showed no effect of increasing metacognition. Three development research articles were carried out, which could facilitate students' metacognitive development. This was demonstrated by the practicality and effectiveness of using PBL tools in learning to facilitate metacognitive abilities. Other research findings indicated that PBL could contribute positively to students' metacognitive development in Indonesia's physics learning context. Students who participated in PBL tended to develop a heightened awareness of their learning strategies and demonstrated improved skills in organizing and evaluating their learning (Yusuf & Widyaningsih, 2018). This was consistent with the idea that metacognition is an important factor in effective learning.

Additionally, research findings diverged from previous studies, indicating varying influences between PBL and learner metacognition. Such differences could be attributed to the unique characteristics of students at each school. Students' metacognitive abilities could have differed from one another, with one of the causes being variations in their initial abilities, levels of independence, and degrees of learning autonomy (Exintaris et al., 2023; Mahdavi, 2014). Other factors might have been influenced by the moderator variables used, as observed in several of the examined studies that did not show any effect. Generally, these studies utilized moderator variables that indirectly affected the dependent variable, in this case, metacognitive skills. Consequently, overall, PBL was found to have an impact on improving metacognition. The developed PBL tool could be used to improve metacognitive abilities in Indonesian physics learning.

Implications

The findings implied that applying PBL could have benefited physics education in Indonesia by enhancing students' metacognitive skills. The research conducted in articles 1, 6, 7, 8, 9, 10, 11, and 12 could have been considered when planning the implementation of PBL in the context of physics education in Indonesia. These studies could have assisted students in designing PBL learning experiences to cultivate their metacognitive abilities. This could also motivate students to be more active in the physics learning process. While there were differences in the methods and approaches employed in these studies, a consistent finding was the positive influence of PBL on learner metacognition. Additionally, alternative strategies to foster students' metacognitive skills included demonstrating the application of self-regulation and monitoring during problem-solving tasks and promoting social interaction within PBL groups (Siegesmund, 2016). Students' social interactions in PBL, such as discussing, asking, and analyzing ideas, could improve critical thinking and metacognitive skills (Sutarto et al., 2022). This could have been accomplished by presenting case studies that offered realistic examples of metacognitive processes, such as utilizing ICT media to visually represent abstract physics concepts. This approach could have motivated students to engage in discussions about solving physics problems (Yusuf & Widyaningsih, 2020). Students must also offer relevant feedback on their metacognitive progress and promote open-mindedness to enable problem-solving in physics by exploring various solutions.

Research Limitations

It must be acknowledged that there were also obstacles in implementing PBL to facilitate students' metacognition, as in articles 2, 3, 4, and 5. Limitations of research regarding the application of PBL and metacognition in physics learning in Indonesia could include infrastructure constraints. Several schools or regions in Indonesia faced infrastructure obstacles, including limited technology access. Naturally, this influenced the implementation of PBL and the development of metacognition in learning. Additional hurdles, such as constrained resources like textbooks, laboratory equipment, or teacher training, could impede the effective implementation of PBL. This could limit the ability of students and learners to develop metacognitive skills in learning. Another factor that required consideration during the implementation of PBL was guiding students to comprehend theories and hypothesize before engaging in learning. This was crucial because students might not have been accustomed to formulating hypotheses, identifying control variables, manipulated variables, response variables, and analyzing data in the context of physics education (Argaw et al., 2017; Rerung et al., 2017). Another challenge that could have arisen was the limitations of the metacognitive instruments utilized in research, such as low validity or reliability. This needed to be considered when planning the implementation of PBL in Indonesia's physics learning context. Based on the results of the literature review analysis, it was found that there was still limited research on the application of PBL to metacognition in physics learning in Indonesia. Therefore, further studies need to be conducted in this area.

CONCLUSION

Based on the findings of the literature review analysis, it was observed that research on the integration of PBL with metacognition in physics education in Indonesia remained limited, necessitating further investigation. Among the 12 articles reviewed, only 2 (16.7%) were dedicated to developing PBL tools to facilitate metacognition, ensuring validity, practicality, and effectiveness in enhancing students' metacognitive processes. Additionally, 6 out of 12 articles (50.0%) reported positive outcomes, indicating that implementing the PBL model in physics education improved metacognitive abilities. However, 4 out of 12 articles (33.3%) found no significant impact on enhancing metacognition through PBL learning methodologies. Hence, in a broader sense, PBL was utilized to enhance metacognitive abilities in physics education in Indonesia. A suggestion for further research was to explore in greater detail the factors affecting the implementation of PBL and students' metacognition. Subsequent studies could also have helped in understanding the lasting effects of PBL on learner metacognition.

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REFERENCES

Ahdiani, N., & Burhan, M. I. (2022). Penerapan model problem based learning untuk meningkatkan hasil belajar kimia materi pokok reaksi redoks dan elektrokimia. *Jurnal Pendidikan Dan Profesi Keguruan*, *2*(1), 73. https://doi.org/10.59562/progresif.v2i1.30564

Al Farizi, T., Alatas, F., & Jannah, N. (2023). Pengembangan modul berbasis problem based learning untuk meningkatkan pengetahuan metakognitif peserta didik pada materi suhu dan kalor. *Jurnal Penelitian Pembelajaran Fisika*, *14*(1), 9–27.

Amin, A. K., Degeng, N. S., Setyosari, P., & Djatmika, E. T. (2021). The effectiveness of mobile blended problem based learning on mathematical problem solving. *International Journal of Interactive Mobile Technologies*, *15*(1), 119–141. https://doi.org/10.3991/IJIM.V15I01.17437

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

Astra, I. M., Supriyati, Y., & Putri, E. F. (2021). Comparison of problem-based learning strategies assisted by animated video and non-assisted by animated video against metacognitive abilities of high school students. *AIP Conference Proceedings*, *2320*, 020018-1-020018–5.

Ayunda, D., Kustiawan, A., & Erlin, E. (2022). Pengaruh model problem based learning berbasis tpack terhadap peningkatan kemampuan berpikir tingkat tinggi siswa. *J-KIP (Jurnal Keguruan Dan Ilmu Pendidikan)*, *3*(3), 584. https://doi.org/10.25157/j-kip.v3i3.8628

Bintang, H., Darnah, E., Masta, N., Rinaldi, R., Guswantoro, T., & Sianturi, M. (2020). Analisis pengetahuan konseptual, prosedural, dan metakognitif siswa melalui pembelajaran integrasi flipped classroom dan PBL. *Physics Education Research Journal*, *2*(2), 105–122. https://journal.walisongo.ac.id/index.php/perj/article/view/6208

Chasanah, R. N., Mujasam, M., Widyaningsih, S. W., & Yusuf, I. (2019). Influence of the use of interactive learning media on students' higher order thinking skills. *Kasuari: Physics Education Journal (KPEJ)*, *2*(1), 26–35.

Chen, J., Kolmos, A., & Du, X. (2021). Forms of implementation and challenges of PBL in engineering education: a review of literature. *European Journal of Engineering Education*, *46*(1), 90–115. https://doi.org/10.1080/03043797.2020.1718615

Danial, M. (2010). Pengaruh strategi pbl terhadap keterampilan metakognisi dan respon mahasiswa the effects of pbl strategy to students metacognition skill and respon. *Chemica*, *11*, 1–10.

Ekasari, A., Diantoro, M., & Parno, P. (2022). Pembelajaran berbasis masalah mampu meningkatkan kemampuan metakognisi siswa SMA. *Journal On Teacher Education (JOTE)*, *4*(2), 1424–1430.

Exintaris, B., Karunaratne, N., & Yuriev, E. (2023). Metacognition and critical thinking: Using ChatGPT-generated responses as prompts for critique in a problem-solving workshop (SMARTCHEMPer). *Journal of Chemical Education*, *100*(8), 2972–2980. https://doi.org/10.1021/acs.jchemed.3c00481

Haryani, S., Masfufah, M., Wijayati, N., & Kurniawan, C. (2018). Improvement of metacognitive skills and students' reasoning ability through problem-based learning. *Journal of Physics: Conference Series*, *983*(012174), 1–5.

https://doi.org/10.1088/1742-6596/983/1/012174

Hidayah, R., Fajaroh, F., Parlan, & Dasna, I. W. (2016). Collaborative problem based learning to improve metacognitive of chemistry students: Systematic literature review. *Preprints*, *August*, 1–23.

Irmawati, H., Muis, A., & Kurniawan. (2023). Penerapan problem based learning untuk meningkatkan keterampilan metakognitif dan hasil belajar siswa kelas vii smp negeri 7 polewali. *Jurnal Pemikiran Dan Pengembangan Pembelajaran Penerapan, 5*(2), 115–123.

Jusriana, R. A. (2016). Pengaruh model problem based learning terhadap motivasi belajar ditinjau dari metakognisi peserta didik kelas xi ipa sman 9 pinrang. *Urnal Pendidikan Fisika*, *4*(1), 53–55.

Kusumaningtias, A., Zubaidah, S., & Indriwati, S. E. (2013). Pengaruh problem based learning dipadu strategi numbered heads together terhadap kemampuan metakognitif, berpikir kritis, dan kognitif biologi. *Jurnal Penelitian Kependidikan*, *23*(1), 33–47.

Lidia, R., Sarwi, S., & Nugroho, S. E. (2018). Pengaruh model pembelajaran problem based learning berbantuan modul terhadap kemampuan metakognitif siswa. *Unnes Physics Education Journal*, *7*(2), 104–111.

Mahdavi, M. (2014). An overview: Metacognition in education. *International Journal of Multidisciplinary and Current Research*, *2*(June), 529–535.

Maskur, R., Sumarno, Rahmawati, Y., Pradana, K., Syazali, M., Septian, A., & Palupi, E. K. (2020). The effectiveness of problem based learning and aptitude treatment interaction in improving mathematical creative thinking skills on curriculum 2013. *European Journal of Educational Research*, *9*(1), 375–383. https://doi.org/10.12973/eu-jer.9.1.375

Munawaroh, M. (2020). The influence of problem-based learning model as learning method, and learning motivation on entrepreneurial attitude. *International Journal of Instruction*, *13*(2), 431–444. https://doi.org/10.29333/iji.2020.13230a

Mustaqim, S. B., Abdurrahman, A., & Viyanti, V. (2013). Pengaruh keterampilan metakognitif terhadap motivasi dan hasil belajar melalui model problem based learning (PBL). *Jurnal Pembelajaran Fisika*, *1*(5), 59–68. https://doi.org/10.2307/j.ctv2jtxrhd.18

Newman, M., & Gough, D. (2020). Systematic reviews in education research. In *Systematic Reviews in Education Research: Methodology, Perspectives and Application* (pp. 3–22). Springer Fachmedien Wiesbaden GmbH. https://doi.org/10.2307/j.ctt14jxsqg.4

Nur, A. R., Prayogi, S., Asy'ari, M., & Muhali, M. (2020). Validitas perangkat pembelajaran berbasis PBL dengan pendekatan konflik kognitif untuk membelajarkan kemampuan metakognisi. *Empiricism Journal*, *1*(1), 1–11. https://doi.org/10.36312/ej.v1i1.260

Özsoy, G., & Ataman, A. (2009). The effect of metacognitive strategy training on mathematical problem solving achievement. *International Electronic Journal of Elementary Education*, *1*(2), 68–83. https://doi.org/10.4172/2161-0487.1000121

Prastyaninda, F. A., Sukarmin, S., & Suparmi, S. (2018). Pembelajaran fisika menggunakan pendekatan problem based learning melalui metode eksperimen dan inkuiri terbimbing ditinjau dari keterampilan metakognitif dan kemampuan berpikir kritis siswa. *INKUIRI: Jurnal Pendidikan IPA*, *7*(2), 209–2019.

Reigeluth, C. M., & Carr-Chellman, A. A. (2009). *Instructional-design theories and models volume iii*. Taylor & Francis.

Rerung, N., Sinon, I. L. S., & Widyaningsih, S. W. (2017). Penerapan model pembelajaran problem based learning (PBL) untuk meningkatkan hasil belajar peserta didik sma pada materi usaha dan energi. *Jurnal Ilmiah Pendidikan Fisika Al-BiRuNi*, *6*(1), 47–55.

Richmond, A. S., Bacca, A. M., Becknell, J. S., & Coyle, R. P. (2017). Teaching metacognition experientially: A focus on higher versus lower level learning. *Teaching of Psychology*, *44*(4), 298–305. https://doi.org/10.1177/0098628317727633

Sari, Y. E., Permatasari, R., & Saputro, E. F. H. (2022). Efektivitas model problem based learning (PBL) pada keterampilan metakoginisi siswa. *QUANTUM: Jurnal Pembelajaran IPA Dan Aplikasinya*, *2*(1), 12–22.

Sawitri, I., Suparmi, & Aminah, N. S. (2016). Pembelajaran fisika berbasis problem based learning (PBL) menggunakan metode eksperimen dan demonstrasi ditinjau dari kemampuan berpikir kritis terhadap prestasi belajar dan keterampilan metakognitif. *Jurnal Inkuiri*, *5*(2), 79–86.

Setiawan, B., & Supiandi, M. I. (2019). The contribution of metacognitive skills and reasoning skills on problem solving ability based on problem based learning (PBL) model. *Anatolian Journal of Education*, *3*(2), 75–86.

Siegesmund, A. (2016). Increasing student metacognition and learning through classroom-based learning communities and self-assessment. *Journal of Microbiology & Biology Education*, *17*(2), 204–214.

Sugiarti, S., Jusniar, J., & Amruddin, M. F. (2023). The effect of problem based learning model on students metacognitive knowledge on acid base material. *UNESA Journal of Chemical Education*, *12*(3), 237–243.

Sutarto, S., Dwi, H. I., Fuster-Guillén, D., Palacios Garay, J. P., Hernández, R. M., & Namaziandost, E. (2022). The effect of problem-based learning on metacognitive ability in the conjecturing process of junior high school students. *Education Research International*, *2022*.

Wahyuni, A. S. (2022). Literature review: Pendekatan berdiferensiasi dalam pembelajaran IPA. *Jurnal Pendidikan Mipa*, *12*(2), 118–126.

Wass, R., Rogers, T., Brown, K., Smith-Han, K., Tagg, J., Berg, D., & Gallagher, S. (2023). Pedagogical training for developing students' metacognition: Implications for educators. *International Journal for Academic Development*, *00*(00), 1–14. https://doi.org/10.1080/1360144X.2023.2246442

Wicaksono, B., Akhdinirwanto, R. W., & Ashari. (2013). Peningkatan kemampuan metakognitif fisika melalui model pembelajaran problem based learning pada smk pancasila 1 kutoarjo. *Radiasi*, *3*(2), 2–5.

Yusuf, I., & Widyaningsih, S. W. (2017). Implementation of virtual laboratory in physics experiment course on critical thinking skills of physics education students of university of papua. *Jurnal Sainsmat*, *VI*(1), 75–81.

Yusuf, I., & Widyaningsih, S. W. (2018). Pembelajaran PBL berbantuan lab-vir melalui lesson study dalam meningkatkan kualitas pembelajaran fisika umum universitas papua. *Jurnal Pendidikan*

Fisika Universitas Muhammadiyah Metro, *VI*(2), 117–127.

Yusuf, I., & Widyaningsih, S. W. (2020). Implementing e-learning-based virtual laboratory media to students' metacognitive skills. *International Journal of Emerging Technologies in Learning (IJET)*, *15*(5), 63–74.

Zabit, M. N. M. (2010). Problem-based learning on students critical thinking skills in teaching business education in malaysia: A literature review. *American Journal of Business Education (AJBE)*, *3*(6), 19–32. https://doi.org/10.19030/ajbe.v3i6.436