

# Collaborative Problem Based Learning to Improve Metacognitive of Chemistry Students: Systematic Literature Review

Rusly Hidayah<sup>1</sup>, Fauziatul Fajaroh<sup>2</sup>, Parlan<sup>3</sup>, I Wayan Dasna<sup>4</sup>

<sup>1</sup> Universitas Negeri Surabaya, Indonesia; ruslyhidayah@unesa.ac.id

<sup>2</sup> Universitas Negeri Malang, Indonesia; fauziatul.fajaroh.fmipa@um.ac.id

<sup>3</sup> Universitas Negeri Malang, Indonesia; parlan.fmipa@um.ac.id

<sup>4</sup> Universitas Negeri Malang, Indonesia; idasna@um.ac.id

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## ABSTRACT

While collaborative problem-based learning (PBL), particularly in Western nations, has been researched and shown to be beneficial in enhancing students' metacognitive skills, it is still sparingly used in Asian nations like Indonesia. This study's goal was to learn more about the potential benefits of cooperative PBL on students' metacognitive skills. The systematic literature review (SLR) research design was used for this study, and the requirements were full text, journal articles, open access, accredited national and international publications between 2010 and 2020, and articles on the role of collaborative PBL in chemistry students' metacognitive development. The findings of the SLR used in this study show that PBL enhances students' metacognitive skills, particularly in chemistry students. The majority of research, however, continues to employ unreliable, nonstandard methods. Therefore, it is believed that this research may be used as supplemental data to acquire in-depth PBL findings.

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## Corresponding Author:

Rusly Hidayah

Universitas Negeri Surabaya, Indonesia; ruslyhidayah@unesa.ac.id

## 1. INTRODUCTION

The emphasis of the modern educational paradigm is now on developing students' high-level thinking skills so they may thrive in the knowledge era (Corebima, 2016). For pupils to develop into people who can handle all challenges in life in the future, especially in facing more competitive job areas, higher-order thinking abilities must be learned. Therefore, whether they like it or not, universities as institutions of higher learning must change the teaching and studying paradigm to develop pupils with strong critical thinking abilities.

According to Emily & Michaele (Emily, R. L., & Michaele, 2012), metacognition is an important higher-order thinking skill for students to have so they can direct their own thought processes as they study. (Peters, 2000). These abilities are seen as high-ranking cognitive competencies necessary for

knowledge management, where students are expected to establish their own studying targets and select the most efficient study techniques.

There is some evidence that problem-based learning (PBL) is a good fit for developing students' metacognitive skills in the context of chemistry coursework (Krishnaswamy, 1996). (Khery, 2013) Some studies (Abrami, Bernard, Borokhovski, Waddington, Wade, & Persson, 2015) have found that PBL is the most efficient strategy for fostering students' metacognition. Using PBL with chemistry students, Nuranna found (Nuranna, 2021) that offline learning produced somewhat better results than online learning. Recent classroom action research by Setiawan (Setiawan, 2020) suggests that using PBL models can improve students' metacognitive abilities across the board.

The developing trend demonstrates that, despite the necessity for them to monitor students' cognitive development, the majority of educators and administrators in Indonesian educational institutions still do not completely apply PBL in the teaching and learning process (Khatimah, H., & Antonius, A, 2020). In Indonesia, teachers typically take the opposing stance. They place a focus on memory, passive learning, and authority (Gwee, 2008). Recent studies by Pratama, Mayasari, Han, and Capraro (2015; Chen, Kolmos, and Du. (2021); Mayasari et al., 2018; (2008), show that the majority of Indonesian lecturers believe that PBL is less effective than student-centred teaching strategies, including direct instruction and traditional memory methods. This is in keeping with the East Asian educational tradition, which places high importance on harmony and uniformity. Additionally, whether teaching an exact or non-precise subject, the PBL technique can improve students' academic performance (Muhib, 2018; Paloloang, Juandi, Tamur, Paloloang, & Adem, (2020)

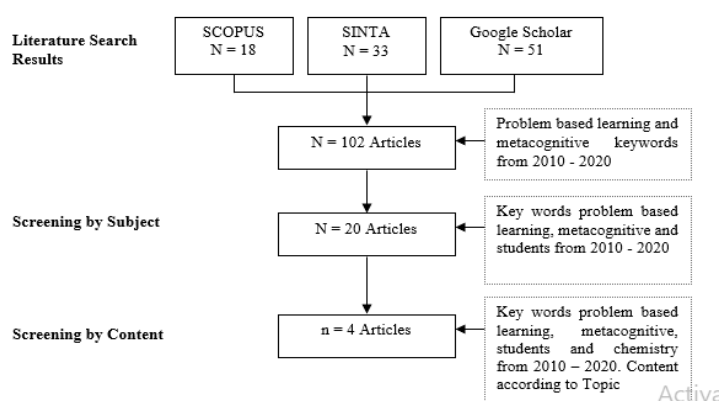
PBL has been shown to be quite effective in helping students develop their metacognitive skills, although this finding has not yet been incorporated into the research by Mayasari et al. This research aims to show how problem-based learning (PBL) improves students' metacognitive abilities, with a focus on chemistry students. The primary focus of this research is on the potential benefits of cooperative problem-based learning in enhancing students' metacognition skills in the context of chemistry.

## 2. METHODS

The systematic literature review was carried out in this study using Scopus, SINTA (Indonesian Research Database), and Google Scholar online publication databases (SLR). Learning about problems, learning about problems The keywords used are Chemistry Students and Metacognitive Ability.

The subject of the study was covered in 102 articles that the researchers were able to locate. The 20 papers that were still unread after reading the 102 articles' abstracts were picked for publishing based on their suitability and adherence to the following criteria: Articles that satisfy the requirements of (1) the year of publication must be around 2010 and 2020; (2) accreditation and repute in national journal publication and so do on an international level; (3) accreditation and respectability in journal articles; and (4) the type of journals are full text open access journal articles.

The literature flow diagram in Figure 1 illustrates how publications were found and scrutinised for this investigation.



When analysing the n = 13 sample papers that met the inclusion criteria, the narrative synthesis method was used to evaluate and synthesise the outcomes of all the research evaluated. This narrative synthesis followed the three processes outlined by Petticrew and Roberts (Petticrew, M., & Roberts, 2006): coding, extracting, and tabulating codes (findings) within and across all included studies. Code extraction was performed according to the study's five components (participants, intervention, comparison, findings, and settings) to obtain data needed for analysis and synthesis. Extracted data is shown in a matrix for easy comparison, allowing the researcher to quickly see if their results are consistent with those of another study. For a thorough evaluation, it is necessary to incorporate data from both high school and college students.

**Table 1: Sample Matrix (n) Articles = 3**

<i>Author</i>	<i>Title</i>	<i>Country</i>	<i>Methods</i>	<i>Instrument</i>	<i>Result</i>
(Tosun, C. and Senocak, 2013)	The Effects of PBL on Metacognitive Awareness and Attitudes toward Chemistry of Prospective Teachers with Different Academic Backgrounds.	Turkey	Quantitative method using a quasi-experimental path by pre-test post-test of group design.	The questionnaire using a Likert scale was shared to 70 prospective teacher students	Students with less of a scientific background gain more from PBL in improving their metacognitive awareness than students with more of a scientific background.
(Haryani, S., Prasetya, A. T., and Permanasari, 2014)	Developing Metacognition of Teacher Candidates by Implementing PBL within the Area of Analytical Chemistry.	Indonesia	Quantitative using a pre-and post-test group design and a quasi-experimental methodology	Twenty future teachers were given a questionnaire using a Likert scale.	The experimental group improved their metacognition the most at recognising patterns of information and the least at planning new procedures. If contributors are dedicated to continuous innovation by shifting from a verification-based chemical lab practise model to a more open, process-optimised one, there is a far larger chance

<i>Author</i>	<i>Title</i>	<i>Country</i>	<i>Methods</i>	<i>Instrument</i>	<i>Result</i>
(Muhali., 2014)	Applying PBL Models to Improve Student Learning Outcomes and Metacognitive Awareness in Chemistry Learning.	Indonesia	Classroom Action Research (CAR)	Student Worksheet (LKS) n 30 students	that the contributor may develop metacognition before concept mastery or vice versa. Throughout the process of implementing problem-based learning, train with a group of contributors who are both more numerous and more invested in its success. Students' metacognition may be improved by employing the PBL paradigm to teach them about the electrolyte and non-electrolyte solution chemistry components.
(Ramdoniati, N., Muntari, and Hadisaputra, 2018)	Development of PBL Chemistry Teaching Materials to Improve Metacognition Skills	Indonesia	<i>Research and Development.</i>	Student exercise based on PBL (LKPD) on electrolyte and non-electrolyte solution material n 94 students	Materials for teaching chemistry that are based on PBL are viable, useful, and successful at enhancing students' metacognition abilities.

### 3. FINDINGS AND DISCUSSION

#### **PBL and metacognitive abilities in Indonesia**

PBL and metacognitive abilities have been the focus of several pieces of research both locally and abroad. In the search for articles published in the recent 10 years (2010-2020) for this study, the subject of students, particularly chemistry students, returned just four publications. The concept of problem-based learning and cognitive abilities, however, was the subject of 102 papers that were discovered. The study's sample papers are included in these four publications. After thoroughly reading each of the four articles, it becomes clear that two were produced using quantitative techniques and a quasi-experimental approach with pre-and post-test group designs (50%), one was produced using classroom action research techniques (25%), and the other two were produced using research and development techniques (25%). While the last piece was finished in Turkey, the majority of the research for the three articles was done in Indonesia. Both the earliest research and the most current research were published in 2018. Almost all of the publications included in the present systematic review ( $n = 4$ ) were published in the last five years, even though the inclusion criteria were intended to encompass studies from ten years ago (2010). (2013-2018). In contrast to the research with the fewest samples ( $n = 20$  student-teacher candidates), which was done by Haryani, S., Prasetya, A. T., and Permanasari, the study with the greatest samples ( $n = 94$ ) was carried out by Ramdoniati, Muntari, and Hadisaputra (2018).

The study's sample papers all cited how PBL had improved students' metacognition skills in chemistry. Tosun and Senocak argue that PBL is more effective at building students' metacognitive awareness than in strengthening their scientific literacy. The experimental group improved the most at recognising information and the least at creating solutions. According to (Muhali., 2014) if the contributor is pledged to continuing innovation to move the model from verification-based chemistry lab execution to open lab practice and optimise the training process with a more trusted pool of contributors and consistently at each stage of performance based on the learning problem, students' metacognition can be upgraded.

The four study investigations used a range of criteria to assess students' PBL and metacognitive chemistry abilities. Four PBL factors—liking for theoretical chemistry classes, liking for chemistry lab work, evaluative attitudes about school chemistry, and behavioural dispositions to learn chemistry—that Tosun and Senocak identified in 2009 were employed in their study. Using the eight aspects of metacognition, Tosun and Senocak assessed the importance of metacognitive abilities among chemistry students (Schraw, G. & Dennison, 2004):

1. Declarative intelligence,
2. Procedural intelligence,
3. Conditional intelligence,
4. Planning,
5. Information management strategies,
6. Monitoring,
7. Debugging strategies,
8. Evaluating.

In addition, Muhali evaluates chemistry students' grasp of the significance of their metacognitive skills by having them demonstrate their level of performance on these eight attributes. Using real-world scenarios, placing a focus on problem-solving, allowing students to set their own learning goals, and having the teacher act as a facilitator were the four criteria on which PBL was judged in Muhali's research (Muhali, 2014).

#### **Indicators in measuring PBL**

Some indicators include presenting the issue to the class, giving a pre-test, organising a study session, overseeing a group exam, presenting the research results, analysing and assessing the problem-solving process, and asking the students to respond to a survey on the implementation. In the interim, Haryani et al. used seven markers from (Anderson, L.W., and Krathwol, 2001) to evaluate chemistry

students' metacognitive abilities. These indications include data interpretation, selecting process, constructing procedure, identifying information, elaborating information, applying to understand, and assessing procedure. According to research by Ramdoniati et al., PBL indicators derived from Maiyuni and Maharani's study include the viability of content, language, presentation, and graphics (2018). The ability of students to foresee, plan, monitor, and assess is utilised as a self-developed indicator of their metacognitive competency. One needs this skill to address the world's difficulties in the twenty-first century.

## Discussion

This study was conducted in contrast to the bulk of preceding, systematic research assessments driven by different challenges. The question is whether PBL effectively fosters metacognitive skills in Indonesian students classified as being in developing countries and more likely to adhere to eastern values. PBL was developed and had its roots in developed countries with Western ideology (individualism and liberalism) (collectivism and conformity). This systematic review combines PBL implementation among Indonesian chemistry students by selecting articles that need to be evaluated. The methodological problems with PBL research in Indonesia, which are frequently not the topic of research by Indonesian scientists, are also attempted to understand in this thorough examination of the literature. Indonesia often has lower research quality due to inferior access to literature and relatively limited incentives for sponsoring research, in contrast to the economic and educational inequalities in developing countries. As a consequence, a comprehensive analysis of the research methodology or the reviewed literature is also carried out.

The study's central research question was framed as follows: "Does collaborative problem-based learning boost the metacognitive skills of chemistry students?" based on the research history I just described. Problem-based learning can improve chemistry students' metacognitive skills, as concluded by all four studies included in the systematic literature review in this study. Based on the SLR's triage of the most pressing concerns, it became clear that problem-based learning is an effective strategy for fostering metacognitive growth among chemistry students.

The fact that several PBL frameworks with diverse components are discussed in the research analysed in this study presents the first issue. The framework used in these studies is unquestionably crucial since it affects how PBL is used in both the classroom and in research. The issue arises when certain studies just take a few aspects of PBL into account in their framework and overlook the rest, Almost entirely neglecting PBL's essential components.

According to (Savery, 2015), PBL has five essential components: real-world situations, autonomous learning, student participation, teachers acting as facilitators, and the use of future professional abilities. Most studies merely describe PBL as a teaching method that gives students issues or cases to solve. Due to the explicit inclusion of the term "Problem Based" in the approach's name, the studies undertaken seem to simplify the PBL idea. Barrows (Barrows, 2002) has long cautioned against the error in oversimplification like this, but as shown by this study and a study carried out by Savery, the problem is still present in many studies undertaken internationally and in Indonesia (Savery, 2015). Despite the fact that research from Indonesia often don't undergo a thorough review procedure before publication, this demonstrates that the misunderstandings they have about PBL are widespread. How is it feasible for researchers to study and/or teach using the PBL technique when the researchers/teachers do not completely comprehend the notion of PBL learning? It is a significant conclusion of this finding.

The second problem is that not all of the research-relevant literature publications used reliable, validated components. The instrument validation process and/or the psychometric outcomes of the instruments used were only disclosed in one of the four studies—that by Haryani et al. As a result of the instrument's lack of validation by three further studies, including those by Tosun and Senocak ((Tosun, C. and Senocak, (2013), Muhali., (2014) and Ramdoniati, N., Muntari, and Hadisaputra, (2018)).

The fourth issue is that the collaborative approach, which is a key element of PBL, is not used by the four research that are comprehensively described in this paper. The written study as a whole prohibited chemistry students from working together to solve instances. The social constructivism at the core of the PBL method, according to Savery and Duffy (Savery, J. R., & Duffy, 1995), needs students to collaborate in order to develop solutions to issues via the coordination and exchange of solving ideas. The development of students' future professional abilities is one of the fundamental aims of the PBL method, and working in teams is one of these skills, according to Barrows (Barrows, 2002), who also stated that group work is crucial in PBL. Therefore, studies that do not involve group work do not comprehend the fundamental tenets and ultimate purpose of the PBL methodology.

Collaboration is essential in today's technologically advanced world, where regional boundaries are becoming more and more hazy. As instructors in higher education, lecturers must be aware of this and comprehend how PBL might help students get ready for upcoming global difficulties. According to Barrows and Savery's research, lecturers' roles in PBL are significantly more important than those in conventional techniques, even if they are distinct. To create a learning environment that promotes cooperation and provides instances that stay tough to excite students' learning enthusiasm, lecturers using the PBL technique need to be more cautious while engaging in social engineering. Scholars from all across the world developed the PBL approach, which has been used for about 50 years since Barrows initially proposed it. (Strobel, J., & Van Barneveld, 2019). PBL has been shown in several studies to enhance metacognitive skills, including those of chemistry students, without exception. Ironically, as this study's findings demonstrate, many instructors only have a flawed or incomplete knowledge of PBL. Lack of access to the most recent PBL material appears to be the major cause of educators' and researchers' misunderstandings. None of the research under examination includes references to famed PBL theorist Barrows or other well-known PBL supporters like Strobel and Barneveld, Savery and Duffy, etc. (Barrows, 2002). Thus, it is intended that PBL educators and researchers would have better access to the literature so they can keep up with the most recent discoveries and the agreement among PBL researchers.

The three studies under review did not use standardised measures of metacognitive ability due to accessibility issues. All the standard instruments are written in English, which could be a problem given that few Indonesian students are fluent. Most standard instruments require at least some familiarity with the English language, although some are more precise than others. The ability to communicate well in writing in English is also assumed. The standard metacognitive ability measure is therefore too difficult for Asian students who are not native English speakers and who lack familiarity with academic skills such as essay writing (Green, 2007), Sommers (Sommers, 2014) argues that in order to minimise cultural bias and to make the instruments more accessible to students worldwide, they must be adapted for use with students from diverse linguistic and cultural backgrounds. Sommers's claim was supported by the results of his systematic review, which demonstrated that Asian pupils generally had lower metacognitive skill scores than children from Western countries. This rating is more indicative of the assessment tool's inherent bias or disparity than of the students' own innate intelligence.

Cost restrictions are another factor that prevents Asia, especially Indonesia, from using standardised or commercial instruments. According to Hatcher (Hatcher, 2011), Baker University in the US has expertise utilising a variety of standard equipment and pays high prices for such instruments. The cost of using the equipment might be doubled since the organisation with the instrument license will charge for presenting the instrument and disclosing the measurement results.

#### 4. CONCLUSION

A thorough review of the literature revealed four studies that show problem-based learning improves chemistry students' metacognitive abilities. The critical notion of collaboration is not reflected in the PBL idea, which was analysed in the research (collaborative). Due to the scale or instrument the researcher used, the research is not standardised, validated, or evaluated, which raises questions about how much trust should be put in the research's conclusions. Future research is thus encouraged to use

a scale or instrument that has been standardised, measured, validated, and tested. Because this method of teaching constantly necessitates collaboration, PBL implementation should be done in a group setting. The results of the thorough literature analysis completed in this study have been added to the lengthy list of cooperative problem-based learning techniques used to enhance the metacognitive skills of chemistry students. It is time for Indonesia's higher education stakeholders, including the government, renowned academics, and professors at various universities, to integrate collaborative problem-based learning into national educational legislation and really apply it to the country's educational goals.

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