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The Influence of Problem-Based Learning (PBL) on Mathematics Learning: Systematic Literature Review

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Abstract
Problem-based learning (PBL) is one of the approaches that is believed can help in improving students' thinking skills and thus improve students' 21st-century learning skills. This study aimed to understand the influence of PBL on math learning by examining the existing literature. This study can help teachers to know the influence of PBL on math learning before implementing PBL in their teaching. Other than that, researchers can know the gaps in math learning methods, especially for the PBL method. The methodology used for this study was the PRISMA approach. A total of 20 articles from 2018 to 2022 have been obtained from two databases, SCOPUS and WOS, and were selected based on three stages in the PRISMA model, namely the identification, screening, and inclusion stages. The findings of the analysis indicate that implementing PBL can improve students' academic achievement in mathematics, improve students' understanding of topics in mathematics, improve students' thinking skills as well as improve students' ability to solve math problems. Furthermore, in terms of affective domains, implementing PBL can help promote students' self-learning and improve their group work and communication skills. Moreover, students' attitudes toward math learning became more positive after implementing the PBL. However, successfully implementing PBL requires students to participate in group activities actively. With that in mind, teachers are encouraged to build a learning environment that can promote students' involvement in PBL activities and help in their learning process. As a recommendation, further studies can be conducted to review in-depth the readiness of teachers to implement PBL in learning mathematics.
Keywords: Problem-Based Learning (PBL), Mathematical Learning, Influence, Systematic Literature Review, 21st-century Learning Skills

Introduction

Education nowadays emphasizes producing students who are skilled in the 21st century and have a holistic personality to meet the latest challenges to be globally competitive. In this regard, the focus of education has shifted from teacher-centered to student-centered. Education nowadays has a stronger emphasis on 21st-century learning, especially using thinking and communication in problem-solving. Math education focuses on developing students with cognitive skills, including problem-solving, reasoning, and creative and

innovative thinking. Problem-based learning (PBL) is one of the teaching strategies that is believed to improve students' 21st-century learning skills, especially high-order thinking skills (HOTS). This situation is evident as PBL is believed to help improve students' critical thinking skills (Aliyu, 2019) and increase students' motivation in problem-solving (Suwono & Dewi, 2019).

The PBL method was first implemented in K12 schools in the United States for various subjects in 1993 by Barrows and Kelson (Torp & Sage, 1998). However, PBL has become an innovative learning technique that is becoming increasingly popular in education worldwide (Silva et al., 2018). The PBL method involves five main steps: understanding the problem, discussion in the collaborative team, solution, reflection, and results (Barrows, 1996). In implementing PBL, students need to try to understand the problem, work with the group members in discussions, search for information from various sources, and apply the information found by the group members to solve the problem. Furthermore, students are given the opportunity and space to solve real-life problems by discussing in groups to find solutions through PBL. Thus, it is believed that implementing PBL in the learning process can improve students' problem-solving skills and group work skills in the process of solving problems in groups (Mokter, 2019).

With that, this study was carried out to systematically summarize the influence of problem-based learning (PBL) on mathematical learning. This systematic review was carried out based on the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 model. The main issues addressed in this paper are:

- What is the trend of research about PBL's impact on math learning, such as research design, participants, school level, and country population?
- What is the impact of PBL on math learning from cognitive and affective aspects?

Methodology

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 model has been used in this study. The procedure follows the PRISMA 2020 guidelines, which include three stages: identification, screening, and inclusion.

Identification

As reported in the PRISMA 2020 guidelines by Page et al (2021), the first stage is identification. Essential keywords in this review paper are Problem-Based Learning (PBL), influence, and learning mathematics. For a broader database, synonyms for related keywords have been used. Furthermore, field code functions and Boolean operators have been used to combine related keywords, as shown in Table 1. This combination of keywords facilitates searching literature that is closely related to and more relevant to the title of this study.

Table 1
The search string used for each database

Database	Search String
SCOPUS	TITLE-ABS-KEY (("problem-based learning") AND (effect* OR influence* OR efficient* OR impact* OR consequence* OR effectiveness) AND (math* OR "math* education"))
WOS	TS=(("problem-based learning") AND (effect* OR influence* OR efficient* OR impact* OR consequence* OR effectiveness) AND (math* OR "math* education"))

In this study, two primary databases are used to obtain data sources: SCOPUS and Web of Science (WOS). Through this selected database, a total of 627 relevant articles have been obtained and summarized in Table 2. Table 2 shows the number of articles encountered for different databases. However, after issuing the articles that were duplicated, 561 articles were identified.

Table 2
Number of articles encountered for each database

Database	Number of Articles
SCOPUS	415
WOS	212

Screening

After identifying the literature related to this study, the next stage is screening. Several selection criteria determine the eligibility and exclusion of an article in the study of this literature review. These selection criteria will effectively help screen the article that is more relevant to the study. The first criterion is the year of publication of an article. This literature review limits the year of publication of the article in the last five years to the most recent year, i.e., between 2018 and 2022. Other than that, only journal articles are included in this research, while other documents such as proceedings, systematic studies, and books have been excluded. Finally, articles with languages not in English or Malay have been excluded. Table 3 shows the summary of the selection criteria for this literature review.

Table 3
Summary of eligibility and exclusion criteria

Criterion	Eligibility	Exclusion
Year of Publication	Between 2018 and 2022	Before 2018
Document Type	Journal Articles	Proceedings, systematic studies, books
Language	English or Malay	Not English or Malay

As a result, this screening process has excluded 466 articles as they do not meet the selection criteria for this literature review. Based on the eligibility criteria, 95 articles have been filtered. In the next step, these articles have been assessed to determine whether the article meets the study's objectives. However, 18 articles were not included in this literature review because the articles were incomplete or could not be found in full articles. As a result, only 76 articles will be assessed in the next step to determine the articles' summary in this literature review.

The next step in the screening is to assess whether the relevant article is worthy of inclusion in the analysis. In this step, the article will be excluded from this literature review because it is unrelated to the study's objectives. To ensure the articles included in the analysis are related, the article has been carefully read by reading the header, abstract, or entire article. From this process, 56 articles unrelated to the impact of PBL on learning or mathematics are excluded. Finally, only 20 articles were included in this literature review.

Inclusion

This literature review is concerned with the influence of PBL on mathematical learning. Figure 1 shows the flow chart for identification, screening, and inclusion procedures based on the PRISMA 2020 model reserved by (Page et al., 2021). As a result, 20 articles selected from the SCOPUS and WOS databases could potentially be included in this literature review. Table 4 shows a summary of the 20 related articles.

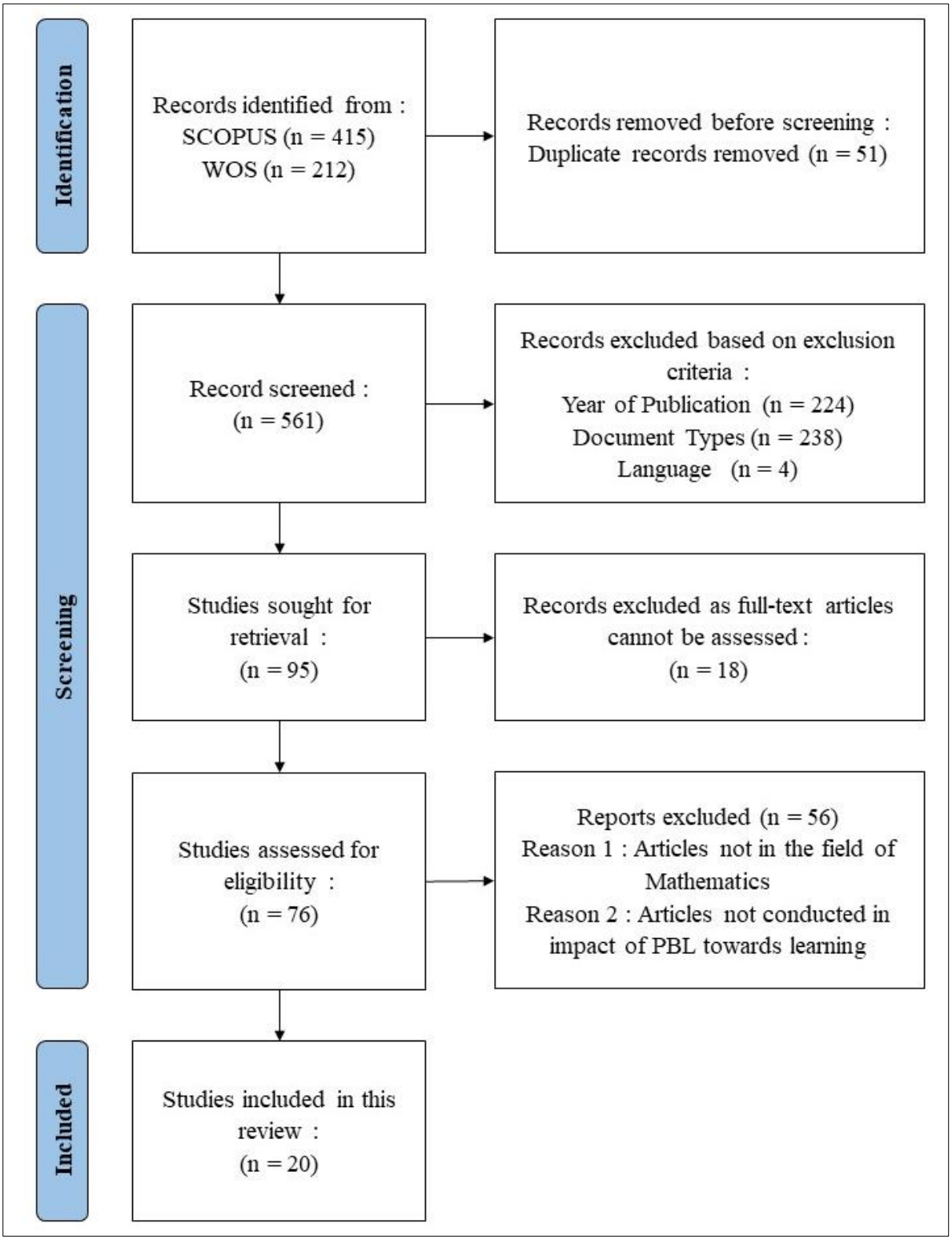

Figure 1. PRISMA 2020 model flowchart adapted from Page et al (2021)

Table 4

Summary of study findings

No	Author (Year)	Research Design	Study Participants	School Level	Country
1	Kong and Matore (2022)	Quantitative	Students	Secondary School	Malaysia
2	Kamid et al. (2021)	Mixed Method	Students Teachers	Secondary School	Indonesia
3	Mairing (2021)	Quantitative	Students	University	Indonesia
4	Mujumdar et al (2021)	Quantitative	Students	University	India
5	Amin et al (2021)	Mixed Method	Students	Secondary School	Indonesia
6	Din et al (2020)	Qualitative	Students	University	Malaysia
7	Tawfik et al (2020)	Quantitative	Students	University	United State
8	Fitriani et al (2020)	Quantitative	Students	Secondary School	Indonesia
9	Ramli et al (2020)	Quantitative	Students	Secondary School	Malaysia
10	Ahdhianto et al (2020)	Quantitative	Students	Primary School	Indonesia
11	Arifin et al (2020)	Quantitative	Students	Secondary School	Indonesia
12	Maskur et al (2020)	Quantitative	Students	Secondary School	Indonesia
13	Prastiti (2020)	Quantitative	Students	Secondary School	Indonesia
14	Darhim et al (2020)	Quantitative	Students	University	Indonesia
15	Navy and Kaya (2020)	Mixed Method	Teachers	Primary School	United State
16	Syaiful et al (2019)	Quantitative	Students	Secondary School	Indonesia
17	Rahmi et al (2019)	Quantitative	Students Teachers	Secondary School	Indonesia
18	Al Said et al (2019)	Qualitative	Teachers	Primary School	Qatar
19	Ramadhani et al (2019)	Quantitative	Students	Secondary School	Indonesia
20	Ertikanto et al (2018)	Quantitative	Students	University	Indonesia

Study Findings

Selected Article Background

Before the influence of PBL was analyzed, the background of these selected articles was analyzed according to the research design, study participants, school level, and the country in which the study was carried out.

Research Design

Of the 20 articles selected, most of the articles with a 75% percentage take the form of quantitative studies. In addition, two articles (Din et al., 2020; Fitriani et al., 2020) were carried out using a qualitative approach, while three articles (Amin et al., 2021; Kamid et al., 2021; Navy and Kaya, 2020) used the mixed method, which combines quantitative design and qualitative design. Figure 2 shows the summary of the research design used for the 20 articles included in this literature review to examine the influence of PBL on Mathematics learning.

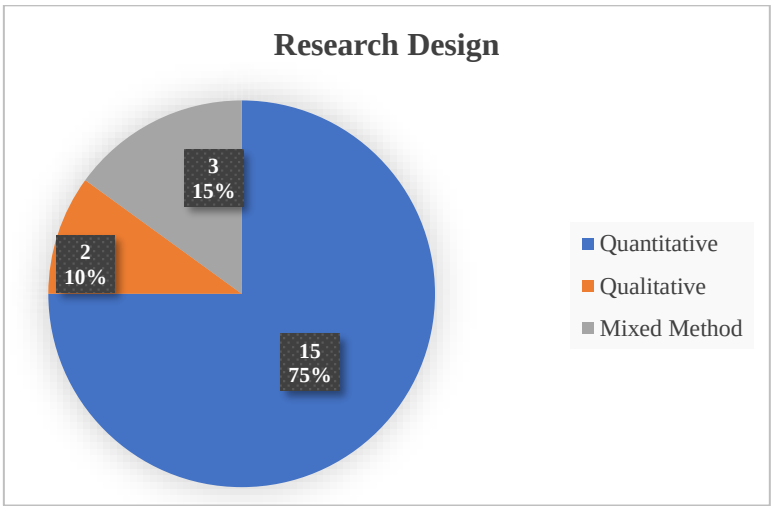

Figure 2. Research design

Study Participants

Regarding study participants, 18 of 20 studies involved students using questionnaires or pre-test and post-test. In addition, interviews and observations were carried out for four articles involving teachers to collect data. 2 of these 20 articles (Kamid et al., 2021; Rahmi et al., 2019) involved students and teachers in their study. Table 5 summarizes the study participants for these 20 articles included in this literature review to examine the effect of PBL on mathematics learning.

Table 5
Study Participants

Study Participants	Article Numbers	Author (Year)
Students	18	Kong and Matore (2022); Kamid et al (2021); Mairing (2021); Mujumdar et al (2021); Amin et al (2021); Din et al (2020); Tawfik et al (2020); Fitriani et al (2020); Ramli et al (2020); Ahdhianto et al (2020); Arifin et al (2020); Maskur et al (2020); Prastiti (2020); Darhim et al (2020); Syaiful et al; (2019); Rahmi et al (2019); Ramadhani et al (2019); Ertikanto et al (2018)
Teachers	4	Kamid et al (2021); Navy and Kaya (2020); Rahmi et al (2019); Al Said et al (2019)

School Level

Of the 20 articles selected, it was found that most studies were carried out at the university with a percentage of 55%. In contrast, three studies (Ahdhianto et al., 2020; Al Said et al., 2019; Navy and Rich, 2020) were carried out in primary schools, while six studies (Arifin et al., 2020; Fitriani et al., 2020; Kamid et al., 2021; Maskur et al., 2020; Prastiti, 2020; Syaiful et al., 2019) were carried out in secondary schools. Figure 3 shows the school level for the 20 articles included in this literature review to examine the influence of PBL on Mathematics learning.

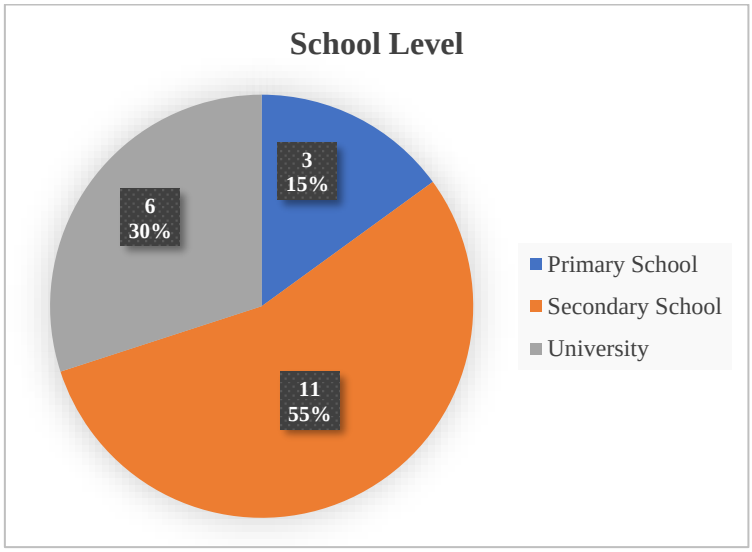

Figure 3. School Level

Country Population

Figure 4 shows the population of countries that study the influence of PBL on the learning of Mathematics. Of these 20 articles, Indonesia has conducted most studies to study the influence of PBL on math learning, which is 65%. Next, three studies (Din et al., 2020; Kong and Matore, 2022; Ramli et al., 2020) were conducted in Malaysia, while two studies (Navy and Kaya, 2020; Tawfik et al., 2020) were conducted in the United States. Moreover, 1 study

(Mujumdar et al., 2020) was conducted in India, and another was conducted in Qatar (Al Said et al., 2019).

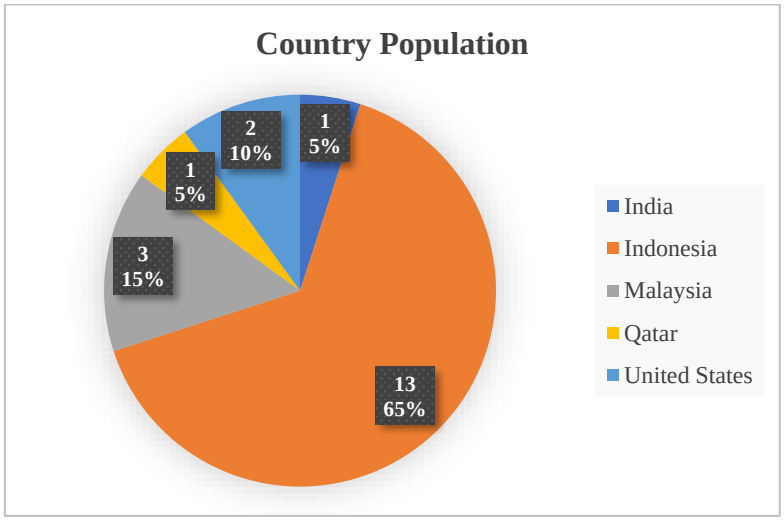

Figure 4. Country population

Influence of PBL on Mathematical Learning

In this study, 20 articles were analyzed to examine the influence of PBL on mathematical learning. Based on the analysis of the study, the implementation of the PBL method will affect the Students from 2 aspects, namely the cognitive aspect and the affective aspect. Table 6 shows the summary of the influence of PBL on mathematics learning.

Table 6 Summary of the influence of PBL on the learning of mathematics

No	Author (Year)	Cognitive Aspects				Affective Aspects			
		Academic Achievements	Students Understanding	Thinking Skills	Problem Solving Skills	Attitude	Self-Learning	Communication Skills	Group Work Skills
1	Kong & Matore (2022)	√				√			
2	Kamid et al (2021)	√		√	√				
3	Mairing (2021)	√	√		√				
4	Mujumdar et al (2021)	√							
5	Amin et al (2021)				√				
6	Din et al (2020)		√		√		√		√
7	Tawfik et al (2020)		√	√			√		
8	Fitriani et al (2020)				√		√		
9	Ramli et al (2020)	√		√	√				
10	Ahdhianto et al (2020)			√	√				
11	Arifin et al (2020)			√					
12	Maskur et al (2020)			√					
13	Prastiti (2020)	√			√				
14	Darhim et al (2020)			√	√				√
15	Navy & Kaya (2020)		√						
16	Syaiful et al (2019)				√	√		√	
17	Rahmi et al (2019)								
18	(Al Said et al., 2019)			√	√	√	√	√	√
19	Ramadhani et al (2019)	√				√		√	√
20	Ertikanto et al (2018)	√		√					
	Total	8	4	9	11	4	4	3	4

PBL Influence on Cognitive Aspects

In cognitive aspects, the implementation of PBL can improve students' achievement in mathematics, improve students' understanding of topics in mathematics, improve students' thinking skills, and improve students' ability to solve math problems. A total of 8 articles discussed the improvement of academic achievement, 4 discussed the improvement of students' understanding, 9 discussed the improvement of students' thinking skills, and 11 discussed the improvement of students' ability in problem-solving. Figure 5 summarizes the influence of PBL from the cognitive aspect.

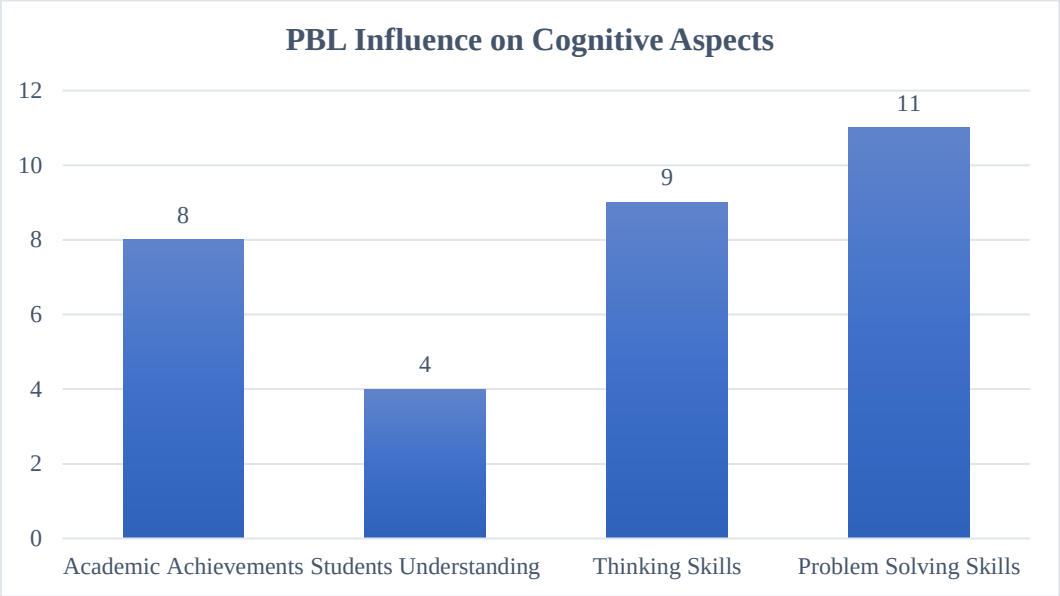

Figure 5. The influence of PBL from cognitive aspects

Through the analysis of 20 articles in question, a total of 8 articles discussed *the improvement of students' academic achievement in mathematics*. In this context, five studies were conducted in secondary school. Applying the PBL method creates a better learning outcome than conventional teaching methods (Kong & Matore, 2022; Prastiti, 2020; Ramli et al., 2020). Teachers involved in the study of Kamid et al (2021) also argue that ethnomathematics learning methods integrated with the PBL model improved students' learning outcomes more effectively. Furthermore, the results of learning mathematics for students that taught using the PBL method integrated with flipped classrooms experienced a significant improvement compared to conventional learning (Ramadhani et al., 2019).

Apart from that, three studies conducted at the university also show an increase in students' academic achievement. Mujumdar et al (2021); Ertikanto et al (2018) concluded that the introduction of the PBL model had a significant influence on students' learning outcomes. Furthermore, PBL learning methods integrated with videos and worksheets also enhance students' academic achievement as this method encourages students to engage actively (Mairing, 2021). Thus, it can be said that the PBL model can influence students' academic achievement, whether applied directly or integrated with other methods.

As for the student's understanding, four studies show an *increase in students' understanding* through the PBL method. One of the studies (Navy & Kaya, 2020) shows that the PBL method can improve students' understanding of topics in mathematics in primary school by helping them connect learning with their real life. Moreover, three other studies have been conducted at the university. University students taught using PBL performed highest in understanding mathematical concepts compared to the case-based learning and the conventional method (Tawfik et al., 2020). Moreover, integrating PBL with videos and worksheets can build a meaningful understanding in students because students are actively learning through this method (Mairing, 2021). Also, integrating PBL with the inverted classroom can give students a deeper and more precise understanding of the Mathematics syllabus (Din et al., 2020).

In addition, 9 studies show the influence of PBL in *improving students' thinking skills*. Implementing PBL in learning mathematics can improve students' thinking skills (Arifin et al., 2020; Darhim et al., 2020; Ertikanto et al., 2018) and creative thinking skills (Ertikanto et al., 2018; Maskur et al., 2020). A study conducted by Tawfik et al (2020) on university students found that PBL helps develop students' reasoning skills.

If students' thinking skills are improved, their ability to solve math problems will also be affected. Four studies show the influence of PBL in *improving students' thinking skills and ability to solve math problems*. First, PBL effectively improves the thinking skills of students in primary school and indirectly improves students' ability to solve mathematical problems (Ahdhianto et al., 2020). This view is consistent with the teachers' viewpoint that PBL is a learning method that can help students enhance their ability to think and solve mathematical problems (Al Said et al., 2019). Besides, the PBL method will help students solve mathematical problems as it can improve their creative thinking skills (Ramli et al., 2020). Also, the study by Kamid et al (2021) shows that the ethnomathematics learning method integrated with the PBL model improves students' thinking and problem-solving skills more.

Furthermore, seven studies showed the influence of PBL in *enhancing kids' mathematical problem-solving abilities*. Implementing PBL can enhance the ability of secondary school students to solve mathematical problems effectively (Prastiti, 2020; Syaiful et al., 2019). Rahmi et al. (2019) found that learning to use PBL-based devices significantly impacted students' ability to solve math problems. They also revealed that math problem-solving skills for students studying with PBL implemented using mobile devices are higher than in conventional learning. Furthermore, integrating PBL with the predict-observe-explain (POE) approach is more effective in improving students' problem-solving ability than simply using a POE approach or conventional learning (Fitriani et al., 2020).

Influence of PBL from Affective Aspects

In terms of affective aspects, implementing PBL helps improve students' attitudes towards mathematics, self-learning, communication, and group work skills. Based on the analysis, four articles discuss students' attitudes toward mathematics to be positive through the implementation of PBL, and four articles discuss the influence of PBL in promoting students' self-learning in mathematics. In addition, three articles discuss the improvement of communication skills through the implementation of PBL, while four articles discuss the improvement of group work skills through the implementation of PBL. Figure 6 summarizes the influence of PBL from the affective aspect.

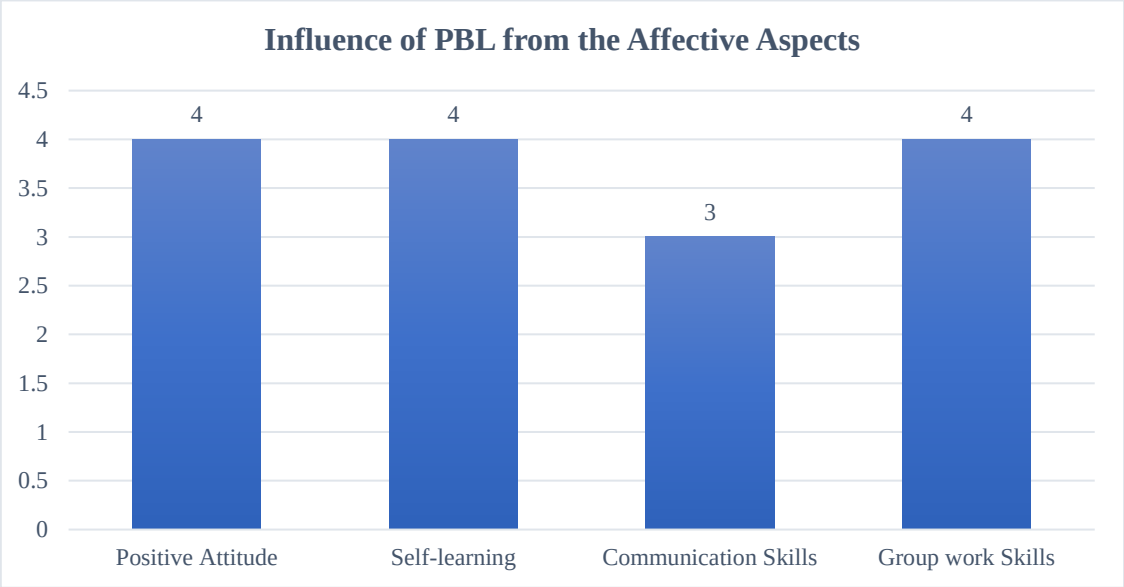

Figure 5. The influence of PBL from affective aspects

Through the analysis of the 20 articles, four articles discussing the implementation of PBL can positively influence *students' attitudes toward mathematics*. In this context, three studies were conducted in secondary school, while another was conducted in primary school. The primary school teachers involved in the study believe that PBL is a practical approach to benefit students' learning by increasing their interest in learning mathematics through the PBL approach (Al Said et al., 2019). Moreover, implementing PBL makes students feel more enthusiastic and motivated to participate in learning mathematics in the classroom (Ramadhani et al., 2019). As a result, PBL affects the development of a better attitude of students toward mathematics (Kong & Mohd Matore, 2022; Syaiful et al., 2019).

Next, four articles discuss the influence of PBL in *promoting self-learning*. The study by Al Said et al (2019) found that implementing PBL can help promote self-learning for primary school students. Fitriani et al (2020) believe that integrating PBL with the predict-observe-explain (POE) approach is more effective in promoting the self-learning of secondary school students than simply using the POE approach or conventional learning. As for the university, students who learn mathematics through the PBL approach showed higher self-learning than conventional learning (Din et al., 2020; Tawfik et al., 2020).

In addition, three articles discussed the influence of PBL on students' *communication skills*, especially in mathematics. The implementation of PBL is more effective than conventional learning in improving the communication skills of students in secondary school in mathematics (Ramadhani et al., 2019; Syaiful et al., 2019). Primary school teachers also argue that implementing PBL helps improve students' communication skills in mathematics (Al Said et al., 2019).

The implementation of PBL requires students to communicate in pairs or *discuss in groups*. Thus, learning mathematics through the PBL approach can promote students' teamwork skills (Al Said et al., 2019). Students in secondary school who were involved felt more eager to have a discussion in the group during PBL activities because they could work

together to find information and find answers. Implementing PBL in mathematics in university can also help promote students' group work skills (Darhim et al., 2020; Din et al., 2020).

Discussion

The implementation of the PBL method can help in improving the academic achievement of students in secondary school (Kamid et al., 2021; Kong & Matore, 2022; Prastity, 2020; Ramadhani et al., 2019; Ramli et al., 2020) or university (Ertikanto et al. 2018; Mairing 2021; Mujumdar et al. 2020). However, the influence of implementing the PBL method on improving primary school academic achievement is still unclear. Thus, further studies can be conducted on students in primary school to examine the influence of PBL implementation on students' academic achievement. Furthermore, implementing PBL can also improve students' understanding as students can connect learning with their real life (Navy & Rich, 2020). In addition, students need to search for information on problem-solving (Mairing, 2021). Thus, implementing PBL is said to help students understand mathematical concepts and increase their involvement in learning.

Implementing PBL requires students to think critically to solve a problem related to them given by teachers. With that in mind, PBL influences students' thinking skills, especially critical thinking (Arifin et al., 2020; Darhim et al., 2020; Ertikanto et al., 2018) and creative thinking (Ertikanto et al., 2018; Maskur et al., 2020). Furthermore, as Tawfik et al (2020) have indicated, learning through the PBL method requires students to use reasoning to solve mathematical problems. Therefore, if students' skills are improved, their ability to solve math problems will be directly improved. Thus, it is believed that the PBL method effectively improves students' ability to solve mathematical problems (Ahdhianto et al., 2020; Al Said et al., 2019; Kamid et al., 2021; Ramli et al., 2020).

In terms of the affective aspect, the attitude and motivation of students in learning mathematics have been enhanced through the implementation of PBL (Al Said et al., 2019; Kong & Mohd Matore, 2022; Ramadhani et al., 2019; Syaiful et al., 2019) as they engage themselves in finding the correct answers and solutions to a problem. In addition, their self-learning is also encouraged because they have familiarized themselves with the search for this solution (Al Said et al., 2019; Din et al., 2020; Fitriani et al., 2020; Tawfik et al., 2020). As they face a problem in the future, they will use their way of finding the solution that they are in their daily lives.

In addition, implementing this PBL also influences students' ability to interact socially. PBL can improve the communication skills of students (Al Said et al., 2019; Ramadhani et al., 2019; Syaiful et al., 2019) as well as teamwork skills (Al Said et al., 2019; Darhim et al., 2020; Din et al., 2020; Ramadhani et al., 2019). The implementation of PBL encourages students to find solutions to problems through discussion in pairs or groups. Thus, communication and teamwork skills can indeed be improved through implementing PBL. However, studies on educators' readiness to guide students in PBL activities or provide a learning environment that can encourage discussion between students are still lacking. With that, further studies can be carried out to identify the readiness of educators to implement PBL.

Conclusion

This systematic review has analyzed 20 articles selected from the SCOPUS and WOS databases to examine the influence of problem-based learning (PBL) on mathematical learning. Based on these 20 articles, the results show that implementing PBL can positively influence students' mathematics learning from cognitive and affective aspects. Implementing PBL can improve students' academic achievement in mathematics, understanding of topics in mathematics, understanding of topics in mathematics, and thinking skills, in addition to improving students' ability to solve math problems. In addition, students' attitudes towards mathematics became more positive after implementing the PBL. Implementing PBL also promotes students' self-learning and improves group work and communication skills, especially in group activities.

Overall, the influence of PBL on math learning is favorable not only in aspects of cognitive but also affective. Therefore, teachers are encouraged to use PBL in Mathematics teaching and learning sessions to benefit students in the cognitive and affective domains. However, successfully implementing PBL requires students' active involvement in group activities. With that in mind, teachers must build a learning environment that can increase students' engagement in PBL activities and guide their learning. As a recommendation, further studies can be conducted to review in-depth the readiness of teachers to implement PBL in learning mathematics.

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