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Systematic Literature Review: Does Problem Based Learning Model Effectively Improve Mathematical Reasoning Ability?

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Abstract

Mathematical reasoning ability refers to a person's ability to use logic and critical thinking in a mathematical context. However, in Indonesia, students' mathematical reasoning abilities from elementary school to tertiary college. Therefore, a more vary learning model is needed, such as the Problem Based Learning (PBL) model, to improve students' mathematical reasoning abilities. PBL focuses on solving real and relevant problems collaboratively. The research method used in this article is Systematic Literature Review (SLR). There are 35 articles that will be explained and are in accordance with this research from 2017-2023. The main findings of this study are that the PBL model effectively improves students' mathematical reasoning across levels and academic ability levels, better for medium and low ability students than the TAI model. PBL also positively affects high school students' metacognitive skills and metacognitive awareness is positively related to mathematical reasoning. The use of LKS/LKPD is effective, but E-LKPD requires further development, while factors such as student background and learning experience as well as additional teaching materials such as flipped classroom still need further exploration.

Keywords: Mathematical Reasoning Ability, Problem Based Learning, Systematic Literature Review.

Introduction

Mathematical reasoning ability in the context of education can help achieve the Sustainable Development Goals (SDGs) agenda. According to Febiyanti et al. (2022), the SDGs is a global development agenda that was agreed upon by United Nation (UN) member states in 2015. The SDGs consist of 17 goals that are implemented nationally in Indonesia through government policies. The SDGs aim to build a more sustainable world that includes economic progress, health, education, and the environment. The SDGs require participation and cooperation from all parties, including communities, governments, and international organizations (Febiyanti et al., 2022).

Quality education is one of the 17 goals of the SDGs that is related to mathematical abilities, specifically reasoning ability. Mathematical reasoning ability is an important skill in education, especially in mathematics education. Mathematics education can help develop critical, analytical, and logical thinking skills. Additionally, decent work and economic growth is also one of the SDGs goals that is related to reasoning ability. Mathematical reasoning ability can help develop the skills necessary for jobs in fields such as science and technology, finance, and data analysis. Therefore, based on the two SDGs goals that have been explained, this research is relevant to these SDGs.

Increasing mathematical reasoning ability can also improve student learning outcomes. This is evidenced by research conducted by Abidah et al. (2021), there was an increase in students' mathematical reasoning ability through the Problem Based Learning (PBL) model, where in the first cycle the average value of students' mathematical reasoning ability was 68.17. Then, in the

second cycle the average value of students' reasoning ability was 78.59. The average score of the third cycle final test was 84.95. Based on these results, students' reasoning skills continue to increase in each cycle and the average score in the third cycle is included in the “very good” category. This shows that increasing mathematical reasoning ability can help improve the quality of education. With quality education, everyone can get a decent job and economic growth. A quality education allows everyone to have the abilities and skills needed in a job. A workforce that has good mathematical reasoning skills tends to be able to meet the demand for higher and higher quality jobs. Thus, it can also support economic growth. In today's digital and global era, many economic sectors rely on data analysis, mathematical modeling, and solutions based on mathematical concepts. Everyone with good mathematical reasoning skills can contribute to innovation, productivity and efficiency in various economic sectors that can drive economic growth. Therefore, it can be concluded that both SDGs goals are still related to mathematical reasoning skills.

Mathematical reasoning ability refers to a person's ability to use logic and critical thinking in a mathematical context. This is because reasoning ability is important for understanding mathematical concepts and solving everyday math problems (Anggraini & Rejeki, 2021). Reasoning ability, according to Sumarmo (Permana & Sumarmo, 2007), is the process of thinking to draw conclusions. This is supported by the definition of reasoning ability according to NCTM (2000), which states that reasoning ability involves drawing logical conclusions based on evidence or preconceived assumptions. Reasoning can be considered as developing an understanding of a situation, context, or concept by connecting it to existing knowledge or past experiences. Based on these definitions, it can be said that reasoning is a process where a person thinks logically to arrive at a conclusion.

Mathematical reasoning ability has several indicators. The mathematical reasoning indicators used are based on NCTM (2000), which include: (1) analyzing the problem, which emphasizes students' ability to understand the given mathematical problem and identify relevant information; (2) applying strategies, which involves selecting and using appropriate methods or techniques to solve mathematical problems; (3) seeking and using connections, which involves relating mathematical concepts to students' daily knowledge or experiences and finding relationships between different mathematical concepts; and (4) reflecting on solutions, which involves re-examining the steps taken to solve the problem and determining if the solution is reasonable and efficient. By considering all these indicators, students can develop a deeper mathematical reasoning ability that will enable them to succeed in solving mathematical problems and applying mathematics in everyday life.

The results of the Programme for International Student Assessment (PISA) organized by the Organization for Economic Cooperation and Development (OECD) in 2022 globally decreased scores, including in Indonesia. However, Indonesia's ranking actually rose 5 positions in the field of mathematics. Although Indonesia's ranking rose 5 positions in math, the 2022 PISA score was still lower than in 2018, with an average of 366 compared to the PISA standard of 472 (Schleicher, 2023). In 2018, Indonesia ranked 73 out of 79 countries with an average score of 379 out of a standard of 489 (Tohir, 2019). Seeing this, reasoning ability is one of the factors that make Indonesia still rank low because the questions issued by PISA emphasize students' reasoning skills, problem-solving, and argumentation rather than calculation and memory (Habibi & Suparman, 2020). This decline in scores is largely due to the Covid-19 pandemic which has caused a knowledge and skills gap (learning loss) (Widyasari et al., 2022). As many as 43% of learners have middle to lower social levels, which affects their learning facilities (Budiasti et al., 2024).

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The reasoning ability of students in Indonesia, especially at the junior high school level, is still relatively low (Hermawan & Hidayat, 2018). Some cases show that the reasoning ability of junior high school students in solving problems related to the pythagorean theorem shows that 20.63% of students have low reasoning ability (Ramdan & Roesdiana, 2022). In addition, Nurhalin & Effendi (2022) found that solving problems related to the system of linear equations of two variables showed that 2 out of 20 students (10%) had low-level mathematical abilities. In general, these studies show that some junior high school students have low mathematical reasoning ability in various mathematics topics or materials.

Malaysia is one of the countries that still discusses reasoning skills. Reasoning ability is a key component in the Low-Level Mathematical Thinking Skill (LLMTS) that must be mastered by students, as stated in the Malaysian Education Blueprint 2013-2025 (Arshad et al., 2017). However, research shows that Malaysian students still struggle to apply the concepts in everyday life despite scoring high in written examinations. The 2022 PISA score results show that mathematical reasoning ability in Malaysia is still low in mathematics, which is 409 compared to the average score set by PISA, which is 472 (Schleicher, 2023).

To overcome the problem of low mathematical reasoning ability in students, a more varied learning model is needed. Research by Herman (2007) showed that the PBL model was effective in improving mathematical reasoning ability, with an increase in the average test results from 7.35 in the first cycle to 7.90 in the third cycle. According to Muhson (2009), the PBL model is a learning model that starts the learning process with a problem, so that students can gather information and create new knowledge. Therefore, it can be concluded that the PBL model is a learning model that involves students directly in solving unstructured contextual problems to create new knowledge. Research conducted by Suryani et al. (2023), strengthened the effectiveness of PBL with an average student pretest score of 43.52, which increased to 81.38 after using the PBL model assisted by Student Worksheets (LKS). The research shows that the PBL model is effective in improving students' mathematical reasoning ability.

The novelty of this study is seen through the wide coverage of materials from primary to higher education which is rarely found in other studies. By highlighting the potential application of the PBL model at various levels of education, this study also introduces new insights into the relationship between metacognitive awareness and mathematical reasoning ability, particularly in the Malaysian educational context. In addition, this study underscores the importance of considering various other factors, such as educational background and student characteristics, in optimizing the effectiveness of PBL models. Overall, this study makes a significant contribution by expanding the scope of the material, exploring the link between metacognition and mathematical reasoning, as well as encouraging further studies related to factors that influence learning outcomes.

Method

This research uses the Systematic Literature Review (SLR) research method. According to Torres-Carrion et al. (2018), SLR is a methodology used to conduct a systematic literature review in a particular field of science. This methodology aims to provide a structured approach to searching and analyzing research works. In addition, Kitchenham et al. (2009) state that SLR is a systematic research method carried out by searching, evaluating, and analyzing various literature reviews that have been published within a certain period of time. So, it can be concluded that SLR is a systematic and structured method for reviewing and analyzing literature in a particular field. The article search was conducted using the keywords "mathematical reasoning ability" and "problem-based learning". The stages in analyzing data using this literature

study are (1) finding relevant literature, (2) compiling rough ideas and determining main themes, (3) creating an outline structure, (4) compiling research questions and directing reference searches, (5) summarizing the main findings and making conclusions (Cahyono et al., 2019). In this study, the stages carried out are (1) Literature Search: The first step taken in this research is to search for literature sources that are relevant to the topic under study. This process can be done using applications such as Publish or Perish to find suitable scholarly articles, (2) Article Selection: Once the articles are found, the next step is to select them. This selection is done based on the suitability of the article topic with the desired research focus, namely reasoning ability and problem-based learning, (3) Essential Data Collection: From the selected articles, important data or information is collected. This data will later be analyzed to understand the main points discussed in each article, and (4) Summarizing Findings and Conclusions: The final step is to summarize the main results found from the articles, then make conclusions that reflect the results of the entire literature analyzed.

Based on the results of the literature search, 35 articles were obtained that could be included in the analysis stage. Reviewed from the year of publication of articles on mathematical reasoning ability and PBL models from 2017-2023. The most published articles were found in 2023, with 11 articles. Meanwhile, in 2017, 2018, and 2019, only 1 corresponding article was found each. The results are presented in the graph in Figure 1.

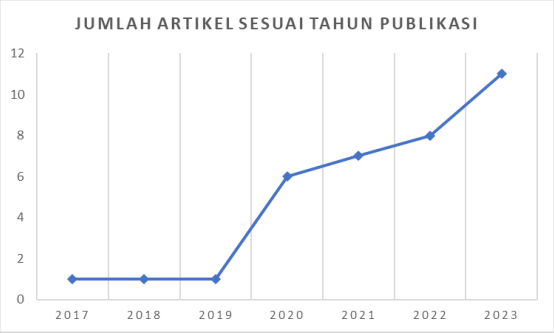


Figure 1. Number of Articles by Year of Publication

The articles used in this research investigate the relationship between different articles using VOSViewer. In VOSViewer, the title and abstract are utilized for visualization. The visualization generated by VOSViewer is displayed in Figure 2.

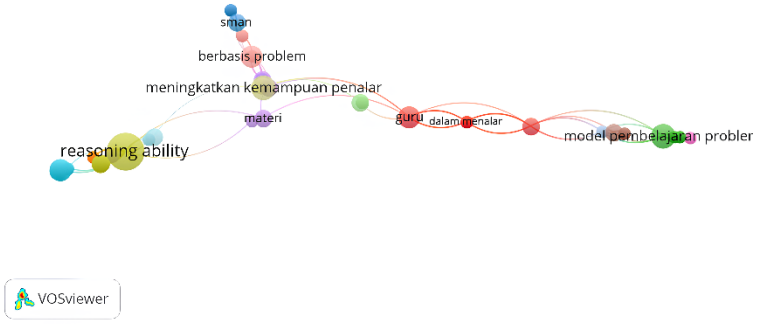


Figure 2. VOSViewer Visualization

Figure 2 above shows a visualization map of the relationships between keywords or terms that appear in the literature related to the PBL model and reasoning abillity. Based on the figure, several groups of interconnected keywords can be identified based on the color and connection between points. The following is a data analysis method based on VOSViewer:

1. Search for the main keyword:

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a) *Reasoning ability* is one of the most prominent keywords in this analysis. This indicates that many studies link reasoning ability with PBL models.
b) *Meningkatkan kemampuan penalaran* emerged as one of the central themes indicating the focus of these studies on efforts to improve reasoning ability through specific learning models.

2. Search for keyword networks:
   a) The keyword model *pembelajaran problem-based learning* is closely related to other keywords such as teacher, material, and problem-based. This suggests that research on the application of PBL models is often related to the role of teachers, subject matter, and PBL models in the teaching and learning process.
   b) *SMAN* indicates that this research may also be related to the context of education at the senior high school level. This is relevant to the scope of research mentioned in this study on the application of PBL at various levels of education.
3. Looking for links to the novelty of the research:
   a) This figure also supports the point of novelty of this research, which is that this research does not only cover one level of education, but from basic education to higher education. It can be seen from the figure that there is a focus on the application of PBL at various levels of education which is rarely found in other studies.
   b) In addition, the association of *guru dalam menalar* shows an emphasis on the role of teachers in guiding students in the reasoning process, which is relevant to the research emphasis on the importance of considering students' educational background and characteristics.
   c) The *materi* in the visualization also indicated that a wide range of materials was a concern. This is in line with the article that mentions the novelty in this study related to the breadth of the material covered.
4. Other factors that influence PBL:
   a) Keywords such as teacher in the network suggest that research is also looking at non-academic factors that can influence the effectiveness of PBL models, such as the role of the teacher and how students are involved in facilitating the reasoning process.

Overall, the VOSviewer visualization provides an overview of how key terms such as reasoning ability, PBL and teachers relate to each other in the literature. However, future research could further enrich this discussion by adding new factors such as metacognition, as well as expanding the scope of the analysis to different levels of education, which is not fully reflected in this visualization.

Results

The PBL model is applied at various levels of education, from elementary school to college. It is one way to improve students' mathematical reasoning ability. Based on the articles found, in the last 7 years the application of the PBL model is dominated by efforts to improve students' mathematical reasoning ability at the junior high school / MTs level, which is as much as 40%. The number of articles based on education level is presented in the pie chart in Figure 3.

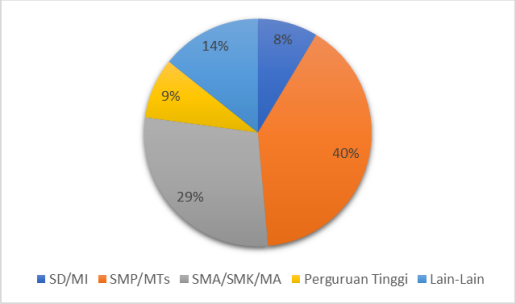


Figure 3. Number of Articles by Education Level

Based on Figure 3, the articles used in this study consist of various levels of education. At the junior high school / MTs education level, articles about the PBL model to improve mathematical reasoning ability were found the most, namely 40%. Then, articles at the SMA/SMK/MA education level were 29%. In SD/MI, only 8% of articles were found and 9% in higher education. The rest, as many as 5 articles found were classified into other categories, as much as 14%. The miscellaneous category is an article of the type, meta-analysis, literature review, and literature analysis. Research at the elementary, junior high, high school, and college education levels used primary data or first data. While other categories use secondary data or second data.

Research results from 35 articles that have a variety of research methods show the results that PBL models can have a positive effect on improving students' mathematical reasoning ability than conventional learning. The positive effect was obtained from various levels of education from elementary school to college. However, the articles are limited to the research subjects and research methods used, so the generalization of the research results is limited. The explanation of each article will be presented in table 1.

Table 1. Articles on mathematical reasoning ability and PBL model 2017-2023

No	Title	Authors, Year	Research Gap	Main Findings & Future Research
1.	Analisis Kemampuan Penalaran Matematis Siswa melalui Model *Problem Based Learning*	(Nababan, 2020)	This study only examines the impact of the PBL model on the metacognitive skills of high school students.	The PBL model improves the metacognitive skills of high school students, as evidenced by the regression coefficient value. Future research should involve more schools and subjects and consider other factors that affect these skills.
2.	Analisis Meta: Pengaruh Model Pembelajaran *Problem Based Learning* (PBL) Terhadap Kemampuan Penalaran Matematis Siswa	(Rohmatulloh et al., 2022)	Only a few studies have examined the effect of the PBL model on the mathematical reasoning ability of junior high school and high school students in Indonesia.	The application of the PBL model is effective in improving students' mathematical reasoning, exceeding traditional methods in motivation, concept mastery, critical thinking, creativity, and mathematical communication. It is recommended to expand the study to different levels of education and geographical areas, as well as explore other factors that influence the effectiveness of the PBL.
3.	Literature Study of the Influence of Problem-Based Learning Model on Students' Mathematical Reasoning Ability	(Nuryami, 2023)	Research on the effect of PBL models on motivation, mastery of mathematical concepts, and application of knowledge in real situations is still lacking.	The PBL model improves students' mathematical reasoning better than traditional methods. Teachers can consider the PBL model to improve learning outcomes. Future research needs to evaluate its effect on motivation, concept mastery, and knowledge application.
4.	Model *Problem Based Learning* (PBL) Berbantuan Lembar Kerja Siswa (LKS) untuk Meningkatkan Kemampuan Penalaran dan Pemecahan Masalah Matematis Siswa	(Suryani et al., 2023)	This study did not consider student characteristics, teacher experience, or the learning environment. Further research is needed to comprehensively understand the effectiveness of PBL with LKS in improving students' math skills.	The PBL model with LKS improves students' mathematical reasoning and problem solving more significantly than direct learning. Further research needs to consider other factors for a more comprehensive understanding.
5.	Model *Problem Based Learning* dan Prespektif Gender terhadap Kemampuan	(Gunur & Ramda, 2020)	There is no significant interaction between the PBL approach in learning and gender on students' mathematical reasoning ability.	The PBL model is more effective in improving students' mathematical reasoning ability than conventional learning. There is no difference in ability between male and female students, and there is no interaction

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	Penalaran Matematis Siswa			between the learning model and gender on students' mathematical reasoning ability. Future research can explore other factors that affect students' mathematical reasoning ability, such as learning motivation, learning environment, and evaluation methods in mathematics learning.
6.	Model *Problem Based Learning* Meningkatkan Kemampuan Penalaran Matematis Siswa SMPN 2 Siantan Kepulauan Riau	(Permana & Muzdalifah, 2023)	In the first cycle, only 35.71% of students obtained a satisfactory level of reasoning, while 64.29% of students were still below expectations.	Learning using the PBL model improved students' mathematical reasoning ability with better learning achievement and positive responses, demonstrating its effectiveness in this regard. Future research could involve more subjects and educational contexts to strengthen these findings.
7.	Penerapan Model *Problem Based Learning* terhadap Kemampuan Penalaran Matematis Siswa	(Dewi & Ansori, 2023)	There has been no comprehensive analysis using meta-analysis or meta-synthesis methods to explore the results of previous studies.	The PBL model is effective in improving grade 5 students' mathematical reasoning ability by learning from real-world problems, working in small groups, and demonstrating understanding through products or performance. Its implementation also has the potential to improve learning outcomes in other areas. It is recommended to conduct a comprehensive analysis using meta-analysis or meta-synthesis methods in future research.
8.	Penerapan Model *Problem Based Learning* untuk Meningkatkan Kemampuan Penalaran Matematis Siswa	(Afifah et al., 2020)	Lack of information about the influence of other factors that may affect students' mathematical reasoning ability apart from the learning model used.	The application of PBL model can significantly improve the mathematical reasoning ability of junior high school students compared to the direct learning model. It is recommended to explore other factors that influence students' mathematical reasoning ability and expand the scope of materials taught with this learning model.
9.	Pengaruh Model Pembelajaran *Problem Based Learning* Berbantuan Lembar Kerja Peserta Didik (LKPD) terhadap Kemampuan Penalaran Matematis Siswa di MTS. Lab IKIP Al-Washliyah Medan	(Ikasari & Firmansyah, 2023)	The idea of PBL model with the help of LKPD is still rarely researched, so this research is important to fill the gap.	The PBL model with the help of LKPD has a positive influence on students' mathematical reasoning ability at MTs. Future research can involve more schools and classes to test its effectiveness in various levels of education.
10.	Meta analysis study: Effectiveness of Problem Based Learning on Indonesian Students' Mathematical Reasoning Ability	(Fitriyah et al., 2022)	Inconsistent results related to the effect of sample size on the effectiveness of PBL models in improving students' mathematical reasoning ability. This study recommends further meta-analysis research involving more studies to explore the impact of sample size on the effectiveness of PBL models.	PBL models are effective in improving reasoning skills, especially in samples with sizes ≤ 30 and > 30. However, there are inconsistent results related to the effect of sample size on the effectiveness of PBL models. It is recommended to conduct a broader meta-analysis with a wider range of publication years and involving more studies to explore the impact of sample size on the effectiveness of PBL models.
11.	Pengaruh Penerapan Model *Problem Based Learning* terhadap Kemampuan Penalaran Matematis Peserta Didik Kelas XI IPA SMAN 1 2X11 Enam Lingkung	(Yani & Elniati, 2023)	This research was only conducted in one school, namely in class XI IPA, so that the generalization of the research results is limited to a wider population.	Students who learn with PBL model have better mathematical reasoning ability than students who learn with direct learning model. It is recommended to involve more schools and classes to expand the conclusions of the results of further research.
12.	Meningkatkan Kemampuan Penalaran Matematika Siswa melalui Model PBL (*Problem Based Learning*)	(Kotto et al., 2022)	Students' mathematical reasoning ability is still low, especially in solving story problems, understanding, analyzing, compiling evidence, giving reasons, and drawing logical conclusions.	There is an increase in students' mathematical reasoning ability through the PBL model, with an average gain score of 0.71, which is in the high category. It is suggested to involve more classes and students to expand the generalization of the research results.
13.	Pengaruh Model Pembelajaran *Problem Based Learning* (PBL) terhadap Kemampuan Penalaran dan Pemecahan Masalah Matematika Siswa Kelas V SDN 1 Lejang Kabupaten Pangkep	(Khairani et al., 2023)	The results showed that the PBL model improved the reasoning and mathematical problem solving skills of fifth grade students, but did not consider their educational background or previous learning experience.	The PBL model has a positive influence on the reasoning and mathematical problem solving skills of fifth grade students. It is recommended to use a larger sample and consider students' educational background and learning experience. Further research is needed to test the application of the PBL models at various levels of education.

14.	Pengaruh Model Pembelajaran PBL Berbantuan Alat Peraga dalam Peningkatan Kemampuan Penalaran Matematis	(Aulya & Purwaningrum, 2021)	There are still shortcomings that make the results not in accordance with the expectations of the reader, so further research is needed to perfect its usefulness.	The PBL model with teaching aids improved students' mathematical reasoning ability, as evidenced by the increase in scores on the post-test compared to the pre-test. Future research can focus on developing innovative and diverse learning strategies to improve students' mathematical reasoning ability as a whole.
15.	Pengembangan Perangkat Pembelajaran Matematika Berbasis *Problem Based Learning* untuk Memfasilitasi Kemampuan Penalaran Matematis	(Arif et al., 2021)	The research was only conducted on grade XI students in one school, so the generalization of the research results is limited.	The development of PBL-based mathematics learning tools can facilitate students' mathematical reasoning ability in grade XI high school. Future research can test the effectiveness and generalization of PBL models in improving students' mathematical reasoning at various school levels and subjects.
16.	Upaya Meningkatkan Kemampuan Penalaran Matematis Siswa melalui Model *Problem Based Learning* pada Materi Aritmetika Sosial	(Abidah et al., 2021)	This study measured students' mathematical reasoning using a qualitative PTK method. Retno Maristin's research also used the qualitative method of PTK, but focused on university students, not junior high school students.	The application of the PBL model on social arithmetic material can improve the mathematical reasoning ability of seventh grade students. It is recommended to expand the number of students studied, compare the effectiveness with other learning models, and explore the long-term impact of using this PBL model.
17.	Meningkatkan Kemampuan Penalaran Siswa dengan Menerapkan Model *Problem Based Learning*	(Amalia & Hia, 2023)	In the first cycle, the research had not reached its success criteria, so adjustments needed to be made for the second cycle.	The application of the PBL model succeeded in improving the reasoning ability of grade XI students significantly, from an average of 60.29 in cycle 1 to 76.10 in cycle 2. It is recommended to involve more classes or schools to test the effectiveness of the PBL model in improving students' reasoning ability in various educational contexts.
18.	Pengembangan Lembar Kerja Peserta Didik Berbasis *Problem Based Learning* untuk Meningkatkan Kemampuan Penalaran Matematis Siswa	(Purba & Purba, 2023)	The learning tools were inadequate because teachers had difficulty developing worksheets that fit the students' characteristics and were able to develop mathematical reasoning.	The development of PBL-based LKPD effectively improves the mathematical reasoning ability of junior high school students. This LKPD is valid, feasible to use in learning, and achieves classical student learning completeness. It is recommended to observe the implementation of PBL-based LKPD in various schools and educational levels to broaden the understanding of the effectiveness of this method in improving students' reasoning ability.
19.	Pengaruh *Problem Based Learning* terhadap Kemampuan Penalaran Matematis dan Kemampuan Pemecahan Masalah	(Alfiah et al., 2021)	This study was only conducted on grade X students, so the generalization of the results of this study is limited to a wider population.	The PBL model improved students' mathematical reasoning and problem solving more effectively than conventional learning. Future research can explore the effectiveness of PBL at various levels of education and other subjects.
20.	Pengaruh Pembelajaran Berbasis Masalah terhadap Kemampuan Penalaran dan Komunikasi Matematis Siswa SMP	(Rasmuin & Khatima, 2023)	Some teachers pay less attention to student reasoning, so students only do problems based on examples without evaluation, analysis, synthesis, generalization, connection, and proof.	PBL has a significant effect on improving the mathematical reasoning and communication skills of grade VIII students. Further research is recommended to use a larger sample and more variables to understand the effect of PBL on students' mathematical abilities more deeply.
21.	Influence of Problem Based Learning Model on Students' Mathematical Reasoning Ability	(Gunawan et al., 2020)	Previous research shows that students' mathematical reasoning ability is low due to a lack of understanding of concepts and difficulty using mathematical patterns and relationships.	The PBL model improved students' mathematical reasoning ability better than the conventional learning model. Students who received the PBL model had better mathematical reasoning ability. It is suggested to involve more schools and classes to test the effectiveness of this learning model more widely.
22.	The Impact of Using Audio-Visual Media in a Problem-Based Learning Model on Improving Students' Reasoning Ability	(Pitaloka et al., 2021)	The research conclusion does not provide information about the test results in detail, such as the difference in scores between the pretest and posttest, as well as the statistical analysis that supports the research findings.	The use of the PBL model assisted by audio-visual media is effective in improving the reasoning ability of grade II students in fraction material. Further research could involve larger samples and more comprehensive statistical analysis methods to support these findings.
23.	Kemampuan Penalaran Matematika Siswa MA dengan Metode *Problem-Based Learning*	(Hadi, 2021)	This study was only conducted in a MA with a total of 32 class X students, so the generalization of the results to a wider population is limited.	MA students' mathematical reasoning ability improved after using the PBL model, although there were still errors in understanding the problem, using formulas, calculating operations, and writing reasons. This research used a case study-based qualitative approach. Future research could look at the effectiveness of PBL in different schools and different learning environments.

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24.	Pengembangan Lembar Kerja Peserta Didik Elektronik (E-LKPD) Berbasis *Problem Based Learning* (PBL) untuk Memfasilitasi Kemampuan Penalaran Peserta Didik pada Materi Lingkaran	(Umaroh et al., 2022)	Suitable teaching materials for online learning are still lacking. Therefore, there needs to be a variety of teaching materials that contain indicators of mathematical reasoning ability.	PBL-based E-LKPD for circle material is considered feasible and gets positive responses from students. It is recommended to develop PBL-based E-LKPD for other mathematics materials and involve more students to expand the results of the study because this study was only conducted with 26 grade IX students.
25.	Analysis Validity and Reliability of Self - Efficacy and Metacognitive Awareness Instrument Toward Mathematical Reasoning	(Tak et al., 2021)	The combination of metacognitive awareness variables and self-efficacy beliefs is still a new phenomenon in the context of mathematics education in Malaysia.	An instrument to measure students' self-efficacy and metacognitive awareness in mathematical reasoning was found to be valid and reliable, with three dimensions of self-efficacy and six dimensions of metacognitive awareness. The instrument has high internal consistency and sufficient validity and reliability to be used with university students. It is recommended to involve a larger sample of mathematics students in Malaysia to expand the generalizability of these findings.
26.	Measurement Model and Adaptation of Self-Efficacy toward Mathematics Reasoning among University Students	(Chan et al., 2022)	The lack of attention from educators to students' mathematical reasoning ability causes low motivation to learn and tends to make students learn by memorizing.	Self-efficacy has a positive impact on mathematical reasoning achievement, and restructuring course learning objectives or developing new modules can improve students' self-regulation and mathematical reasoning ability. Future research can focus on developing modules to improve self-efficacy and identifying effective learning strategies to improve self-regulation and mathematical reasoning ability.
27.	Measurement Model Testing: Adaption of Metacognitive Awareness Toward Mathematic Reasoning Among Undergraduate Education Students	(Tak et al., 2022)	Not many studies have examined the relationship between metacognitive awareness and mathematical reasoning ability in undergraduate students. This study contributes new findings to the measurement of the metacognitive awareness model and finds a positive relationship with mathematical reasoning.	There is a positive relationship between metacognitive awareness and mathematical reasoning ability in undergraduate students. Improving metacognitive awareness can improve students' mathematical reasoning ability. It is recommended to integrate reasoning elements in mathematics learning to improve students' reasoning skills. Future research can develop learning strategies to strengthen metacognitive awareness to improve students' mathematical reasoning, taking into account other factors such as the environment or genetics that affect mathematical reasoning ability.
28.	An Analysis of Student's Mathematical Reasoning and Mental Computation Proficiencies	(Singh et al., 2020)	There is still a need to better understand the extent to which current test scores reflect students' abilities in mathematical reasoning.	Primary school students in Malaysia have high mental computation skills, but their mathematical reasoning is low. This study emphasizes the importance of developing reasoning skills in mathematics education. It is recommended to explore the factors that influence mathematical reasoning and develop learning strategies to improve it.
29.	Pengembangan LKS Beracuan *Problem Based Learning* untuk Mendeskripsikan Kemampuan Penalaran Matematika Siswa SMK	(Herdiansyah et al., 2023)	Previous research shows that students rely more on memorization than reasoning in solving math problems. However, there is no research that focuses on the development of PBL-based LKS to improve the mathematical reasoning ability of vocational students on the material of arithmetic series and sequence.	The development of PBL-based worksheets is effective in improving the mathematical reasoning ability of vocational students on the material of arithmetic series and sequence. Future research can test the use of PBL-based worksheets at different educational levels or other mathematics materials, as well as focus on developing other mathematics learning methods that also improve students' mathematical reasoning ability.
30.	Pengembangan Modul Pembelajaran Berbasis Masalah untuk Membantu Meningkatkan Kemampuan Penalaran Siswa SMK pada Materi Fungsi, Persamaan Fungsi Linier dan Fungsi Kuadrat	(Akbarita & Narendra, 2019)	Lack of widespread implementation to test the effectiveness of the developed problem-based learning module.	The development of PBL modules using the Thiagarajan development model can help improve the reasoning ability of vocational students in the areas of functions, linear function equations, and quadratic functions. Further research can test the effectiveness of PBL modules by involving more students and exploring other subject matters.
31.	Peningkatan Kemampuan Penalaran Matematis Siswa SMA	(Apriani, 2020)	This research was only conducted in one experimental class with a limited number of students, specifically 32 people, which limits	The use of PBL improves the mathematical reasoning ability of high school students, especially when compared to their initial math ability. This model encourages students to individually or collaboratively

	Melalui *Problem Based Learning*		the generalization of the research results to a wider population.	find solutions to real-world problems and increases direct interaction among students. The majority of students responded positively to this method. Future research could involve a larger sample and use a more robust research design to strengthen the generalizability of the results.
32.	Perbedaan Model *Problem Based Learning* dan Model Kooperatif ditinjau dari Kemampuan Penalaran Matematis Siswa	(Syahlan et al., 2022)	There is a lack of research comparing the PBL model and the Team Assisted Individualization (TAI) cooperative model in terms of students' mathematical reasoning ability.	Differences in students' mathematical reasoning ability were observed between the PBL model and the TAI cooperative model. PBL is suitable for students with medium and low Knowledge of Advanced Mathematics (KAM), while TAI is more suitable for students with medium and high KAM. This study highlights the importance of selecting an appropriate learning model to enhance students' problem-solving abilities in mathematics. It is suggested to involve more schools and grade levels to extend the generalizability of the results. Additional variables can also be considered in future research to understand the impact of learning models on students' mathematical reasoning ability, including longitudinal studies to evaluate long-term impacts.
33.	*Problem Based Learning*: Meningkatan Kemampuan Penalaran Matematis Siswa SMK Berdasarkan Motivasi Belajar	(Ali et al., 2022)	There is a lack of research on how students' learning motivation affects their mathematical reasoning ability when using PBL in vocational schools.	Students who used PBL demonstrated better mathematical reasoning ability and learning motivation compared to those who used conventional learning methods. Future research can explore the effect of learning motivation on mathematical reasoning ability with PBL in other vocational schools. The study could involve larger samples from different regions to strengthen the generalizability of the findings.
34.	Penerapan Model *Problem Based Learning* dengan Pendekatan Saintifik untuk Meningkatkan Kemampuan Penalaran Adiptif Siswa SMP	(Patiawati, 2017)	Currently, there is no research focused on improving the adaptive reasoning skills of junior high school students through the use of PBL models with a scientific approach in learning mathematics.	The application of the PBL model with a scientific approach can significantly enhance students' adaptive reasoning skills in learning mathematics, particularly in the Circle material, in junior high school. Future research is recommended to involve more schools and classes to expand the generalizability of the findings regarding the effectiveness of this learning model.
35.	Pengembangan Lembar Kerja Siswa (LKS) Berbasis Problem Based Learning untuk Meningkatkan Kemampuan Penalaran Matematika	(Handayani & Mandasari, 2018)	Lack of information on the evaluation of the results of using PBL-based LKS in improving the mathematical reasoning ability of junior high school students.	The development of PBL-based worksheets for grade VIII junior high school mathematics successfully improves students' mathematical reasoning ability with proven validity, practicality, and effectiveness, helping students solve mathematical problems relevant to real life. Future research should involve more schools and students to test the effectiveness of the LKS more comprehensively.

Discussion

This study examines the effectiveness of PBL model in improving mathematical reasoning ability of students from various levels of education with diverse materials such as social arithmetic, functions, and linear equations. Overall, PBL was found to be effective in improving students' mathematical reasoning skills. Some studies also highlighted the impact of PBL on students' metacognitive skills, especially at the high school level. In addition, research with the help of LKS or LKPD shows positive results, although the use of E-LKPD is still limited.

Based on table 1, it is known that the 35 articles used in this study cover a variety of materials from elementary to higher education levels within a period of 7 years. The materials discussed include: (1) social arithmetic, (2) flat-sided spaces, (3) functions, (4) linear function equations and quadratic functions, (5) rows and series, (6) linear programs, (7) quadrilateral flat shapes, (8) number patterns, (9) statistics, (10) System of Three Variable Linear Equations (SPLTV), (11) circles, and (12) fractions. Although the materials used are different, the research results obtained state that the PBL model can improve students' mathematical reasoning ability. This means that the PBL model is effective to be applied at every level of education to improve students' mathematical reasoning ability. However, when viewed from table 1, research conducted by Syahlan et al. (2022), stated that the PBL model was more suitable for students

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with medium and low KAM, while the TAI cooperative model was more suitable for students with medium and high KAM.

Research conducted by Nababan (2020), states that the PBL model has a positive effect on students' metacognitive skills in high school. However, the study did not explain the existence of other factors that might affect these metacognitive skills. Research conducted by Tak et al. (2022) also discussed student metacognition. However, what was discussed was students' metacognitive awareness. It turns out that metacognitive awareness has a positive relationship with students' mathematical reasoning ability even though metacognitive awareness is still a new phenomenon in the context of mathematics education in Malaysia. So it can be concluded that in Indonesia it turns out that the PBL model has a positive effect on the metacognitive skills of high school students, but other factors that influence it are not explained. Another study conducted in Malaysia showed that metacognitive awareness is positively related to students' mathematical reasoning ability.

The PBL model is one of the factors that can influence students' mathematical reasoning ability. However, the articles used in this study lack information on the influence of other factors that may affect students' mathematical reasoning ability. For example, research by Afifah et al. (2020) and Khairani et al. (2023) only discussed the PBL model as a positive factor without considering other factors such as students' educational background or learning experience. In contrast, research conducted by Gunur & Ramda (2020) discussed other factors besides learning models. The study examined the PBL model and the gender perspective, and the results showed that the PBL model was effective in improving students' mathematical reasoning ability compared to conventional learning. However, there was no difference in ability between male and female students, and there was no interaction between learning models and gender on students' mathematical reasoning ability.

Among the 35 articles used in this study, several articles discussed the PBL model with the help of LKS or LKPD. This is because the PBL model assisted by LKS or LKPD has a positive influence on students' mathematical reasoning ability. Research conducted by Handayani & Mandasari (2018), stated that the developed LKS was proven to be valid, practical, and effective in improving the mathematical reasoning ability of junior high school students. In addition to LKS or LKPD, there is also the concept of E-LKPD in online learning. However, according to research conducted by Umaroh et al. (2022), the PBL model assisted by E-LKPD is still not widely available. Therefore, it is recommended to develop PBL-based E-LKPD for other mathematics materials and involve more students to expand the research results. The study only examined the PBL model assisted by E-LKPD for circle material with only 26 students in Class XI. Furthermore, the learning tools presented are still inadequate because teachers face difficulties in preparing worksheets that match the characteristics of students and are able to develop students' mathematical reasoning ability. Additionally, research conducted by Ikasari & Firmansyah (2023) also noted that the idea of the PBL model with the help of LKPD is still rarely researched. Research conducted by Suryani et al. (2023), regarding the PBL model assisted by LKS did not consider other factors that could affect the results of the study, such as student characteristics, teacher experience, or learning environment. Overall, it can be concluded that the PBL model with the help of teaching materials can improve mathematical reasoning ability. Therefore, further research can be conducted on PBL models that use other teaching materials such as the flipped classroom.

Based on the research conducted, some limitations found in this study can significantly affect the results. The following is an explanation of these limitations and recommendations for further research:

1. Research Limitations
   a. Limited Focus on PBL Learning Model

      Many of the articles discussed in this research only focus on the PBL model as a factor affecting students' mathematical reasoning ability without considering other factors. For example, research by Afifah et al. (2020) and Khairani et al. (2023) did not examine students' educational background or learning experiences that could play an important role in influencing learning outcomes.

      Impact: By not considering other factors such as learning motivation, family support, or teaching quality, the research results may be biased, and the results regarding the effectiveness of PBL may not fully reflect the actual conditions in the classroom.

   b. Lack of Studies on Metacognition and Other Factors

      This study found that aspects of metacognition, especially students' metacognition, have not been studied in depth, although research results in Malaysia showed a positive relationship between metacognitive awareness and mathematical reasoning ability. Research conducted in Indonesia has mostly focused on the impact of PBL without further exploring metacognitive factors.

      Impact: By ignoring aspects of metacognition, research may miss a more holistic understanding of how students think, plan and solve mathematical problems. This may affect the generalizability of the results.

   c. Limitations on the Teaching Materials Used

      Some studies, such as the one conducted by Umaroh et al. (2022), only examined the use of E-LKPD on circle material with a limited sample (26 students). In addition, research using LKPD/LKS in the PBL model is still rare, even though teaching materials such as LKPD are proven to improve students' mathematical reasoning skills.

      Impact: With a narrow scope of teaching materials and a limited research sample, the results of the study may not be generalizable to all mathematics topics or other classroom situations. In addition, the results may not be representative of the wider student population.

   d. Lack of Consideration of Environmental Factors and Student Characteristics

      Some studies such as the one conducted by Suryani et al. (2023) did not consider student characteristics, teacher experience or learning environment as factors that could influence the results. These factors may play an important role in the effectiveness of PBL, but are often overlooked.

      Impact: The results of the study may be influenced by uncontrolled variables, reducing the internal validity of the study. This means that the effectiveness of PBL may be affected by student characteristics that were not taken into account.

2. Recommendations for Further Research
   a. A More Holistic Study of Other Factors

      Further research needs to consider other factors that can influence students' mathematical reasoning ability, such as motivation, family support, educational background, and learning experience. This study also needs to examine the effect of PBL in combination with these other factors to gain a more comprehensive understanding.

   b. Exploration of Metacognition in the Indonesian Education Context

      Although research in Malaysia shows a positive relationship between metacognitive awareness and mathematical reasoning ability, similar research needs to be conducted in Indonesia. By further exploring aspects of metacognition, future research could help explain how PBL can develop students' thinking skills beyond mathematical reasoning.

   c. Use of Diverse Teaching Materials

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The development and testing of PBL with various teaching materials, such as E-LKPD for various mathematics materials, needs to be done. In addition, the expansion of this study by involving more students and a variety of mathematics topics can provide more comprehensive results.

d. Consideration of Student Characteristics and Environmental Factors

Future research should consider variables such as individual student characteristics, socio-economic background, teacher experience, and learning environment. This is important to make the study more representative and the results more generalizable to a wider population.

By addressing these limitations, future research can provide a deeper understanding of how PBL affects students' mathematical reasoning ability as well as other factors at play.

Conclusion

This research shows that the PBL model is effective in improving students' mathematical reasoning skills at various levels of education and subject matter, such as social arithmetic, functions, and linear equations. Several studies have also noted the positive impact of PBL on students' metacognitive skills, especially at the high school level. However, other factors that may influence metacognitive skills, such as educational background and learning experience, have not been explored. In addition, the application of PBL with the help of E-LKPD is also effective in improving mathematical reasoning skills, but the use of E-LKPD is still limited. Some studies reveal that the effectiveness of PBL is more suitable for students with medium and low academic ability. Other factors such as learning environment, student characteristics, and teacher experience are often ignored in existing research.

The following are recommendations based on the research findings, as well as how they can be implemented in educational practice:

1. Expanding the Factors Studied
   Recommendation: Further research should consider other factors that can influence students' mathematical reasoning ability, such as learning motivation, family support, educational background, and learning experience.
   Implementation: In practice, teachers can involve parents to provide learning support at home, and motivate students by creating an interactive learning environment that is relevant to everyday life. In addition, an initial assessment of students' educational background and learning experience can be conducted to adjust teaching strategies.
2. Exploring Aspects of Metacognition in the Indonesian Education Context
   Recommendation: Research on metacognitive awareness and how this affects students' mathematical reasoning needs to be conducted, especially in Indonesia, to understand more deeply how students think and solve problems.
   Implementation: Teachers can integrate metacognitive strategies, such as self-reflection and planning in the teaching and learning process. For example, asking students to plan steps before solving problems and evaluate their own solutions.
3. Development and Testing of More Diverse Teaching Materials
   Recommendation: It is necessary to develop and test PBL-based teaching materials, such as E-LKPD for various mathematics materials. A more diverse number of students and materials also need to be involved so that the results of the study are more representative.
   Implementation: In practice, teachers and curriculum developers can start designing E-LKPDs that cover more math topics, not only circles. Teachers can use online learning platforms to distribute E-LKPDs and engage more students in online learning.

4. Considering Student Characteristics and Environmental Factors
   Recommendation: Future research should consider variables such as student characteristics, socio-economic background, teacher experience and learning environment to provide a more comprehensive picture.
   Implementation: Teachers can conduct observations or surveys to understand students' backgrounds and learning environment conditions. This information can then be used to adjust teaching approaches and ensure each student gets a learning experience that suits the student's needs.

By implementing these recommendations, education can be more effective in developing students' mathematical reasoning abilities as well as metacognitive skills that support lifelong learning.

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