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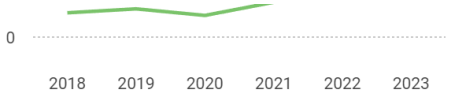

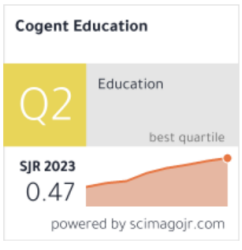

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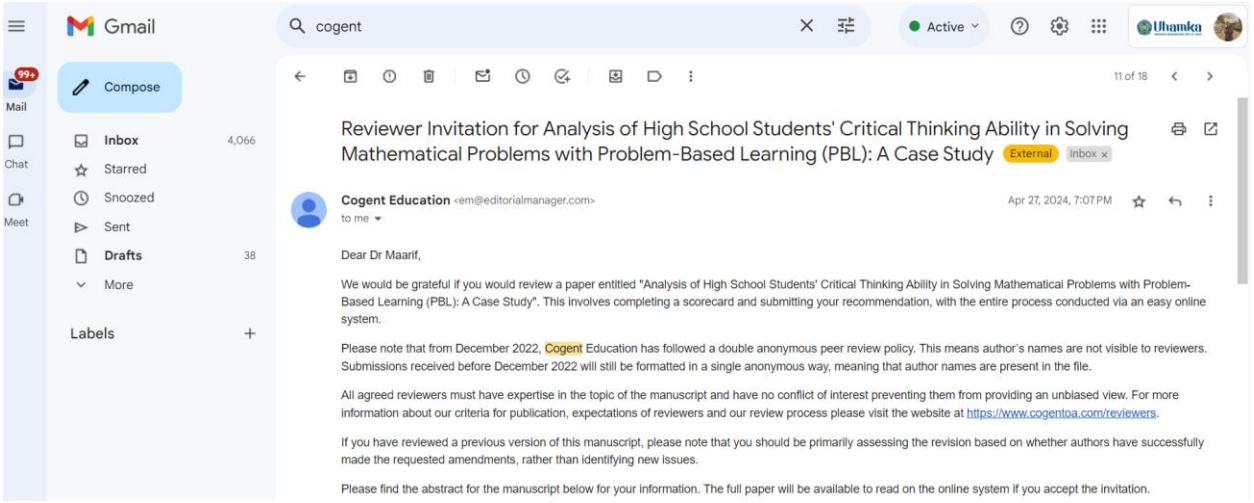
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Reviewer Invitation for Analysis of High School Students' Critical Thinking Ability in Solving Mathematical Problems with Problem-Based Learning (PBL): A Case Study
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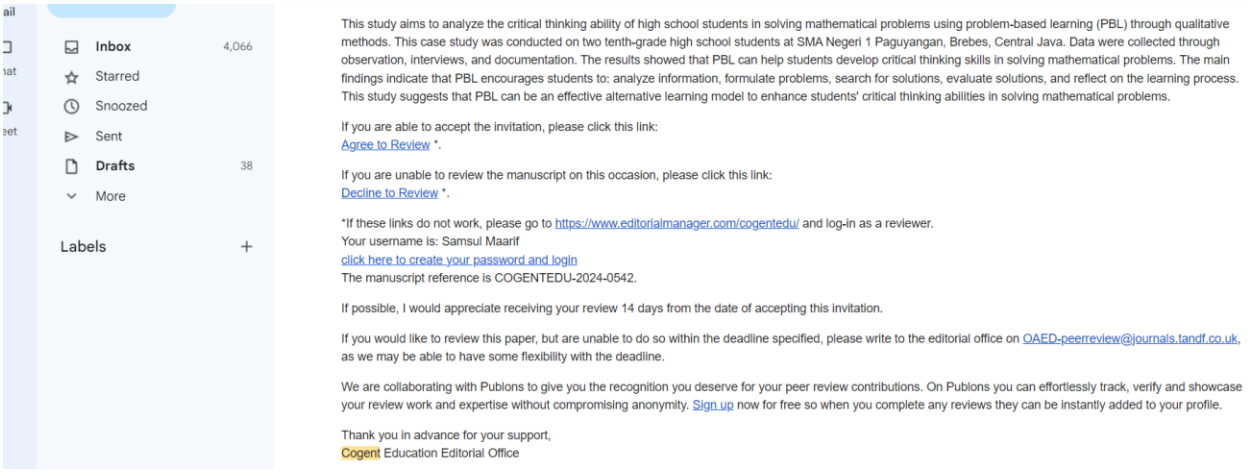
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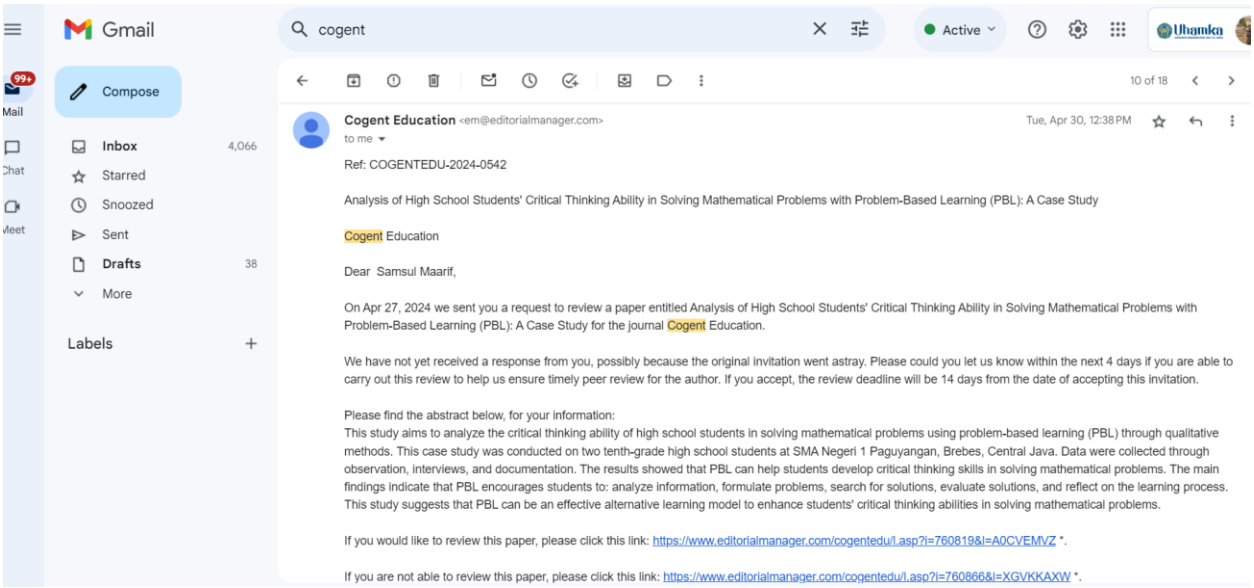
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Analysis of High School Students' Critical Thinking Ability in Solving Mathematical Problems with Problem-Based Learning (PBL): A Case Study
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Dear Samsul Maarif,
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This study aims to analyze the critical thinking ability of high school students in solving mathematical problems using problem-based learning (PBL) through qualitative methods. This case study was conducted on two tenth-grade high school students at SMA Negeri 1 Paguyangan, Brebes, Central Java. Data were collected through observation, interviews, and documentation. The results showed that PBL can help students develop critical thinking skills in solving mathematical problems. The main findings indicate that PBL encourages students to: analyze information, formulate problems, search for solutions, evaluate solutions, and reflect on the learning process. This study suggests that PBL can be an effective alternative learning model to enhance students' critical thinking abilities in solving mathematical problems.
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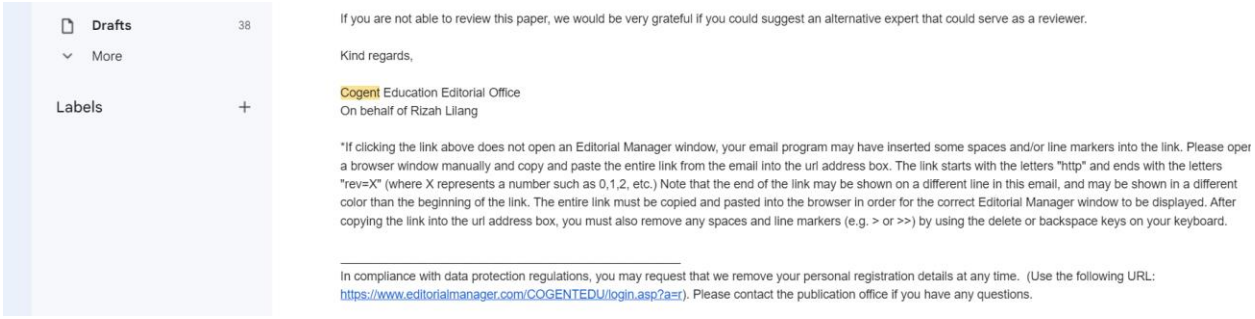

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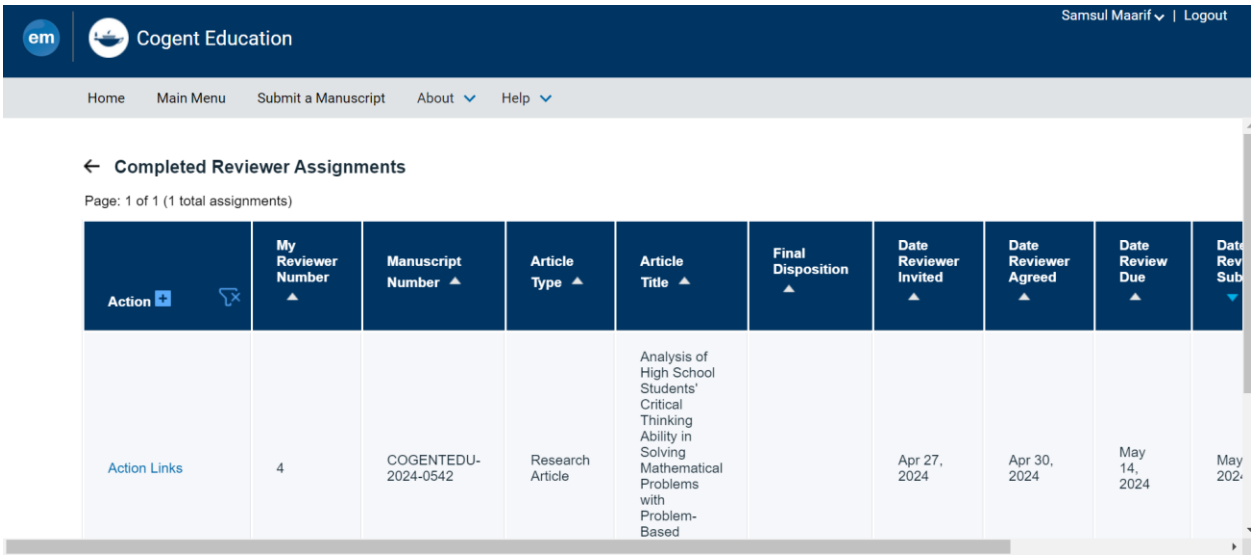

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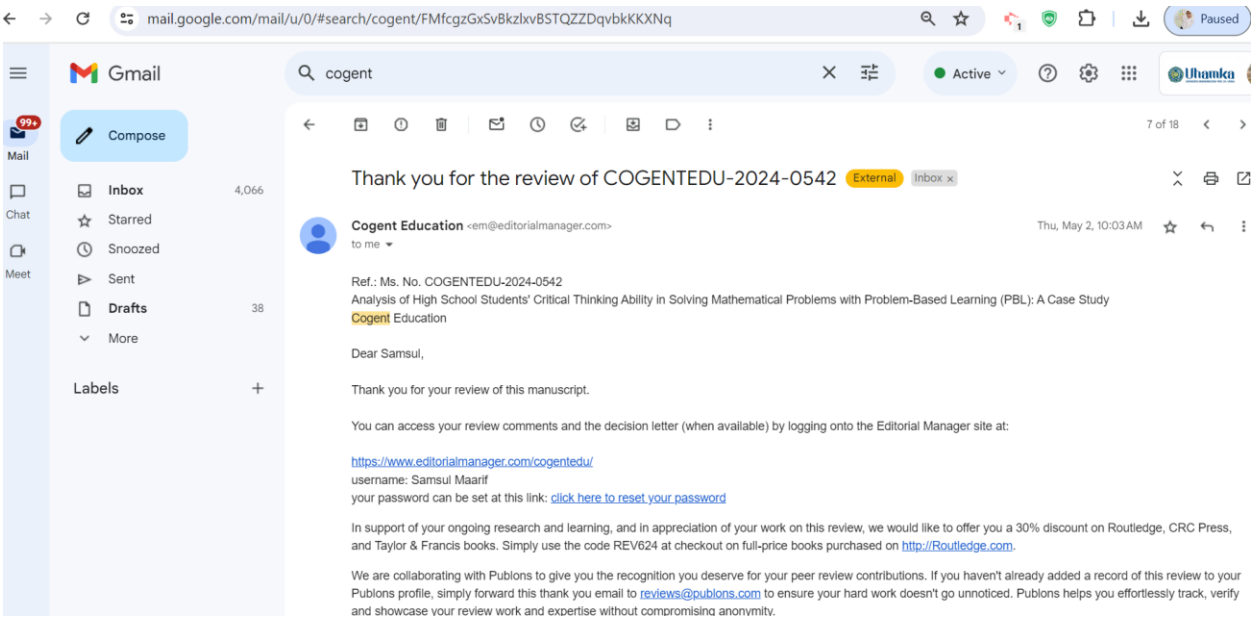

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Analysis of High School Students' Critical Thinking Ability in Solving Mathematical Problems with Problem-Based Learning (PBL): A Case Study

Original Submission
Samsul SMF Maarif, Ph.D Reviewer 4

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Comments to the author	This article needs a major revision because there are several important elements that have not been seen including: 1. Abstract: - At the beginning of the abstract, the importance and novelty of the research carried out should be explained - In the methodology section of the abstract it is necessary to add how the data was analyzed to arrive at conclusions - Is the conclusion in this abstract section a learning obstacle or a new theory? This has to be explained. If this is a learning obstacle, it needs to be explained at the beginning. 2. Introduction: - In the statement "Problem-based learning (PBL) is one of the effective learning approaches in developing critical thinking skills", the statement that supports that PBL is an effective model would be better to use updated references, because the development of a theory has been well developed. So it is necessary to further study the PBL model of treatment. - In the introduction, there are many statements from research that reveal PBL to support critical thinking. If most research has led to PBL support for critical thinking, why is there a need to dig deeper (or re-research PBL and critical thinking). This needs to be revealed as a research gap.

- In the introduction, the research gap is not clear. Please complete the gap analysis as a differentiator or refinement of research conducted on previous studies. Research gaps are very important to reveal as part of constructing a novelty.

3. Literature Review:
- In the literature review section, the statement "Critical thinking ability is an important aspect in high school education that has been the focus of attention in educational literature", is it still relevant? Theoretically, all aspects of mathematics are important in mathematics sections. Does this statement quote need to be written down? It would be better because this is part of the literature review, in the initial parts the theoretical definition of critical thinking will be explained
- In the literature review section, critical thinking section, improve the writing of quotations
- There is the term "Educational literature" in several paragraphs. What is the author's reason for including terminology in this article? It needs to be explained, because the focus of this research is on critical thinking using PBL
- In the literature review (PBL) section. The terminology "use of real-world" seems inappropriate. In mathematics it would be more appropriate to use "mathematical context"
- In the literature review section "The Relationship between PBL and Critical Thinking Skills"
- , these statements need to be supported by strong references to support the research conducted
- The statement "These studies often employ strong research designs and relevant methodologies to measure the impact of PBL on students' critical thinking abilities". It should not only reveal the relevance between the two, but reveal where PBL can support CT from each PBL step. And this is strengthened by examining the parts of CT that can be supported by PBL. This applies to the following statements

4. Method:
- In the case study methodology, it should be revealed what strategies or activities were carried out during the mathematics learning. So it becomes clear what kind of PBL learning case is the focus of the research. Researchers can reveal what activities occur at each meeting with the implementation of PBL so that they can be observed thoroughly.
- In the methodology section, it is necessary to briefly describe the characteristics of the research subjects.
- It is necessary to reveal the suitability of observation instruments with the application of PBL implemented in learning
- Is there no interview in the research? Because it is important to triangulate the data that has been taken. Interviews are important to cross-check the results of observations and documentation
- Is data analysis just a description of the data? In general, all research must describe data. It is necessary to add how qualitative data analysis is carried out. For example, in grounded theory: open code, axial code and theoretical code. For case study data analysis, of course there are steady steps, such as a data reduction process. So in the data analysis section the steps need to be described. Not just describing data. In general, qualitative research uses analyzed data, reducing, triangulating processes to arrive at a conjecture.
- In the results section there is a test instrument used, but in the methodology section it is not described. Please describe the critical thinking test instrument complete with the indicators used and how the instrument is tested for validity and reliability.

5. Result:

- In the research results section, the statement "The research findings confirm that PBL has a positive impact in helping students develop their critical thinking skills in solving mathematical problems", This is a qualitative research. But at the beginning it was concluded that there was a positive impact. Is this a question? Because this research explores how students develop critical thinking

skills in PBL learning. So data is needed to support this statement.
- The statement "PBL provides an effective platform for students to expand their critical thinking skills, which are crucial in preparing them for real-world challenges beyond the classroom" must also be supported by research data. Because to determine whether a treatment is effective or not, there needs to be supporting data.
- Table 03. Where do the percentages come from? If I'm not mistaken, this is only 2 respondents? Therefore, it is important to describe the results of observations for each research subject according to their respective characteristics
- Figure 01. In the image section of the research subject answer sheet, it is necessary to translate it into English. This makes it easier for readers to understand the content of the respondent's answers
- Figure 02. In the image section of the research subject answer sheet, it is necessary to translate it into English. This makes it easier for readers to understand the content of the respondent's answers
- Respondents' answers should be confirmed again through an interview process to dig deeper and through the triangulation process

6. Discussions:
- -The discussion or discussion section is a two-way communication, namely from the researcher's side and from the other person's side. Please discuss the findings and then compare them with the results of previous research. So in the discussion section you have to cover a lot of research results to compare them with the phenomena of research findings that have been carried out
- Adjust the results of the discussion with the research results and research questions that have been determined

7. Conclussions
- Match the research conclusions to the research questions and research results that have been determined

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Analysis of High School Students' Critical Thinking Ability in Solving Mathematical Problems with Problem-Based Learning (PBL): A Case Study

--Manuscript Draft--

Full Title:	Analysis of High School Students' Critical Thinking Ability in Solving Mathematical Problems with Problem-Based Learning (PBL): A Case Study
Manuscript Number:	COGENTEDU-2024-0542
Article Type:	Research Article
Keywords:	Critical thinking; problem-based learning (PBL); mathematics; high school
Manuscript Classifications:	50.12.15.4 Critical Theory; 50.2.2.2.2 Critical Thinking & Study Skills; 50.7.1 Adult Education and Lifelong Learning; 50.7.27.5 Study Skills; 60.3.4.4.1 Critical Theory; 60.3.4.5 Critical Thinking
Abstract:	This study aims to analyze the critical thinking ability of high school students in solving mathematical problems using problem-based learning (PBL) through qualitative methods. This case study was conducted on two tenth-grade high school students at SMA Negeri 1 Paguyangan, Brebes, Central Java. Data were collected through observation, interviews, and documentation. The results showed that PBL can help students develop critical thinking skills in solving mathematical problems. The main findings indicate that PBL encourages students to: analyze information, formulate problems, search for solutions, evaluate solutions, and reflect on the learning process. This study suggests that PBL can be an effective alternative learning model to enhance students' critical thinking abilities in solving mathematical problems.

Analysis of High School Students' Critical Thinking Ability in Solving Mathematical Problems with Problem-Based Learning (PBL): A Case Study

Abstract: This study aims to analyze the critical thinking ability of high school students in solving mathematical problems using problem-based learning (PBL) through qualitative methods. This case study was conducted on two tenth-grade high school students at SMA Negeri 1 Paguyangan, Brebes, Central Java. Data were collected through observation, interviews, and documentation. The results showed that PBL can help students develop critical thinking skills in solving mathematical problems. The main findings indicate that PBL encourages students to: analyze information, formulate problems, search for solutions, evaluate solutions, and reflect on the learning process. This study suggests that PBL can be an effective alternative learning model to enhance students' critical thinking abilities in solving mathematical problems.

Keywords: Critical thinking, problem-based learning (PBL), mathematics, high school

Introduction

Critical thinking ability is an important skill in the modern era that enables students to analyze information, solve problems, and make decisions effectively (Bailin et al., 1999). Problem-based learning (PBL) is one of the effective learning approaches in developing critical thinking skills (Zabit, 2010a). This learning model places students as the main subject and prioritizes problem-solving as the learning method. Through PBL, students are encouraged to actively engage in the learning process, solve real- world problems, and stimulate their critical thinking (Barron, 2013). PBL allows students to learn in a more contextual and real-world oriented manner (Zabit, 2010b). In the context of mathematics learning, PBL can help students connect mathematical concepts with practical applications in everyday life (Surya & Syahputra, 2017). Thus, students not only understand concepts theoretically but also can apply them in relevant and meaningful contexts (Scholkmann, 2020). Additionally, PBL also develops students' collaboration and communication skills (Owens & Hite, 2022). In the problem-solving process, students often work in groups or teams, collaborating to find the best solutions (Chang et al., 2017). This allows them to learn from others' perspectives, appreciate diverse opinions, and develop effective communication skills (Graesser et al., 2017). PBL also enhances students' intrinsic motivation towards learning (LaForce et al., 2017). By challenging them to solve relevant and interesting problems, PBL makes learning more engaging and meaningful for students (Fukuzawa et al., 2017). This helps increase students' engagement in the learning process and produce better learning outcomes (Orji & Ogbuanya, 2022). Overall, PBL is a powerful learning approach in developing students' critical thinking abilities in the context of mathematics learning (Saputra et al., 2019). By emphasizing problem-solving, contextualization, collaboration, and intrinsic motivation, PBL helps students prepare for the challenges of the real world in the future (Amin et al., 2020).

This research has two main objectives. First, to analyze the critical thinking ability of high school students in solving mathematical problems using the Problem-Based Learning (PBL) approach. Second, to describe the learning process of students in solving mathematical problems by applying PBL. Thus,this study aims not only to understand the extent to which students can utilize their critical thinking skills in the context of PBL but also to provide a clear overview of the steps of solving mathematical problems distinctly.

Literature Review

Commented [SM1]: At the beginning of the abstract, the importance and novelty of the research carried out should be explained

Commented [SM2]: In the methodology section of the abstract it is necessary to add how the data was analyzed to arrive at conclusions

Commented [SM3]: Is the conclusion in this abstract section a learning obstacle or a new theory? This has to be explained. If this is a learning obstacle, it needs to be explained at the beginning.

Commented [SM4]: In the statement "Problem-based learning (PBL) is one of the effective learning approaches in developing critical thinking skills", the statement that supports that PBL is an effective model would be better to use updated references, because the development of a theory has been well developed. So it is necessary to further study the PBL model of treatment.

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Critical Thinking Skills in High School

Critical thinking ability is an important aspect in high school education that has been the focus of attention in educational literature (Rahman & Manaf, 2017). This concept encompasses students' ability to critically and rationally analyze, evaluate, and synthesize information (Ennis, 2018). In the context of high school education, critical thinking ability enables students not only to understand subject matter more deeply but also to develop stronger general thinking skills (Ghanizadeh, 2017). The definition of critical thinking ability often includes aspects such as analytical skills, evaluation, inference, logical reasoning, and critical reflection on received information (Din, 2020). These dimensions of critical thinking ability can be further elaborated in concepts such as argument analysis, evidence evaluation, and identification of assumptions underlying a statement or argument(Wale & Bishaw, 2020). (Wale & Bishaw, 2020). In the context of education, strategies for developing critical thinking skills include the application of teaching methods that encourage students to pose critical questions, question information, and construct arguments based on evidence (Akpur, 2020).

Educational literature also highlights the importance of critical thinking skills in preparing students to face challenges in the modern era, where information is abundant and rapid changes occur. Critical thinking skills enable students to become independent learners who can critically evaluate information, solve complex problems, and make good decisions in various contexts (Shanta & Wells, 2022). Therefore, the development of critical thinking skills in high school is considered an integral part of preparing students for success in their personal and professional lives in the future. Thus, learning approaches that promote critical thinking skills have become a major focus in educational reform to enhance the quality of learning and student outcomes at the high school level.

Problem-Based Learning (PBL)

Problem-Based Learning (PBL) is a learning approach that places students as the main subject in the learning process (Ali, 2019). This method emphasizes the use of real-world problems as a starting point for exploring and learning mathematical concepts (Almulla, 2020). In this approach, students are presented with situations or problems that require solutions, and they are given the opportunity to developtheir own understanding through exploration and collaboration with fellow students (Almulla, 2019). PBLis based on the constructivist theory in education, which emphasizes active learning and the construction of understanding by students themselves (Cattaneo, 2017). By providing real-world context, PBL helps students to see the relevance of mathematical content to their everyday lives, which can enhance their motivation and engagement in learning (Kalamas Hedden et al., 2017).

The main characteristics of PBL include presenting real challenges to students, giving autonomy to students in finding solutions, and using collaboration among students to solve problems (Hussein, 2021). Through this approach, students not only learn about mathematical concepts but also develop social skills, problem-solving skills, and their critical thinking abilities(Almulla, 2020). The benefits of PBL in mathematics learning include improving understanding of mathematical concepts, increasing student motivation, and preparing students to face real-world situations where mathematical skills are required (Almulla, 2019). However, there are also some challenges associated with the implementation of PBL, including the need for longer preparation and implementation time for learning as well as the need for strong support from teachers and schools(Chang et al., 2017).

The Relationship between PBL and Critical Thinking Skills

Commented [SM7]: In the literature review section, the statement "Critical thinking ability is an important aspect in high school education that has been the focus of attention in educational literature", is it still relevant? Theoretically, all aspects of mathematics are important in mathematics sections. Does this statement quote need to be written down? It would be better because this is part of the literature review, in the initial parts the theoretical definition of critical thinking will be explained

Commented [SM8]: In the literature review section, critical thinking section, improve the writing of quotations

Commented [SM9]: There is the term "Educational literature" in several paragraphs. What is the author's reason for including terminology in this article? It needs to be explained, because the focus of this research is on critical thinking using PBL

Commented [SM10]: The statement "Therefore, the development of critical thinking skills in high school is considered an integral part of preparing students for success in their personal and professional lives in the future" does not coherence with the previous statement in this paragraph.

Commented [SM11]: In the literature review (PBL) section. The terminology "use of real-world" seems inappropriate. In mathematics it would be more appropriate to use "mathematical context"

The relationship between Problem-Based Learning (PBL) and the development of critical thinking skills has been a major focus in educational literature(Thorndahl & Stentoft, 2020). Various studies have investigated how PBL can influence students' critical thinking abilities in various educational contexts, including in mathematics learning. The findings of these studies provide insights into the extent to which PBL can be an effective tool in enhancing students' critical thinking skills(Yennita & Zukmadini, 2021). Articles demonstrating empirical evidence of the effectiveness of PBL in improving students' critical thinking skills hold high value in educational literature. This empirical evidence helps reinforce arguments about the importance of using the PBL approach in developing students' critical thinking skills.These studies often employ strong research designs and relevant methodologies to measure the impact of PBL on students' critical thinking abilities. Some literature articles may also discuss factors influencingthe relationship between PBL and students' critical thinking skills. These factors may include students' characteristics, learning environments, or teaching methods used by teachers. Understanding these factors can help in developing more effective strategies in implementing PBL to enhance students' critical thinking skills. Additionally, educational literature may also discuss the practical implications of the relationship between PBL and critical thinking skills. This may include advice for teachers on how to integrate PBL into their teaching more effectively or recommendations for curriculum development that strengthens critical thinking skills through the PBL approach.

Overall, the literature review on the relationship between PBL and critical thinking skills provides a deeper understanding of how PBL can be used to enhance students' critical thinking skills. Taking into account the empirical evidence, influencing factors, and practical implications, this literature provides valuable guidance for educational practitioners in developing effective learning strategies.

Research Methodology

This research applies a qualitative method with a case study design to analyze the critical thinking ability of high school students in solving mathematical problems with problem-based learning (PBL). The case study design was chosen because it allows researchers to delve into specific contexts and understand the interaction between relevant variables in more detail. In the context of this research, the researchers are interested in understanding how PBL directly affects students' critical thinking abilities. The research subjects consist of two tenth-grade students at SMA Negeri 1 Paguyangan, Brebes, Central Java. The selection of subjects was based on the results of critical thinking ability tests and interest in mathematics learning. This test was used to ensure that the research subjects have a relevant level of critical thinking ability to observe the impact of PBL. Additionally, interest in mathematics learning was also considered important to ensure that the research subjects are truly engaged in the learning process. SMA Negeri 1 Paguyangan, Brebes, Central Java was chosen as the research location because it has implemented the PBL approach in mathematics learning. Thus, the researchers can directly observe the implementation of PBL and evaluate its impact on students' critical thinking abilities. Through this approach, the researchers hope to gain a deep insight into how PBL affects the learning process and student learning outcomes.

The research process involves direct observation of two students during the implementation of mathematics learning using the PBL approach. The data obtained from these observations are then analyzed qualitatively to identify patterns and trends that emerge in student interactions with the learning materials. Thus, this research is expected to provide a deeper understanding of the mechanisms of PBL in enhancing high school students' critical thinking abilities.

Data was collected through:

Commented [SM12]: The statement "These studies often employ strong research designs and relevant methodologies to measure the impact of PBL on students' critical thinking abilities". It should not only reveal the relevance between the two, but reveal where PBL can support CT from each PBL step. And this is strengthened by examining the parts of CT that can be supported by PBL. This applies to the following statements

Commented [SM13]: In the literature review section "The Relationship between PBL and Critical Thinking Skills"
, these statements need to be supported by strong references to support the research conducted

Commented [SM14]: In the case study methodology, it should be revealed what strategies or activities were carried out during the mathematics learning. So it becomes clear what kind of PBL learning case is the focus of the research. Researchers can reveal what activities occur at each meeting with the implementation of PBL so that they can be observed thoroughly.

Commented [SM15]: In the methodology section, it is necessary to briefly describe the characteristics of the research subjects.

Commented [SM16]: Please in the section "The research process involves direct observation of two students during the implementation of mathematics learning using the PBL approach" it is revealed how learning is carried out at each meeting.

Observation

We present the observation results of the student learning process during Problem-Based Learning (PBL) sessions in mathematics education, which are outlined in several indicators in this observation report.

Table 01. Observation Instrument

No.	Observation Indicators
1	Student activity during PBL sessions
2	Level of student participation in discussion and collaboration
3	Student's ability to identify problems
4	Student's ability to formulate questions and hypotheses
5	Student's ability to search for information and resources
6	Student's ability to apply relevant mathematical concepts
7	Level of student engagement in proposing alternative solutions
8	Student's ability to design problem-solving strategies
9	Level of student ability in evaluating and validating solutions
10	Student's ability to draw conclusions and explain results

By using table 01 with indicators like these, observers can conduct structured observations during PBL learning to gain a deeper understanding of student learning processes and the impact of this approach on their critical thinking abilities. Interviews: delving into students' understanding of mathematical concepts and their problem-solving thought processes.

Documentation

Documentation is an important stage in the observation process conducted to analyze students' work, including worksheets and reports produced. This stage involves collecting materials generated by students during the learning process. Documentation includes various forms such as notes, sketches, diagrams, or writings that reflect students' understanding and problem-solving regarding the material learned. Analyzing students' work from this documentation provides a deeper insight into students' understanding of the learning material and their ability to apply mathematical concepts. Worksheets and reports produced by students can also reveal their thought processes in solving the given mathematical problems, thus providing valuable insights for educators in evaluating the effectiveness of learning.

The process of analyzing this documentation involves observing the suitability of students' answers with the criteria established beforehand, such as the appropriateness of problem-solving methods, the accuracy of results, and the depth of understanding of the concepts demonstrated. Additionally, the analysis also includes identifying patterns or trends that emerge from students' work, which can provide additional information about the overall class's level of understanding. Besides providing information about individual students' progress, analyzing students' work from documentation can also assist teachers in adjusting their teaching approaches according to students' needs and levels of understanding. By understanding students' strengths and weaknesses in handling mathematical material, teachers can plan more appropriate learning activities to enhance students' understanding and skills.

Data analysis

Descriptive analysis

Commented [SM17]: In the results section there is a test instrument used, but in the methodology section it is not described. Please describe the critical thinking test instrument complete with the indicators used and how the instrument is tested for validity and reliability.

Commented [SM18]: It is necessary to reveal the suitability of observation instruments with the application of PBL implemented in learning

Commented [SM19]: There needs to be a strong reference to determine the indicators for the observation instrument. Complete the references underlying the instrument

Commented [SM20]: It is necessary to reveal what kind of documentation was carried out in the research

Commented [SM21]: Is there no interview in the research? Because it is important to triangulate the data that has been taken. Interviews are important to cross-check the results of observations and documentation

Commented [SM22]: Is data analysis just a description of the data? In general, all research must describe data. It is necessary to add how qualitative data analysis is carried out. For example, in grounded theory: open code, axial code and theoretical code. For case study data analysis, of course there are steady steps, such as a data reduction process. So in the data analysis section the steps need to be described. Not just describing data. In general, qualitative research uses analyzed data, reducing, triangulating processes to arrive at a conjecture.

This analysis stage involves the researcher in carefully examining various aspects of students' critical thinking skills and how students learn and interact with the learning material. First, in descriptive analysis, the researcher explores information about students' critical thinking abilities through observationof their behavior while solving mathematical problems. This includes observing students' ability to identify problems, formulate questions, analyze information, and evaluate generated solutions. Detailed descriptions of each aspect of critical thinking skills enable the researcher to understand the overall level of students' critical thinking skills comprehensively. Second, descriptive analysis also includes monitoringthe student learning process during PBL. This involves observing students' interaction with the learning material, such as how they collaborate with classmates, how they utilize resources, and how they respond to challenges presented in the problems they face. By observing students' learning processes, the researcher can identify patterns or trends in students' learning approaches that can provide insights into the effectiveness of PBL. Third, in descriptive analysis, the researcher also highlights individual differences among students in terms of critical thinking abilities and their learning processes. This includes identifying students who show significant progress in critical thinking abilities and effective learning strategies, as well as recognizing barriers that students may face in developing their critical thinking skills. By understanding these individual differences, the researcher can provide more specific recommendations for improving learning and teaching in the classroom.

Research findings

The research findings confirm that PBL has a positive impact in helping students develop their critical thinking skills in solving mathematical problems. This study found that through the PBL approach, students are encouraged to actively engage in the learning process, find alternative solutions, and critically reflect on their understanding of mathematical concepts. Thus, PBL provides an effective platform for students to expand their critical thinking skills, which are crucial in preparing them for real- world challenges beyond the classroom. The main findings of this research highlight that PBL encouragesstudents to ask critical questions, challenge assumptions, and develop a deeper understanding of the subject matter. Additionally, PBL also promotes collaboration among students, where they can support each other and enrich their own understanding through discussions and idea-sharing. This indicates that PBL is not just a learning approach, but also an effective method in building students' critical thinking skills and facilitating student-centered learning.

Observation results

Table 02. Observation results

No.	Observation Indicators	Observation results
1	Student activity during PBL sessions	Students are actively engaged in learning, focused, and enthusiastic.
2	Level of student participation in discussions and collaboration	Students actively participate in discussions and collaborate with their peers.
3	Students' ability to identify problems	Students are able to identify problems clearly.

Commented [SM23]: In the research results section, the statement "The research findings confirm that PBL has a positive impact in helping students develop their critical thinking skills in solving mathematical problems", This is a qualitative research. But at the beginning it was concluded that there was a positive impact. Is this a question? Because this research explores how students develop critical thinking skills in PBL learning. So data is needed to support this statement.

Commented [SM24]: The statement "PBL provides an effective platform for students to expand their critical thinking skills, which are crucial in preparing them for real-world challenges beyond the classroom" must also be supported by research data. Because to determine whether a treatment is effective or not, there needs to be supporting data.

Commented [SM25]: In the research results section (table 02). The observation results are not clear. The results of this observation are for which respondents? The results of observations for each research subject should be described in full. Because this section is important for exploring data according to the characteristics of each research subject.

4	Students' ability to formulate questions and hypotheses	Students can formulate relevant questions and hypotheses.
5	Students' ability to search for information and resources	Students actively seek information and utilize available resources.
6	Students' ability to apply relevant mathematical concepts	Students can apply mathematical concepts accurately.
7	Level of student engagement in proposing alternative solutions	Students actively propose alternative solutions.
8	Students' ability to design problem-solving strategies	Students are able to design effective problem-solving strategies.
9	Level of students' ability to evaluate and validate solutions	Students can critically evaluate and validate solutions.
10	Students' ability to draw conclusions and explain results	Students can draw clear conclusions and explain results effectively.

During Problem-Based Learning (PBL) sessions as seen in Table 02, students are actively engaged in learning activities by discussing, working in groups, and seeking solutions to the given problems. They demonstrate a high level of enthusiasm and focus in completing the assigned tasks. Additionally, the level of student participation in discussions and collaborations is also remarkable. They actively participate in discussions and collaborate with their peers in seeking solutions, actively exchanging ideas, providing feedback, and supporting each other's ideas in achieving the best solutions.

Students' ability to identify problems and formulate questions and hypotheses is also evident. They can clearly identify the given problem, understand the challenges faced, and break down the problem into smaller components to facilitate understanding. Additionally, students demonstrate the ability to think creatively in formulating relevant questions and hypotheses to solve the given problem. Students' ability to search for information and resources is also effective, actively seeking information and utilizing various available resources, whether in the form of textbooks, the internet, or assistance from teachers and classmates. Regarding the application of relevant mathematical concepts, students are able to apply these concepts accurately in the context of the given problem, as well as critically evaluate and validate the solutions generated. They are also able to draw clear conclusions and detail the results of the problem-solving process they undergo logically and systematically.

Table 03. Categories that can be formed based on observation results

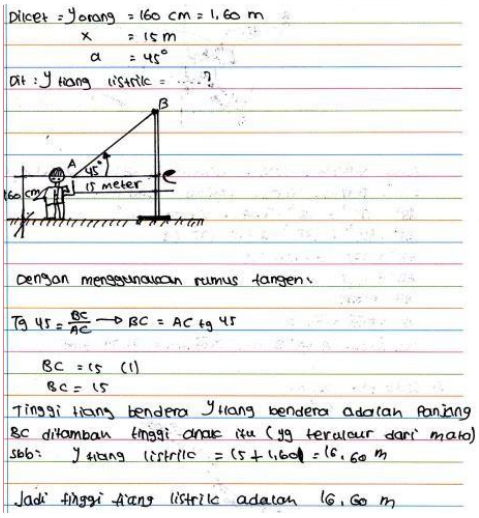
No.	Indicator	Observation results	Category
1	Student Activities and	Student activities during PBL sessions	95% of students are active during PBL sessions.

Commented [SM26]: Table 03. Where do the percentages come from? If I'm not mistaken, this is only 2 respondents? Therefore, it is important to describe the results of observations for each research subject according to their respective characteristics

	Engagement	Level of student participation in discussions and collaborations	91% of students are active in discussions and collaborations
		Level of student engagement in presenting alternative solutions	90% of students actively propose alternative solutions.
2	Students' Thinking Process Ability	Students' ability to identify problems	81% of students are proficient in identifying problems.
		Students' ability to formulate questions and hypotheses	86% of students are proficient in formulating questions and hypotheses.
		Students' ability to search for information and resources	90% of students are proficient in searching for information and resources.
		Students' ability to apply relevant mathematical concepts	80% of students are proficient in applying relevant mathematical concepts.
		Students' ability to design problem-solving strategies	82% of students are proficient in designing problem-solving strategies
		Level of students' ability to evaluate and validate solutions	85% of students are proficient in evaluating and validating solutions.
		Students' ability to draw conclusions and explain results	85% of students are proficient in drawing conclusions and explaining results.

The evaluation results of students' activities and engagement in Problem-Based Learning (PBL) sessions are shown in Table 03, indicating satisfactory achievements. From the collected data, it can be concluded that the level of student participation is very high, with 95% of students actively involved during PBL sessions. Furthermore, 91% of students are engaged in discussions and collaborations, while 90% of students actively propose alternative solutions, reflecting a strong level of student engagement in the learning process. As for students' thinking process abilities, satisfactory achievements are also observed. The majority of students are able to identify problems (81%), formulate questions and hypotheses (86%), as well as search for information and resources (90%) effectively. Students' ability to apply relevant mathematical concepts reaches 80%, while their ability to design problem-solving strategies and evaluate solutions reaches 82% and 85% respectively. The final results indicate that 85% ofstudents are able to draw conclusions and explain the results of their learning. Thus, it can be concluded that students have successfully developed various critical thinking and problem-solving skills through active participation in PBL sessions.

Hasil tes Kemampuan pemecahan masalah matematika



Picture 01: Subject 1 test results

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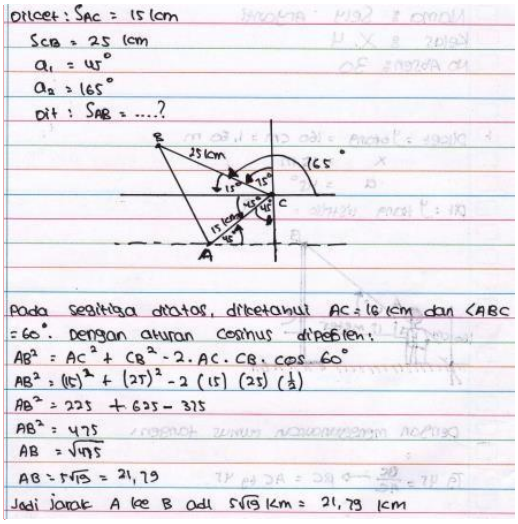
Based on the evaluation results seen in Picture 01, Subject 1, which has been observed through the worksheets, demonstrates abilities consistent with those findings. From the data on student activity and engagement, it can be concluded that Subject 1 may be among the 95% of students who are active during the PBL session, with a strong level of participation in discussions and collaboration. Subject 1's ability to propose alternative solutions, as reflected in the evaluation results, may also be high, considering that 90% of students actively propose alternative solutions. Furthermore, when evaluating Subject 1's ability in the thought process, the evaluation results show that the majority of students are able to identify problems, formulate questions and hypotheses, and search for information and resources effectively. In this context, Subject 1, who may belong to the category of students capable in all these aspects, can be considered consistent with the evaluation findings. Additionally, if Subject 1 can systematically solve mathematical problems according to the problem-solving steps, this also reflects evaluation results indicating the student's ability to apply relevant mathematical concepts, design problem-solving strategies, and evaluate and validate solutions.



Picture 02 Subject 2 test results

The results from picture 02, which show that subject 2 can solve mathematical problems systematically according to problem-solving steps, can be connected with the provided evaluation results in several ways. Firstly, subject 2's ability to solve mathematical problems systematically according to problem-solving steps demonstrates the student's proficiency in applying relevant mathematical concepts. This aligns with the findings from the evaluation results, indicating that 80% of students are able to apply relevant mathematical concepts. Thus, subject 2 may fall into the category of students with this ability. Furthermore, problem-solving steps include the ability to formulate questions, gather information, design problem-solving strategies, and evaluate solutions. If subject 2 can solve mathematical problems systematically, it also indicates that subject 2 may have good abilities in these areas. This aligns with the evaluation results showing that the majority of students are proficient in formulating questions and hypotheses (86%), seeking information and resources (90%), as well as designing problem-solving strategies (82%).

Discussion

Based on the evaluation results of student activities and abilities during Problem-Based Learning (PBL) sessions, as well as the findings from the worksheets indicating the abilities of subjects 1 and 2 in systematically solving mathematical problems according to problem-solving steps, the discussion will further analyze each problem-solving step of both subjects.

1. Analyzing information

Reading and understanding the problem carefully is an important initial stage in the process of solving mathematical problems. This involves students' ability to carefully read and understand the context and requirements contained in the given mathematical problem. Students need to identify the

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Commented [SM29]: Respondents' answers should be confirmed again through an interview process to dig deeper and through the triangulation process

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main statements, the variables involved, and the relationships between various pieces of information provided. The ability to understand the problem carefully will help students avoid misunderstandings and clarify the steps needed to solve the problem. After understanding the problem carefully, students need to be able to identify relevant and irrelevant information. This requires the ability to sift through the information provided in the problem, considering the importance and relevance of this information to the solution of the problem. Students need to recognize essential information to solve the problem and discard irrelevant or unnecessary information.

This ability helps students focus on key aspects of the problem and direct their efforts towards the most productive steps in finding a solution. Furthermore, students also need to be able to identify the mathematical concepts related to the given problem. This involves students' ability to connect the information provided in the problem with the mathematical concepts they have learned previously. Students need to be able to recognize the relationship between the variables presented in the problem and relevant mathematical concepts, as well as identify techniques or strategies appropriate for solving the problem. This ability enables students to build a strong foundation in formulating the right approach to solving complex mathematical problems.

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2. Formulating problems

Students defining the problem clearly is an important step in the problem-solving process. This involves students' ability to identify and articulate the problem they are facing clearly and accurately. Students need to be able to break down the problem into smaller components, determine aspects to be considered, and identify relevant constraints. By defining the problem clearly, students can thoroughly understand the challenges they face and prepare the necessary steps to solve them. After defining the problem, students need to establish problem-solving objectives. This involves formulating the desired goals or outcomes of the problem-solving efforts. Students need to identify expected outcomes or success criteria that can be used to evaluate the effectiveness of the solutions generated. By setting clear objectives, students can focus their efforts on the most relevant and effective steps to achieve the desired solution. Furthermore, students need to be able to formulate questions related to the problem at hand. Thisinvolves students' ability to ask relevant and challenging questions that can help deepen their understanding of the problem. These questions can assist students in identifying the necessary information, exploring alternative solutions, and considering the implications of various approaches. By formulating appropriate questions, students can guide their problem-solving process systematically and effectively.

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3. Finding solutions

Students exploring various possible solutions is a crucial stage in the problem-solving process. This involves students' ability to consider different approaches or strategies that can be used to solve the given problem. Students need to be able to weigh the advantages and disadvantages of each potential solution, as well as identify alternatives they can utilize. By exploring various possible solutions, students can exercise their creativity and develop a deeper understanding of different ways to address the problem at hand. After exploring various possible solutions, students need to select the most appropriate one. This involves critically evaluating each solution that has been explored and selecting the solution that best aligns with the problem-solving objectives established beforehand. Students need to consider factors such as effectiveness, efficiency, and feasibility of each solution being considered. By choosing the most appropriate solution, students can ensure that they are directing their efforts towards the most productive steps in solving the problem.

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Finally, after selecting the most appropriate solution, students need to implement that solution tothe problem at hand. This involves the implementation of the action plan previously formulated, as wellas the concrete steps required to apply the chosen solution. Students need to be able to translate relevant mathematical concepts into concrete actions and execute the necessary procedures to achieve the desired solution. By implementing the solution to the problem carefully and meticulously, students can ensure that they successfully solve the problem effectively and efficiently.

4. Evaluating solutions

After students have selected the solution they consider most appropriate, the next step is to check whether the chosen solution is correct. This involves the process of verification or validation of the generated solution to ensure its correctness and accuracy. Students need to perform relevant testing steps or apply appropriate verification methods to verify that the chosen solution can indeed solve the problem correctly. By conducting careful checks, students can identify and rectify any errors or shortcomings in their solutions before deciding to consider it as an accurate solution. Furthermore, after verifying the correctness of the solution, students need to explain why the solution is correct. This involves the ability of students to detail and articulate the thinking or process used in finding the solution. Students need to be able to identify the steps or strategies used to reach the solution and explain why that approach is the appropriate or effective approach in the given problem context. By explaining the reasons behind the chosen solution, students can reinforce their understanding of the involved mathematical concepts and sharpen their critical thinking skills.

Finally, students need to determine whether the solution found can be generalized to other problems. This involves reflecting on the applicability of the generated solution in a broader context or similar situations. Students need to be able to identify the principles or common patterns underlying the solutions they have found, as well as express their understanding of how the solution can be applied to similar problems in the future. By determining the generalization of the solution, students can develop a deeper understanding of the involved mathematical concepts and broaden the application of their problem-solving skills.

5. Reflecting on the learning process

After completing the problem-solving, the next important step for students is to reflect on what they have learned from the process. This involves reflecting on their learning experiences, the achievements they have made, and the obstacles they may have faced during the problem-solving process.Students need to take time to critically consider how they can enhance their understanding of the material learned and identify lessons they can take away to improve their approach to solving mathematical problems in the future. Furthermore, students need to be able to identify the strengths and weaknesses of their learning process. This involves a thorough evaluation of the steps they took in solving the problem, as well as reflection on the strategies and techniques they used. Students need to be able to recognize the factors that helped or hindered their success in reaching a solution, and consider ways to overcome the challenges they faced. By identifying the strengths and weaknesses of their learning process, students can gain valuable insights into areas they need to improve to achieve better results in the future.

Finally, students need to determine the steps they can take to enhance their learning process. This involves formulating clear and focused action plans to address the weaknesses that have been identified and reinforce the strengths they have demonstrated. Students need to be able to identify new strategies or approaches they can try, as well as set specific and measurable goals to achieve the desired

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improvements. By establishing actionable steps, students can proactively develop their skills in mathematical problem-solving and achieve better outcomes in their learning.

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Conclusion

PBL has proven to be an effective alternative learning model in enhancing students' critical thinking skills in solving mathematical problems. By providing real-world problem situations as a startingpoint, PBL stimulates students' interest and directs them to explore mathematical concepts more deeply. This approach promotes active student engagement, allowing them to discover alternative solutions, question assumptions, and critically reflect on the learning process. Additionally, PBL also encourages the development of various critical thinking skills, such as the ability to analyze information, solve problems, and make appropriate decisions. By considering real-world contexts, students are also trainedto apply mathematical concepts in relevant situations, enhancing their understanding of the subject matter.Through collaboration with peers in problem-solving, students can also hone their communication and teamwork skills, which are essential skills in everyday life and the workplace. Thus, PBL is not just a learning model but also a holistic approach to strengthening students' critical thinking skills in mathematical learning.

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Recommendations

Based on the findings of this research, it is recommended that PBL be used as a learning model in mathematics education in high schools. PBL can help students develop critical thinking skills and other important 21st-century skills that are essential for students to possess.

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