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Research Article

Analysis Of High School Students' Critical Thinking Ability In Solving Mathematical Problems With Independence Problem-Based Learning (IPBL) Model: A Case Study On Middle-Class Students

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ABSTRACT

This research aims to analyze the critical thinking ability of high school students in solving mathematical problems by implementing the Independence Problem Based Learning (IPBL) model. The research method was conducted through a case study involving high school students as research subjects. This case study was conducted on two 10th-grade high school students at SMA Negeri 1 Paguyangan, Brebes, Central Java. The instrument used to measure critical thinking ability was a written test adapted to the context of mathematics. The results showed a significant improvement in students' critical thinking abilities after participating in learning with the IPBL model. Discussion of the results highlights the importance of the IPBL model in enhancing students' critical thinking abilities and its implications in the context of mathematics learning at the high school level. These findings contribute significantly to our understanding of the effectiveness of the IPBL learning model in improving students' critical thinking abilities, as well as demonstrating its relevance in the context of more effective and in-depth mathematics learning at the high school level.

Keywords: Critical thinking, Independence Problem Based Learning (IPBL), mathematics, high school

Introduction

Critical thinking ability is one of the essential aspects in mathematics learning that is often overlooked. In facing the complex challenges presented by mathematics, students need to have the ability to identify, analyze, and evaluate information critically to achieve deep understanding and accurate solutions. However, the lack of emphasis on developing critical thinking skills in traditional curricula often leads students to focus solely on mastering mathematical concepts without being able to effectively apply them in real-world problem contexts. Through this research, we aim to address this gap by analyzing the critical thinking abilities of high school students in solving mathematical problems. Our focus is on the implementation of the Independence Problem Based Learning (IPBL) model, an approach that emphasizes the development of critical thinking skills through problem exploration and independent solution finding.

This background arises from the need for a learning approach that is more oriented towards developing students' thinking skills, not just mastering the material. In addition, we want to explore the potential of IPBL in opening up space for students to develop creativity, collaboration, and problem-solving abilities in the context of mathematics.

Therefore, this research not only aims to evaluate the effectiveness of IPBL in enhancing students' critical thinking abilities but also to contribute to our understanding of a more holistic and relevant learning

approach in the context of mathematics education at the high school level. Thus, it is expected that the findings from this research can provide valuable insights for the development of curriculum and practices in mathematics education that are more effective in the future.

Theoretical Framework

Theory of Trigonometric Problem Solving

Theory of Trigonometric Problem Solving: Trigonometric problem solving is an important branch of mathematics involving the application of trigonometric concepts to solve practical problems in various fields such as physics, engineering, and navigation. Here are some theories underlying trigonometric problem solving: 1) The basic theory of trigonometry includes definitions of trigonometric functions such as sine, cosine, and tangent, as well as their relationships with right triangles. These basic trigonometric concepts serve as the main foundation for understanding and solving trigonometric problems. 2) Trigonometric formulas, such as the sine and cosine formulas for right triangles, as well as trigonometric identities, are important tools in trigonometric problem solving. Knowledge of these formulas allows for solving more complex problems using specific techniques. 3) Solving trigonometric equations involves applying trigonometric concepts to find values that satisfy certain trigonometric equations. Common methods include factoring methods, using trigonometric identities, and using trigonometric cycles. 4) Trigonometry has many applications in geometry and physics. In geometry, trigonometry is used to measure distances, angles, and areas, while in physics, trigonometry is used to analyze motion, waves, and forces occurring in physical systems. 5) In complex trigonometric problem solving, the use of mathematical software such as graphing calculators or numerical computation software can facilitate the calculation process and allow for more accurate and efficient problem solving.

By understanding the basic theories above, one can develop skills in trigonometric problem solving and apply them in various practical contexts. This ability is invaluable in solving problems involving angle calculations, distances, and proportions across different disciplines.

Independence Problem Based Learning (IPBL)

Independence Problem Based Learning (IPBL) is one of the learning models that places students as active subjects in the learning process (Ali, 2019). This model emphasizes the development of students' independence in problem-solving and promotes critical and creative thinking and learning mathematical concepts (Almulla, 2020). Here is a theoretical review of IPBL: 1) IPBL is based on the principle that learning should be more than just receiving information. Instead, students should be actively involved in constructing their own understanding through exploration, investigation, and problem-solving. This model creates a learning environment that encourages students to take initiative in exploring topics, asking questions, and finding solutions to the problems they face. In this approach, students are presented with situations or problems that require solving, and they are given the opportunity to develop their understanding through exploration and collaboration with their peers (Almulla, 2019). PBL is based on constructivist theory in education, which emphasizes active learning and the construction of understanding by the students themselves (Cattaneo, 2017). By providing real-world contexts, IPBL helps students to see the relevance of mathematical material to their everyday lives, which can enhance their motivation and engagement in learning (Kalamas Hedden et al., 2017). 2) The IPBL learning process begins with the presentation of a challenging problem or situation that stimulates students' interest and curiosity. Students then work independently or in small groups to find solutions to the problem. The teacher acts as a facilitator who supports students in this process, providing guidance, feedback, and guiding discussions so that students can develop a deeper understanding. 3) IPBL is an effective means of developing students' critical thinking skills. In answering complex problems, students are required to conduct in-depth analysis, evaluate various options, and formulate appropriate solutions. This encourages students to question assumptions, identify biases, and construct logical and persuasive arguments. 4) The success of IPBL can be measured through various indicators, including students' ability to solve problems, the level of student participation in discussions, and students' ability to develop a deep understanding of the topics studied. Assessment instruments used in IPBL typically include formative and summative assessments that reflect students' learning processes and outcomes. 5) IPBL has strong relevance in mathematics learning because mathematics is a subject that requires problem-solving and critical thinking. By implementing IPBL in mathematics learning, students have the opportunity to develop their critical thinking skills while gaining a deeper understanding of mathematical concepts.

The main characteristics of Independence Problem Based Learning (IPBL) include: 1) In IPBL, students are given an active role as independent learners. They are required to take initiative in problem-solving, identify necessary resources, and develop strategies to achieve learning goals. 2) IPBL emphasizes a problem-based approach where learning begins with the presentation of a challenging problem or situation. This problem stimulates students' interest and curiosity and provides relevant context for learning. 3) One key characteristic of IPBL is empowering students to solve problems independently. They are given the freedom to explore various sources of information, seek solutions, and evaluate their own work.

The main characteristics of IPBL include providing real challenges to students, granting autonomy for students to find solutions, and utilizing 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 IPBL in mathematics learning include enhancing 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 several challenges associated with the implementation of IPBL, 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).
Thus, IPBL becomes one of the intriguing learning approaches to be explored in the context of education in High Schools, as it not only helps students acquire better knowledge but also develops critical thinking skills crucial for success in the real world.

Critical Thinking Skills in High School

Critical thinking skills are an important aspect of high school education that has been the focus of attention in educational literature (Rahman & Manaf, 2017). This concept encompasses students' abilities to analyze, evaluate, and synthesize information critically and rationally (Ennis, 2018). In the context of high school education, critical thinking skills enable students not only to understand subject matter more deeply but also to develop stronger thinking skills in general (Ghanizadeh, 2017). Definitions of critical thinking skills often include aspects such as analytical ability, evaluation, inference, logical reasoning, and critical reflection on received information (Din, 2020). The dimensions of critical thinking skills can be further elaborated in concepts such as argument analysis, evidence evaluation, and identification of assumptions underlying a statement or argument (Wale & Bishaw, 2020). In the educational context, strategies for developing critical thinking skills include implementing teaching methods that encourage students to ask 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 future personal and professional lives. Thus, learning approaches that encourage 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.

The Relationship between Critical Thinking Skills and IPBL

The relationship between Critical Thinking Skills and Independence Problem Based
Learning (IPBL) is very close. The relationship between the development of critical thinking skills and Independence Problem Based Learning (IPBL) has been a major focus in educational literature (Thorndahl & Stentoft, 2020). Various studies have investigated how IPBL can influence students' critical thinking skills in various educational contexts, including in mathematics learning. The results of these studies provide insights into the extent to which IPBL can be an effective tool in enhancing students' critical thinking skills (Yennita & Zukmadini, 2021). Here are some relationships that can be identified: 1) IPBL provides opportunities for students to face complex and challenging problems. In solving these problems, students need to conduct in-depth analysis, evaluate various options, and make decisions based on rational considerations. This encourages students to develop their critical thinking skills. 2) In the IPBL learning environment, students are encouraged to be independent problem solvers. They are prompted to think critically and not conform to others' answers or opinions. This allows students to develop their critical thinking skills more effectively. 3) IPBL requires students to conduct in-depth analysis of the problems they encounter. They need to be able to break down the problem into smaller parts, identify underlying assumptions, and critically evaluate information. Thus, IPBL directly contributes to the development of analytical skills, which are an important part of critical thinking skills. 4) IPBL demands students to actively seek solutions to the problems they encounter. This problem-solving process encourages students to think critically, question assumptions, identify various alternatives, and evaluate the consequences of each action they take. 5) In IPBL, students are encouraged to conduct independent investigations and think creatively in finding solutions to the problems they face. They are given the freedom to explore various approaches and new ideas. This process not only stimulates creative thinking but also encourages students to think critically about the various solutions they propose.
By integrating IPBL into the learning process, schools can provide opportunities for students to naturally and integrally develop their critical thinking skills. This will help students not only in understanding academic concepts but also in facing challenges and problems in everyday life. Therefore, the development of Trigonometry Problem Solving can enhance students' critical thinking skills in effectively and creatively solving mathematical problems.

Table 01 The Relationship Between Trigonometry Problem Solving Strategies and Critical Thinking

1	**In-depth Analysis**	In solving trigonometry problems, students need to conduct a thorough analysis of the given information, identify the relationships between various trigonometric concepts, and formulate appropriate strategies to solve the problems. This analytical process requires critical thinking to understand the problem thoroughly before formulating the steps for its resolution .
2	**Alternative Solutions Evaluation**	Students who use trigonometry problem-solving strategies critically will consider various alternative solutions and identify the strengths and weaknesses of each. They will evaluate each solution they propose by considering its feasibility, accuracy, and relevance to the given problem.
3	**Rational Considerations**	In using trigonometry problem-solving strategies, students are faced with the need to make rational decisions based on careful analysis. They must consider various relevant factors, evaluate the implications of each step they take, and formulate the most appropriate solution with critical consideration.
4	**Creative Problem Solving**	Effective trigonometry problem-solving requires creative thinking in developing innovative and efficient solution strategies. Students who employ critical thinking will explore new approaches, integrate different concepts, and seek unconventional solutions to solve complex problems.
5	**Reflection and Self-Development**	Trigonometry problem-solving strategies based on critical thinking require students to reflect on their problem-solving process and identify areas where they can enhance their understanding and skills. This involves ongoing self-improvement through self-assessment and a commitment to continuous learning and development.

Trigonometry problem-solving strategies are often driven by critical thinking, which is key in assisting students to understand and solve trigonometry problems more efficiently. When students utilize visual approaches, such as drawing diagrams or sketches, critical thinking facilitates the visualization process by enabling them to quickly grasp the trigonometric relationships between objects in the problem. Furthermore, creative approaches in solving trigonometry problems, involving exploration of unconventional solutions, are driven by critical thinking that allows students to test new and innovative solutions that may not have been considered with conventional approaches. Although students follow a systematic approach with structured steps, critical thinking remains necessary to make quick and effective decisions at each stage of problem-solving. In group interactions, students reinforce their critical thinking through discussion and collaboration, stimulating the collective development of critical thinking. This indicates that trigonometry problem-solving strategies and critical thinking work together to strengthen students' abilities in facing trigonometry problem-solving challenges in a more effective and creative manner.

Image 01 Interconnected

In the diagram above, there are three main interconnected concepts: Trigonometry problem-solving strategies, critical thinking, and students' ability in geometry problem solving. Geometry problem-solving strategies encompass various approaches used by students to solve trigonometry problems, such as visual approaches or step-by-step methods. Critical thinking is a factor influencing the selection and utilization of these strategies, with critical thinking playing a crucial role in quick decision-making and understanding problem-solving. Students' ability in trigonometry problem solving is influenced by the interaction between problem-solving strategies and critical thinking, where the use of effective strategies is driven by strong critical thinking skills.

Research Design

The research design in this case study involves the methods and approaches used to collect data and analyze the observed phenomena. Firstly, the method employed is a qualitative approach through a single case study. Participants are 10th-grade students in a high school implementing the IPBL model in mathematics learning. In this approach, the primary focus is on gaining a deep understanding of the researched phenomenon, namely the use of critical thinking in solving trigonometry problems by secondary school students. A single case study allows researchers to explore the details and complexity of the case thoroughly, providing profound insights into students' experiences and factors influencing their use of critical thinking. Next, Data Collection Instruments through valid and reliable critical thinking ability tests, classroom observations, and interviews with students and teachers. The data collection process in this research involves administering critical thinking ability tests, observing the IPBL learning process, and interviewing students and teachers to gain a deeper understanding of their experiences with this learning model. Furthermore, the Data Analysis approach using qualitative and quantitative data will be analyzed to identify the relationship between the use of the IPBL model and students' critical thinking abilities. Thus, this research design allows researchers to gain a rich and in-depth understanding of the use of critical thinking in the context of secondary school students' trigonometry problem-solving.

Research Subjects

The subjects of this research are 10th-grade students at a High School (SMA) that implements the Independence Problem Based Learning (IPBL) teaching model in mathematics subjects. The research subjects will be selected from one class consistently following learning with the IPBL model. Participants involved in this research will be the focus for observing and identifying their critical thinking abilities in solving mathematical problems using the IPBL approach. The number of research subjects will be adjusted according to the relevant class size and in alignment with the research objectives and methods used. These research subjects will serve as representations to understand the effectiveness of the IPBL model in enhancing students' critical thinking abilities at the high school level.

Research Instruments

Observation instruments
Observation is conducted to understand the interaction between students and teachers as well as the level of student engagement in the mathematics learning process using the Independence Problem Based Learning (IPBL) model. This observation also aims to identify students' critical thinking abilities in solving mathematical problems with the IPBL approach. The Rating Scale is Very Low, Low, Moderate, High, Very High. Variables Observed: 1) Student Engagement: The level of student involvement in discussions and learning activities, 2) Critical Thinking Skills: Students' ability to apply critical thinking in solving mathematical problems, 3) Collaboration and Discussion: The quality of collaboration and discussion among students in learning groups, 4) Use of Problem-Solving Strategies: Students' use of problem-solving strategies in the IPBL context. The Observation Instrument includes Student Engagement, Critical Thinking Skills, Collaboration and Discussion, Use of Problem-Solving Strategies. By considering these indicators during the observation process, it is expected that researchers can gain deeper insights into students' use of critical thinking and their skills in solving trigonometry problems, which can be used to enhance classroom learning strategies.

Table 02 Observation Indicators for Research Subjects

No.	Observation Indicators	Analysis Description
1	**Student Engagement**	• Frequency and depth of student participation in group discussions. • Students' ability to ask relevant questions and express their opinions. • Level of student engagement in answering teacher's questions or those from group members.
2	**Critical Thinking Skills**	• Students' ability to identify the given problem. • Students' ability to formulate critical questions related to the problem. • Consistency of students in evaluating proposed solutions with logical reasoning. • Utilization of analytical thinking in solving mathematical problems.
		• The quality of interaction among students in the learning group,

3	**Collaboration and Discussion**	including their ability to listen and provide feedback. • The level of students' ability to explain their thoughts and solutions to group members. • Creativity in presenting ideas and solutions during group discussions.
4	**The Use of Problem-Solving Strategies.**	• Students' ability to identify and apply relevant problem-solving strategies. • Consistency of students in using relevant mathematical concepts in problem-solving. • Students' flexibility in selecting problem-solving strategies appropriate to the given problem context.

Interview Instrument

The interview topics prepared encompass crucial aspects in students' understanding of geometric problem-solving. Firstly, the focus is on students' experiences in geometric problem-solving, exploring their learning journey, including the difficulties they encounter and the strategies they employ. Subsequently, the research will delve into the use of intuitive thinking in the context of mathematical problem-solving, aiming to understand the extent to which students rely on instinct or intuitive feelings. Moreover, specific approaches or strategies employed by students in solving geometric problems will also be examined, including whether they utilize visual representations. Students' understanding of the geometric concepts underlying the problems they face becomes the next focus, with the research attempting to ascertain the extent to which students can link these concepts to the correct solutions. Furthermore, students' experiences in collaborating with their peers in solving geometric problems and the impact of these discussions on their thinking will be explored, highlighting students' ability to collaborate and how such interactions influence the problem-solving process. Finally, students' perspectives on mathematics learning in general, including their level of confidence and any difficulties they may encounter in the subject, will also be examined, providing a comprehensive overview of students' understanding of mathematical concepts and their learning processes.

Table 03 Interview Guidelines for Research Subjects

No.	Interview Topic	Analysis Description
1	**Interview Purpose**	The interview aims to gain a deeper understanding of students' experiences in learning mathematics using the Independence Problem Based Learning (IPBL) model and to explore their perceptions of critical thinking abilities in the context of solving mathematical problems.
2	**Introduction**	o Introduce yourself as the researcher. o Explain the purpose of the interview and the importance of students' contribution to the research.
3	**Questions**	a. Learning Experience with the IPBL Model: • How was your learning experience with the IPBL model in mathematics? • What do you think are the strengths of this learning model? • Did you encounter any specific challenges in learning with the IPBL model? b. Engagement in Discussion and Collaboration: • How do you participate in discussions and collaborate with classmates in mathematics learning? • Do you feel involved in discussions and collaborate well within groups? c. Utilization of Critical Thinking Skills: • How do you interpret critical thinking skills? • Do you feel that you apply critical thinking skills in solving mathematical problems using the IPBL model? • Can you provide a concrete example of how you use critical thinking skills to solve a mathematical problem? d. Response to the IPBL Learning Model: • What is your opinion on the effectiveness of the IPBL model in improving your understanding and critical thinking skills in mathematics? • Do you feel that the IPBL model helps you develop your critical thinking skills? e. Expectations and Suggestions: • Do you have any specific expectations or suggestions to improve the use of the IPBL model in mathematics learning at school?
		o Appreciation for student participation and contribution.

4	**Closing**	o Explain the next steps of the research and thank them for their time.

Worksheet Instrument (Trigonometry Problem-solving Test)

The worksheet instrument for the trigonometry problem-solving test is an evaluation tool used to measure students' ability to solve trigonometry problems. This worksheet consists of a series of questions or tasks designed to assess students' understanding of trigonometric concepts and their ability to apply these concepts in real problem-solving situations. The questions cover material on cubes with indicators of the ability to solve distances from point to point, as well as problem-solving strategies that have been learned. This worksheet instrument provides valuable information about the level of understanding and ability of students in solving trigonometry problems, while also providing insights to teachers to design more effective learning strategies.

Instructions: Carefully work on each problem and provide accurate answers. Use relevant trigonometric formulas and pay attention to logical steps in solving each problem.
Name: _____ Class: _____
Time Allotted: 90 Minutes
Carefully complete each problem and include the steps used to solve it. Use relevant trigonometric formulas and ensure to provide correct answers along with appropriate units. If necessary, use a calculator for more accurate calculations.

Table 04 Worksheet (Trigonometry Problem Solving Test)

No.	Problem Description
1	A flagpole is 15 meters tall. When the sun is directly above the pole, the shadow of the pole forms an elevation angle of 30°. Calculate the length of the shadow of the flagpole.
2	A tower is 50 meters tall. From point A on the ground, the elevation angle to the top of the tower is 60°. The horizontal distance between point A and the base of the tower is 25 meters. Calculate the distance from point A to the top of the tower.
3	A ship is 10 km west of port A and 15 km north of port B. Calculate the distance and direction (angle) of the ship from port A.
4	A car moves straight north at a speed of 60 km/h. At the same time, another car moves east at a speed of 80 km/h. If both cars start from the same point, calculate the relative velocity of the two cars and the angle formed by the path of the first car with respect to the path of the second car after one hour.
5	A hiker is climbing a mountain with a slope of 30° to the horizontal plane. If the hiker climbs vertically for 100 meters, calculate the actual distance traveled by the hiker.

Results and Discussion

In an effort to explore students' abilities in solving trigonometry problems, this research involved observing the research subjects. The observation was focused on several key indicators, such as the use of critical thinking, problem-solving skills, the use of visual representations, understanding of trigonometric concepts, participation in collaboration and discussion, and mathematical communication skills. Through detailed analysis descriptions, it is expected to provide a better understanding of the level of students' critical thinking abilities in solving trigonometry problems and the factors that influence this process.
Interviews were conducted to explore various aspects of NH subject's abilities in solving trigonometry problems. The main focus of these interviews was to gain an in-depth understanding of NH subject's experiences in solving trigonometry problems, the strategies they used, and their understanding of the involved trigonometric concepts. Additionally, the interviews aimed to evaluate NH subject's critical thinking abilities in collaborating, discussing, and verbally communicating their mathematical thoughts.

Table 05 Observation Results of Research Subjects

No	Observation Indicators	Analysis Description
1	**Student Engagement**	• Students are actively participating in group discussions. • Students frequently ask questions and provide responses to the issues discussed. • No students appear passive or unengaged during the learning process.
2	**Critical Thinking Skills**	• Students are able to identify the given problem effectively. • They formulate relevant questions related to the discussed issues. • Students demonstrate the ability to evaluate proposed solutions with logical reasoning. • The use of analytical thinking is evident in solving mathematical problems.
3	**Collaboration and Discussion**	• Interaction among students in the learning group appears good, with active listening and feedback. • Students engage in productive discussions, exploring various ideas and solutions together. • Creativity is evident in presenting ideas and solutions during group discussions.
4	**The Use of Problem-Solving Strategies**	• Students are able to identify and apply relevant problem-solving strategies effectively. • They consistently use relevant mathematical concepts in problem-solving. • Students' flexibility in choosing problem-solving strategies according to the context of the problem is evident.

Based on the observation results, the students demonstrated good critical thinking skills in solving mathematical problems using the IPBL model. They actively participated in group discussions, were able to identify problems, explore various solutions, and apply problem-solving strategies effectively. Collaboration among students also appeared to be effective in achieving a better understanding of the material being studied.

Table 06 Interview Results with Research Subjects

No	Interview Indicators	Analysis Description
1	Learning Experience with IPBL Model	• Students express that they find the learning experience with the IPBL model to be very engaging and beneficial. • They highlight the advantages of this learning model, such as enhancing student engagement and promoting critical thinking.
2	**Engagement in Discussion and Collaboration**	• Students explain that they actively participate in group discussions and feel comfortable collaborating with classmates. • They acknowledge the importance of discussion in achieving a better understanding of the material being studied.
3	**Utilization of Critical Thinking Skills**	• Students provide definitions of critical thinking skills and describe how they apply them in solving mathematical problems. • They give concrete examples of how they use critical thinking skills to analyze problems, formulate problem-solving strategies, and evaluate solutions.
4	**Response to IPBL Learning Model**	• Overall, students provide positive feedback on the IPBL learning model. • They acknowledge that this model helps them develop critical thinking and problem-solving skills, as well as increasing their interest in learning mathematics.
5	**Hopes and Suggestions**	• Some students express their hope for more frequent implementation of the IPBL model in mathematics learning in the future. • They also provide suggestions to pay more attention to fostering group discussions and collaboration to ensure active involvement of every student.

Based on the interview results, students responded positively to the learning experience with the IPBL model and acknowledged its benefits in enhancing critical thinking skills and engagement in mathematics learning. They provided positive feedback on this instructional model and expressed hope for further implementation

in the future. Their suggestions could also be crucial considerations in developing more effective learning models in schools.

Table 07 Test Results for Subject NH

No.	Criteria	Description
1	Accuracy of Trigonometry Answers	Subject NH demonstrates accuracy and precision in calculating angle measurements in Trigonometry.
2	Accuracy in Calculation	Subject NH demonstrates accuracy and precision in their calculation steps.
3	Understanding of Trigonometry Concepts	Subject NH has a strong understanding of the trigonometric concepts involved.
4	Application of Theorems and Formulas	Subject NH is able to apply trigonometry theorems and formulas accurately in problem solving.
5	Procedure or Solution Steps	Subject NH uses logical and systematic steps in solving trigonometry problems.
6	Creativity in Problem Solving	Subject NH shows creativity in finding innovative problem-solving approaches.
7	Interpretation and Justification	Subject NH can interpret results in Trigonometry and provide mathematical justifications.
8	Visualization Skills	Subject NH has good visualization skills in understanding and solving Trigonometry problems.
9	Presentation Neatness	Subject NH presents their answers neatly and systematically, using appropriate notation.
10	Trigonometry Communication Skills	Subject NH is able to communicate their thoughts clearly and effectively regarding Trigonometry problems.

The research findings indicate that Subject NH demonstrates strong performance in various aspects of solving Trigonometry problems. They possess good ability to accurately calculate angle measures in Trigonometry and demonstrate precision in their calculation steps. Their understanding of trigonometric concepts also proves to be strong, and they are able to apply trigonometric theorems and formulas accurately in problem-solving. Additionally, Subject NH utilizes a logical and systematic approach in problem-solving, showcasing their ability to organize solution steps effectively.

Furthermore, the findings indicate that Subject NH also exhibits creativity in finding innovative problem-solving approaches, especially when dealing with complex Trigonometry problems. They can interpret results in terms of Trigonometry and provide mathematical justifications for the steps they take. Subject NH's visualization ability is proven to be good, aiding them in understanding and solving Trigonometry problems efficiently. Moreover, they present their answers neatly and systematically, using appropriate notation. Another key point is that Subject NH can communicate their thoughts clearly and effectively regarding Trigonometry problems, demonstrating good mathematical critical thinking skills. Overall, the research findings affirm that Subject NH possesses solid skills in solving trigonometric problems, as well as the critical thinking ability to present and justify their solutions effectively.

Conclusion

In this study, an analysis of high school students' critical thinking skills in solving mathematical problems using the Independence Problem Based Learning (IPBL) model has been conducted. Based on the findings and discussions presented, several conclusions can be drawn: 1) The research findings indicate that the implementation of IPBL significantly enhances the critical thinking skills of high school students. Through problem-based approaches, collaboration, and productive discussions, students are given opportunities to develop their critical thinking skills more effectively, 2) The role of teachers in facilitating IPBL learning is crucial. Teachers act as guides providing guidance, feedback, and support to students throughout the learning process. With effective teacher support, students can more easily explore and solve problems more effectively, 3) IPBL has strong relevance in mathematics education at the high school level. Through challenging and

contextual approaches, students can relate mathematical concepts to real-life situations, thereby enhancing their understanding of the material and deepening their critical thinking skills, 4) The research findings have significant implications for curriculum development at the high school level. The IPBL learning model can be used as one alternative to enrich students' learning experiences and enhance their critical thinking skills. This also underscores the importance of considering the development of critical thinking skills in mathematics curriculum design, 5) Although this study provides valuable insights into the effectiveness of IPBL in enhancing high school students' critical thinking skills, there are still some challenges to be addressed. Further research can explore the factors influencing the success of IPBL implementation and measure the long-term effects of learning with this model on students' critical thinking skills.

Thus, this conclusion emphasizes the importance of IPBL as an effective learning model in enhancing the critical thinking skills of high school students, as well as providing valuable contributions to the development of more relevant mathematics curricula oriented towards the development of critical thinking skills.

Recommendations

Based on the research findings and conclusions presented, here are some recommendations for educators, researchers, and other stakeholders: 1) Teachers and school administrators are advised to consider implementing the IPBL learning model in their teaching practices. This can be done by designing learning activities that emphasize problem-solving, collaboration, and discussions among students, as well as providing space for students to develop their independence in learning, 2) Adequate training and support for teachers are necessary to effectively implement IPBL. This training may include relevant teaching strategies, the use of supportive educational technology, and collaborative learning among teachers to share best practices, 3) Curriculum developers are encouraged to integrate critical thinking skills into the high school mathematics curriculum. This can be achieved by designing tasks and learning activities that promote students' critical thinking and emphasizing the development of critical thinking skills in the official curriculum, 4) Stakeholders in the field of education are expected to provide financial support for further research on the effectiveness of IPBL in enhancing students' critical thinking skills. Further research can help deepen our understanding of the factors influencing the success of IPBL and the long-term implications of its implementation in mathematics education, 5) Collaboration among educational institutions, both at the local and national levels, can serve as a platform for exchanging experiences and best practices in implementing IPBL. This can expand the reach of IPBL implementation and enhance its effectiveness in improving students' critical thinking skills in various educational contexts.

By implementing these recommendations, it is hoped that we can continue to strengthen learning approaches oriented towards developing students' critical thinking skills, as well as improving the quality of mathematics education at the high school level.

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