

(Research/Review) Article

The Influence of the STEM Approach on High School Students' Mathematical Problem Solving Ability in Trigonometry

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Abstract: This study aims to analyze the effectiveness of the STEM approach and the scientific approach in learning Trigonometry in terms of students' mathematical problem-solving ability and self-efficacy. The research employed a quasi-experimental method with a nonequivalent comparison group design. The study population consisted of all Grade X MIPA students at MA Al-Ma'had An-Nur in the 2023/2024 academic year, with the sample taken from classes X MIPA 1 and X MIPA 2. Data collection instruments included pre-test and post-test assessments of mathematical problem-solving ability and a student self-efficacy questionnaire. Effectiveness criteria were based on post-test averages exceeding 75 for problem-solving ability and self-efficacy scores above 72, as well as improvements from pre-test results. Data were analyzed using the t-test at a 5% significance level to determine learning effectiveness in both groups. Differences in students' initial conditions and treatment effects were examined using Hotelling's T^2 and the N-Gain score test. An independent-sample t-test of N-Gain was used to compare the superiority between the two approaches. The results indicated that both the STEM and scientific approaches were effective in improving students' mathematical problem-solving ability and self-efficacy. The STEM approach significantly influenced both variables and was superior in enhancing problem-solving ability, although not superior in improving students' self-efficacy.

Keywords: Mathematical Problem Solving; Scientific Approach; Self-Efficacy; STEM Approach; Trigonometry Learning.

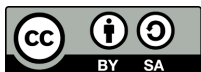
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1. Introduction

Education plays a crucial role in developing human resources capable of adapting to the ever-evolving advancements in science and technology. Quality education is considered high when implemented effectively and achieves its goals. Various innovations in learning can support the creation of competitive, high-quality learning processes worldwide. One modern approach that meets the demands of the 21st century is the Science, Technology, Engineering, and Mathematics (STEM) approach.

STEM is an approach that integrates science, technology, engineering, and mathematics. This approach focuses on the learning process of solving real-world problems and shows students how to integrate concepts and principles from science, technology, engineering, and

mathematics. Developing products, processes, and systems that are useful for human life through STEM in mathematics learning can be done by applying or linking all components contained in the subject matter. Students are expected to be accustomed to practicing critical thinking skills, analyzing, processing data, and solving everyday problems. The application of the STEM approach helps students understand and apply the material learned in the context of various problems.

Learning using STEM (Science, Technology, Engineering, and Mathematics) can be integrated with flexible learning models, can grow students' knowledge and create solutions to rapidly changing problems in the future. Mawaddah (2021) stated that mathematics learning still involves little student performance in project activities, contextual problem solving, and the use of technology. The results of research by Wahono et al. (2020) support that STEM education is a universally important tool that effectively prepares students from diverse national and cultural backgrounds, across Asia, for better learning outcomes.

Acar et al. (2018) presented the results of their study on students who were given learning using STEM and those who were not given learning using STEM, showing that students who were given STEM learning obtained better mathematics learning outcomes than those who did not receive STEM learning. Students in the study acknowledged that they could deepen their understanding of mathematics through learning using STEM. Learning using the STEM approach is very important, because it provides training to students to be able to integrate every aspect at once (Mulyani, 2019). Previous studies have been conducted related to STEM for students. According to Supriyatun (2019) in her research, the conclusion was that the STEM approach can improve students' critical thinking skills and problem-solving abilities. Based on this explanation, it can be concluded that the STEM approach in learning can be an alternative choice to improve students' mathematical abilities, especially in terms of mathematical problem solving.

The STEM approach enables students to understand mathematical concepts by applying practical applications and interdisciplinary approaches, which subsequently enhances their mathematical problem-solving abilities. References indicate that project-based learning and real-world contexts encourage students to think critically and creatively, which are essential for solving mathematical problems (Priatna et al., 2022). STEM supports the development of self-efficacy by providing challenging yet engaging learning experiences. This helps students feel more competent and confident in their ability to understand and solve mathematical problems. A study by Rahmawati et al. (2022) demonstrated an increase in students' self-efficacy through the STEM approach, which enabled them to be more confident in their mathematical abilities. Trigonometry is often considered difficult by students due to its abstract nature. The STEM approach provides a way to relate trigonometry concepts to real-world applications, such as in engineering and technology, which makes the material more understandable and relevant to students (Pratiwi et al., 2021).

Evawati's (2019) research revealed that classroom learning is still dominated by lectures delivered by teachers using a whiteboard. This teacher-centered approach makes students less active and shows little interest in learning. Some students often create noise or engage in activities that are not conducive to learning. During lessons, students tend to be passive, as evidenced by their silence when given the opportunity to ask or answer questions.

One of the goals of mathematics learning is for students to develop problem-solving skills. One way to improve problem-solving skills is by teaching students to create appropriate mathematical explanations for a problem. Problem-solving skills are necessary to train students to deal with the increasingly complex challenges of their lives. It is hoped that this will improve students' ability to complete various problem-solving tasks.

Field research shows that the mathematical problem-solving abilities of most students are still unsatisfactory. This is evident from several studies on mathematical problem-solving abilities that have been conducted. The results of research by Fitria et al. (2018) indicate that students' mathematical problem-solving abilities are still low, as evidenced by the percentage of students who stated that they were unable to understand and re-examine problems given by teachers.

Based on Kanida's (2019) observations, students showed low interest in trigonometry because they felt the material was not useful, especially in the topic of trigonometric ratios in right triangles. This indicates that students do not understand or are familiar with the application of trigonometry in everyday life. Although they can identify the formulas that must be used when facing story problems involving trigonometric ratios in the context of everyday life, they still experience confusion in operating them, so that students' abilities in trigonometry material are still low. Students' errors in solving problem-solving test questions on the topic of trigonometry, students have errors in choosing what method or formula to use to solve the problem and do not understand the method or formula chosen, students do not use all the information provided in the question which affects the wrong results (Wahyuni & Widayanti, 2020: 85). However, according to Komala et al. (2020: 47) they cannot write in the form of a solution, so students have difficulty determining what trigonometry formula is used to solve the problem.

The 2022 PISA results show that Indonesian students' mathematical literacy is still below the OECD average, necessitating improvements in mathematics teaching and learning methods in schools. Specific data from 2022 confirms that Indonesian students' mathematical problem-solving ability remains low compared to international standards. PISA results indicate that students' mathematical problem-solving abilities are still relatively low. This ability is one of the essential cognitive skills students must possess in the learning process. Mathematical problem-solving abilities also need to be developed to achieve optimal academic success.

Based on the description above, one of the affective aspects is self-efficacy. According to Bandura (1997), self-efficacy is a person's belief in their ability to plan and complete the necessary actions to address future situations. In the context of mathematical problem-solving skills, self-efficacy serves as a tool to assess the extent to which students successfully complete problem-solving problems (Jatisunda, 2017). This relates to the extent to which a person believes in their ability to carry out learning activities and complete learning tasks.

Student self-efficacy remains low, as evidenced by research by several experts. Research by Riani & Rozali (2014) found that 68% of students' self-efficacy was in the lower to middle category, while the remaining 32% had good self-efficacy. Based on observations by Arifin et al. (2018), many students hesitate to express their opinions during the mathematics learning process. Lack of interest in mathematics makes them tend to give up quickly when doing assignments and rely more on the answers given by their friends. Student learning outcomes have also not met expectations or are still low. Furthermore, students feel less confident in their knowledge, so they often copy answers from friends who are considered smart without first getting an explanation from the teacher (Widyasari et al., 2018). Several studies have shown that students have difficulty with trigonometry. Research by Pajares & Urdan (2006) revealed that many high school students have low self-efficacy in mathematics, especially in difficult topics such as trigonometry.

One alternative that can be done is to apply the right learning approach, by paying attention to students' abilities in mathematical problem solving and their self-confidence. Students need to be actively involved, because in addition to taking notes and listening, they also learn from the activities they do. Students are accompanied by teachers and given the opportunity to explore the fields of science, technology, engineering, and mathematics. They are also given the opportunity to present the results of their findings, with the hope of improving their abilities in mathematical problem solving in accordance with the STEM approach on relevant material. Therefore, with the STEM approach to trigonometry material, it is expected to have an impact in reducing the problems faced by students in learning trigonometry. In addition, it also describes the effect of the STEM approach in improving mathematical problemsolving skills, as well as being able to increase student self-efficacy.

Based on the description above, the researcher is interested in conducting a study entitled "The Effect of the STEM Approach on High School Students' Mathematical Problem-Solving Ability and Self-Efficacy in Trigonometry". Research is said to be influential when there are differences between the classes studied. In addition to examining the influence test, this study also looked at its effectiveness. Trigonometry learning in high school still faces various obstacles. Many students have difficulty understanding concepts, are less active in the learning process, and have low self-confidence (self-efficacy). This often occurs because learning is still centered on teachers with lecture methods, so students become passive and are not used to thinking critically or solving problems independently.

The STEM (Science, Technology, Engineering, and Mathematics) approach offers a more contextual and applicable learning alternative. Through this approach, students are encouraged to understand mathematical concepts by connecting them to real-life situations and simple projects that require collaboration, creativity, and logical thinking. However, the application of STEM to mathematics learning, particularly trigonometry, is still rare in Indonesia.

This research focuses on improving students' mathematical problem-solving abilities and self-efficacy through the STEM approach compared to the scientific approach on the Right Triangle Trigonometric Comparison material in class X MA Al-Ma'had An-Nur Bantul in the 2023/2024 academic year.

The aim of this research was to determine the effectiveness and influence of the STEM approach on student learning outcomes and to compare it with a scientific approach. It is hoped that the STEM approach will not only improve cognitive abilities but also build students' confidence in facing academic challenges.

Theoretically, the results of this study can enrich the literature on the application of STEM in mathematics learning and serve as a reference for teachers in designing more innovative learning strategies. Practically, this approach helps students see the relevance of trigonometry in everyday life and increases learning motivation.

Thus, the STEM approach has the potential to create a more interactive, meaningful learning process and encourage students to become creative problem solvers who are confident in facing the challenges of the 21st century.

2. Method

This section details the research methods used in developing STEM-based learning tools. This description includes research stages, trial design, research techniques, data analysis techniques, and product feasibility criteria. Each stage is explained systematically to help readers understand the research process as a whole.

Research Stage

This research employed a Research and Development (R&D) method, aiming to produce a mathematics learning tool based on the STEM (Science, Technology, Engineering, and Mathematics) approach. The research stages were conducted systematically to ensure the resulting product had good validity, practicality, and effectiveness. The research stages are explained as follows:

Needs analysis

The initial stage was carried out to identify problems occurring in mathematics learning, particularly in trigonometry. Observations showed that the learning process was still teacher-centered, students were less active, and problem-solving skills and self-efficacy were still low.

Therefore, innovations in learning approaches are needed that can engage students and foster their self-confidence.

Product planning

Based on the needs analysis, researchers developed STEM-based learning tools, including Lesson Plans (RPP), Student Worksheets (LKPD), problem-solving ability tests, and self-efficacy questionnaires. Each tool was designed to align with the characteristics of the 2013 Curriculum and integrate elements of science, technology, engineering, and mathematics into everyday life.

Expert validation

The designed product was then validated by two mathematics education lecturers and one mathematics teacher at the school. Validation covered several aspects, including content suitability, construction, language, and presentation. The validation process aimed to ensure that the learning tool was suitable for use before being implemented in the classroom.

Product revision

Based on input and suggestions from the validators, improvements were made to the content and presentation of the learning materials. These improvements included adjusting the difficulty level of the questions, adding real-world context to the worksheets, and refining the instructions for student activities to make them easier to understand.

Limited trial

After the product was revised, a limited pilot test was conducted on a small group of students to assess the clarity of the instructions, the attractiveness of the presentation, and the level of understanding of the material. Data from this stage was used for further refinement before wider implementation.

Field trials

The final stage was conducted in two classes: an experimental class and a control class. The experimental class implemented STEM-based learning, while the control class used a scientific approach. The results from both classes were then compared to determine the effectiveness of the learning tools on students' mathematical problem-solving skills and self-efficacy.

Trial Design and Instruments

This study used a quasi-experimental design with a pretest-posttest control group design. This design aims to compare the effectiveness of two learning approaches on students' problem-solving abilities and self-efficacy. The experimental class received learning based on the STEM (Science, Technology, Engineering, and Mathematics) approach, while the control class used a scientific approach. Both classes were given a pretest before learning and a posttest after learning to measure improvements in learning outcomes. The research instruments used included several types. First, a mathematical problem-solving ability test in the form of descriptive questions that measured the ability to understand problems, design

strategies, solve problems, and review results. Second, a student self-efficacy questionnaire with a Likert scale, which assessed confidence in one's abilities, perseverance, and the ability to manage emotions and learning motivation.

Additionally, observation sheets of student and teacher activities were used to assess implementation and active participation during the learning process. Interviews and field notes were also used as supporting data to describe student responses to the implementation of the STEM approach. This combination of instruments provided comprehensive data to assess the effectiveness and impact of the learning approach used.

Technique Analysis Data

The data obtained from the research results were analyzed using quantitative and qualitative approaches. Quantitative analysis was conducted to determine differences in learning outcomes between the experimental and control classes. The first step was to conduct normality and homogeneity tests to ensure the data met the requirements for statistical analysis. Next, an independent t-test was conducted to examine the differences in the average pretest and posttest results between the two groups. To measure student improvement, a normalized gain (N-Gain) test was used, which indicates learning effectiveness based on the difference in scores before and after treatment. Meanwhile, qualitative data such as observations, interviews, and field notes were analyzed descriptively to provide an overview of learning activities, student responses, and obstacles that emerged during the learning process.

The results of the two analytical approaches were then interpreted in an integrated manner to assess the extent to which the STEM approach influenced students' problem-solving abilities and self-efficacy compared to the scientific approach.

Product Eligibility Criteria

The feasibility of STEM-based learning products is assessed from three main aspects, namely validity, practicality, and effectiveness.

Validity aspects

Validity is determined by expert assessment of the learning tools. A product is considered valid if the average score is ≥ 3.25 on a scale of 4, categorized as "very appropriate." Validated aspects include the suitability of the material to core competencies, clarity of indicators, conceptual validity, and alignment with the STEM approach.

Practical aspects

Practicality is measured by teacher and student responses to the use of learning tools. A product is considered practical if it is easy to use, has clear instructions, and increases student engagement in learning activities.

Effectiveness aspects

Effectiveness is determined based on improvements in students' mathematical problem-solving skills and self-efficacy after learning using STEM-based devices. If there is a significant improvement compared to scientific learning, the device is deemed effective.

3. Results and Discussion

Initial Product Development Results

The development of learning products based on the STEM approach to Trigonometry material is carried out through several stages, namely: (3.1.1) analysis stage, (3.1.2) design stage, (3.1.3) development stage, (3.1.4) implementation stage, and (3.1.5) evaluation stage. The products developed are in the form of learning tools consisting of Learning Implementation Plans (RPP), Student Worksheets (LKS), Learning Implementation Observation Sheets, as well as mathematical problem-solving ability test instruments and student self-efficacy questionnaires.

Analysis level

The analysis phase was conducted to identify field needs and potential problems that arise in trigonometry learning. Based on interviews with mathematics teachers at MA Al-Ma'had An-Nur and initial observations of 10th-grade MIPA students, several key issues were identified that underlie the need for innovation in learning.

Current learning remains teacher-centered and dominated by lectures and routine practice exercises. As a result, students tend to be passive, rarely ask questions, and exhibit low learning motivation. Furthermore, trigonometry is often considered difficult due to its abstract nature and lack of real-life context, making it difficult for students to grasp the concepts in depth. Observations also indicate that the average score for students' mathematical problem-solving abilities remains below the Minimum Completion Criteria (KKM), which is 75.

In addition to these factors, students' self-efficacy in mathematics is also relatively low. Many students tend to give up easily when faced with complex problems and lack confidence in their own abilities. This condition results in low levels of active participation and self-confidence in the learning process.

The curriculum analysis results indicate that trigonometry material in the even semester of 10th grade has significant potential for integration with the STEM (Science, Technology, Engineering, and Mathematics) approach. This approach is considered relevant because it allows students to conduct real-world experiments and projects, such as creating a clinometer to measure the height of an object using trigonometric concepts.

Based on the analysis, the STEM approach was chosen as the basis for developing the learning tools. Its primary goal is to improve mathematical problem-solving skills while strengthening students' self-efficacy, making trigonometry learning more interactive, contextual, and meaningful.

Design stage

At this stage, learning tools are designed that integrate STEM elements into project-based mathematics learning activities. The main goal of this stage is to produce a learning design that can connect trigonometry concepts with their real-life applications, so that students not only understand the theory but are also able to use it to solve contextual problems.

The product developed includes several main components. First, a STEM-based Lesson Plan (RPP) is structured following the learning stages of reflection, research, discovery, application, and communication as outlined by Laboy-Rush (2010). This model guides students to reflect on problems, explore, discover concepts through experimentation, apply them in real-world contexts, and communicate the results.

Second, project-based Student Worksheets (LKS) are designed to help students understand trigonometry concepts through practical activities. In these worksheets, students are asked to create a simple clinometer using inexpensive materials such as a protractor, straws, string, and weights. The tool is then used to measure the height of various objects around the school, making learning more engaging and meaningful.

Third, a Mathematical Problem Solving Ability Test (KPMM) instrument was developed in the form of descriptive questions. This test includes four main indicators: the ability to understand problems, design mathematical models, solve them, and interpret the results.

Next, a self-efficacy questionnaire was developed based on Bandura's (1994) dimensions of level, strength, and generality. This questionnaire consists of 24 items using a Likert scale of 1–4 to measure students' level of self-confidence in facing various mathematics learning situations.

Finally, a learning implementation observation sheet was developed to assess the practicality and smoothness of the device's implementation in the classroom. In addition to these components, the product design also includes a flowchart of learning activities, from identifying real-world problems and planning projects to conducting experiments and presenting the results of measuring object heights. Therefore, this design stage serves as the foundation for developing interactive, applicable learning products that align with the principles of the STEM approach.

Development stage

This stage represents the realization of the product design. The initial product was then validated by two expert validators: a Mathematics Education lecturer at Yogyakarta State University and a high school mathematics learning practitioner.

Table 1. The validation results.

Rated aspect	Average Score	Category
Suitability of Material with Curriculum	4,60	Very Valid
Integration of STEM Concepts	4,45	Very Valid
Language and Presentation Suitability	4,30	Valid
Clarity of Instructions and Flow	4,35	Valid
Eligibility of LKS and RPP	4,50	Very Valid

The average overall score is 4.44 with the category “Very Valid”, so the product is worthy of implementation with minor revisions in the form of editorial adjustments and the addition of contextual examples.

Implementation stage

The implementation phase was conducted at MA Al-Ma'had An-Nur Bantul in the even semester of the 2023/2024 academic year. The research subjects consisted of two classes: class X MIPA 2 as the experimental class, which received learning using the STEM approach, and class X MIPA 1 as the control class, which received learning using the scientific approach. The activity took place over five meetings, totaling 15 teaching hours.

In practice, learning activities in the experimental class follow the main stages of the STEM approach, which include reflection on real-world problems, research and construction of clinometers, data collection on elevation angles, calculation of object heights using trigonometry concepts, and presentation of measurement results in the form of group reports. This process encourages students to connect trigonometric theory with direct applications in their environment.

During the activity, the teacher acts as a facilitator, guiding and directing students in discovering concepts through active learning experiences. Meanwhile, students act as the primary subjects of learning, actively participating in discussions, experiments, and presentations of group work results.

Observations showed that the learning atmosphere in the experimental class was much more lively than in the control class. Students appeared enthusiastic and actively engaged in the learning process, engaged in collaborative discussions, and were able to communicate their findings to the class. The implementation of the STEM approach successfully created an interactive, contextual learning environment oriented toward developing critical thinking and problem-solving skills.

Evaluation stage

The evaluation phase was conducted to assess the implementation of the learning and the effectiveness of the STEM approach in improving students' mathematical problem-solving skills and self-efficacy. This evaluation used three main instruments: observation of the learning implementation, a mathematical problem-solving ability test, and a student self-efficacy questionnaire.

Based on observations, the learning implementation averaged 86%, which is considered very good. This indicates that all components of the learning activities were implemented well according to plan. Students responded positively to the learning activities, assessing that the implementation of the STEM approach made the learning process more engaging and helped them understand trigonometry concepts concretely through experimental activities and direct application in the field.

Furthermore, teachers also assessed that STEM-based learning was more effective than conventional approaches because it increased students' active participation in the learning process. Students appeared more enthusiastic, expressed their opinions boldly, and demonstrated improvements in critical thinking and group collaboration skills. Thus, the evaluation results indicate that implementing a STEM approach to trigonometry not only improved students' learning outcomes but also strengthened their confidence in addressing mathematical problems independently.

Product Trial Results

The trial was conducted to determine the feasibility and implementation of the learning tools. Data was obtained from observation sheets, teacher reflections, and student responses.

Table 2. The following shows the percentage of learning implementation.

Meeting	Implementation (%)	Category
1	82	Good
2	85	Good
3	87	Very good
4	88	Very good
5	89	Very good
Rate-rate	86	Very good

These results indicate that the learning tools were easy to use and ran smoothly, both for teachers and students. All stages of the activity—from problem reflection, research, concept discovery, implementation, and communication of results—went smoothly.

Student responses to the learning were also positive; 92% of students stated that the STEM approach helped them understand the relationship between trigonometry concepts and real-life situations, such as measuring the height of a flagpole or a school building.

Validity Test Result

Validity and reliability tests were conducted to ensure that the research instruments used had an adequate level of validity and consistency. Two types of validity were tested: content validity and construct validity.

Content validity was assessed through expert judgment on instrument items, including the Mathematical Problem-Solving Ability Test (KPMM) and a self-efficacy questionnaire. The assessment results indicated that all items were valid, with minor revisions to clarify the meaning of the questions and ensure alignment with the research indicators.

Furthermore, construct validity was tested using confirmatory factor analysis (Exploratory Factor Analysis/EFA) with the help of SPSS 27 software. The results of the Kaiser-Meyer-Olkin (KMO) test showed a value of 0.78 (> 0.5) and Bartlett's Test of Sphericity was significant ($p < 0.05$), which indicated that the data was worthy of further analysis using factor analysis. All items in the instrument had a loading factor value above 0.5, so it was declared construct valid.

Reliability testing was conducted using the Cronbach's Alpha coefficient. The calculation results showed that the problem-solving ability test had an α value of 0.84 and the self-efficacy questionnaire had an α value of 0.82, both of which are in the highly reliable category.

Thus, the test results show that all instruments used in this study have met adequate validity and reliability criteria, so they are suitable for use to measure research variables accurately and consistently.

Practicality Test Result

The practicality of the learning was evaluated through observations of implementation in the experimental class. Based on the analysis, the average practicality reached 86% (very good). This means that the STEM-based learning tools are practical and easy to implement in the classroom.

Teachers responded positively that project activities such as making a clinometer effectively motivated students and reinforced trigonometry concepts. Students also found project-based learning more enjoyable, less monotonous, and more self-confident.

Effectiveness Test Result

The effectiveness test was conducted using an inferential test on pre-test and post-test data on students' mathematical problem-solving abilities and self-efficacy. Some statistical tests conducted include normality test, homogeneity test, Hotelling's Trace, one-sample t-test, N-Gain test, and independent sample t-test: (1) Results of Normality and Homogeneity Tests, All data are normally distributed ($p > 0.05$) and homogeneous ($p > 0.05$), thus fulfilling the requirements for further analysis; (2) Results of Learning Effectiveness Test, Results *one-sample t-test* shows that the average problem-solving ability of students in the experimental class is more than 75 ($p < 0.05$) and the score *self-efficacy* more than 72 ($p < 0.05$), meaning the STEM approach is effective; (3) N-Gain Test Results, N-Gain values show an increase in problem-solving ability and self-efficacy after learning.

Table 3. The effectiveness test result.

Class	N-Gain Rate (%)	Category
Experiments (STEM)	49,73	Less Effective
(Scientific) Control	55,84	Quite Effective

Although the increase in the control class was slightly higher, the results of the follow-up test showed a significant difference between the two classes ($p < 0.05$), which means that STEM learning had a real influence on students' mathematical problem-solving abilities.

Product Revisions

Based on the results of the field trials and feedback from teachers and students, several revisions were made to the STEM-based learning tools to make them more effective and easier to implement in the classroom. These revisions focused on aspects of instructional understandability, time efficiency, contextual relevance, and completeness of project assessments.

Major improvements were made to the wording of the instructions in the Student Worksheet (LKS), simplifying the language to make it more accessible to students of all ability levels. Furthermore, the project duration was adjusted from three to four meetings, allowing students sufficient time to optimally design, build, and test the clinometer.

To enhance the relevance of the learning, examples of the application of the STEM approach in everyday life were added, such as the use of trigonometry concepts in architecture and civil engineering. Furthermore, the project assessment rubric was refined by incorporating aspects of creativity and group collaboration, so that assessment focuses not only on the final result but also on the students' learning process.

The revised product was then retested on a limited basis and received positive results, both in terms of implementation and student response. Thus, this STEM-based learning tool is ready for broader implementation in high school mathematics instruction.

4. Discussion

The results of the study indicate that the implementation of the STEM approach has a positive influence on students' mathematical problem-solving abilities in trigonometry. Students who participated in learning with the STEM approach showed higher improvements compared to students in the control class who used the scientific approach. This is because STEM-based learning emphasizes the integration of science, technology, engineering, and mathematics, so that students not only understand concepts theoretically but are also able to apply them in real-life contexts.

Through experiments and projects, students are encouraged to think creatively, collaborate, and find solutions to given problems. These activities develop higher-order thinking skills and foster a sense of responsibility for the results of group work. Thus, learning is not solely teacher-centered but also encourages active student participation in every stage of the learning process.

These findings align with research conducted by Acar et al. (2018) and Priatna et al. (2022), which showed that implementing STEM-based learning can improve critical thinking and mathematical problem-solving skills. Both studies confirmed that when students are faced with real-world problems that require the integration of multiple disciplines, they are encouraged to utilize their knowledge and creativity more optimally.

Meanwhile, the study also showed that the implementation of the STEM approach did not significantly improve students' self-efficacy. Although there was an increase in average scores, statistical tests showed that the difference was not significant compared to the control class. Several factors are suspected to be the cause, including the relatively short duration of STEM implementation, which was only five meetings, so its impact on building students' self-confidence was not optimal. Furthermore, some students still had difficulty adapting to a learning pattern that demands independence, creativity, and intensive teamwork.

However, observations and interviews showed positive changes in students' attitudes toward mathematics learning. They became more confident in expressing their opinions, more active in group discussions, and showed a greater interest in the application of mathematics in everyday life. This indicates that while the increase in self-efficacy was not yet quantitatively significant, qualitatively, there were signs of positive developments in students' motivation and self-confidence.

Overall, these findings indicate that the STEM approach is effective in improving mathematical problem-solving skills and has significant potential to strengthen students' self-efficacy if implemented more sustainably. For optimal results, the STEM approach should be integrated into other mathematics topics and implemented over a longer period of time to give students the opportunity to adapt and develop confidence through repeated and meaningful learning experiences.

5. Conclusion

Based on the results of data analysis and discussion that have been carried out, it can be concluded that the application of the STEM (Science, Technology, Engineering, and Mathematics) approach has proven effective in improving mathematical problem-solving abilities and self-efficacy of high school students in trigonometry material. This can be seen from the average post-test score of mathematical problem-solving abilities of 84.65 and the final self-efficacy score of 84.54 which is included in the high category. The results of the effectiveness test through one sample t-test show a significance value of $p < 0.05$ and a calculated t value greater than t_{table} , so that learning with the STEM approach is declared effective. However, the results of the comparison test with the scientific approach show that the STEM approach only has a significant effect on mathematical problem-solving abilities, while its effect on students' self-efficacy is not yet significant.

Classes using the STEM approach showed a higher increase in problem-solving skills than classes using the scientific approach, while the increase in self-efficacy was relatively equal in both groups. This condition indicates that STEM learning encourages students to think critically, creatively, and analytically in solving problems, but increasing confidence in mathematical abilities requires a longer process and time. Overall, learning with the STEM approach is considered superior to the scientific approach in developing students'

mathematical problem-solving skills, because it is able to link abstract concepts with real-world contexts and provides a meaningful, collaborative, and applicable learning experience.

The results of this study provide important implications for the implementation of mathematics learning in schools. The STEM approach can be used as an innovative learning strategy to develop higher-order thinking skills through project-based activities and experiments relevant to real life. Teachers are required to be more creative in designing integrative, challenging learning that facilitates collaboration among students. Implementing this approach requires careful planning and sufficient time, considering that students need to adapt to a learning model that demands high levels of independence and collaboration. School support in the form of providing facilities, time, and training for teachers is essential for optimal implementation of STEM learning.

Based on these results, it is recommended that mathematics teachers begin implementing a STEM approach by adjusting the difficulty level of projects to students' abilities and utilizing simple materials that are easily obtained in the surrounding environment. Teachers also need to pay attention to students' self-efficacy, especially for those with low confidence in their mathematical abilities, because increasing self-efficacy will support improved problem-solving abilities. Getting used to solving contextual problems related to real life will help students understand the application of mathematical concepts more deeply and increase their motivation to learn.

Furthermore, for future researchers, the results of this study can serve as a basis for conducting further studies with different materials or levels to strengthen empirical evidence regarding the influence of the STEM approach on mathematical problem-solving skills and other affective aspects. Future research can also expand the study by adding other variables such as creativity, learning motivation, or critical thinking skills to obtain a more comprehensive understanding of the effectiveness of STEM-based learning. Thus, the implementation of the STEM approach is expected to be a sustainable effort in improving the quality of mathematics learning and forming a generation that thinks logically, creatively, and confidently in facing future challenges.

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