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Effectiveness of stem-based stad model in improving the understanding of science concepts

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Abstract

This study aims to examine the effectiveness of the STEM-based Student Teams Achievement Division (STAD) cooperative learning model in enhancing elementary school students' understanding of science concepts. The research employed an experimental design using a pretest-posttest control group approach. The sample was selected through cluster random sampling. The research instrument consisted of a multiple-choice test designed to assess students' conceptual understanding of science, which was validated through tests of validity, reliability, item discrimination, and difficulty level. The results of the pretest homogeneity test confirmed that the initial abilities of both the experimental and control groups were equivalent, indicating that any observed differences in posttest scores could be attributed to the intervention. Further prerequisite testing showed that the posttest data were normally distributed and homogeneous, justifying the use of a parametric pooled-variance t-test. The analysis yielded a t_{count} of 5.38, which exceeded the t_{table} value of 1.99 at the 5% significance level, leading to the rejection of the null hypothesis (H_0) and the acceptance of the alternative hypothesis (H_a). These findings demonstrate that the implementation of the STEM-based STAD model significantly improves students' conceptual understanding of science. Therefore, this instructional model can be considered an effective pedagogical strategy for enhancing the quality of science education in elementary schools.

INTRODUCTION

Background of the Study

Science learning in elementary school aims to develop students' understanding of scientific concepts that support critical thinking and problem-solving (Du et al., 2025). Science is not just about memorizing theories and definitions, but also understanding the basic principles of science and how these concepts are applied in everyday life. However, the reality on the ground shows that many students still have difficulty understanding science concepts. This difficulty can be caused by several factors, such as less innovative learning methods, the lack of use of interesting learning media, and the lack of active student involvement in the learning process (Nurhasanah et al., 2025). This results in low student motivation to learn and their understanding of science concepts tends to be shallow. One of the main causes of low student understanding in science learning is the learning approach that is still dominated by the lecture method (Ma, 2021). The lecture method often makes students passive in learning, where they only listen to explanations from the teacher without any in-depth interaction. In addition, this method lacks opportunities for students to explore concepts independently through experiments or discussions. As a result, students' understanding of science concepts tends to be mechanical and non-contextual, so they have difficulty in applying the concepts they have learned into real situations.

To overcome these problems, a more interactive and hands-on experience-based learning approach is needed. This approach allows students to be more active in the learning process, either through experiments, discussions, or group work. Thus, students can more easily understand the concepts of science because they experience and observe firsthand how the principles of science work. One of the approaches that can be applied is the Student Teams Achievement Division (STAD) type cooperative learning model based on Science, Technology, Engineering, and Mathematics (STEM). This model combines cooperation between students with the integration of science, technology, engineering, and mathematical concepts to improve their understanding and critical thinking skills. The STAD-type cooperative learning model is one of the learning strategies designed to increase student engagement in learning (Safiudin, 2024). In the STAD, students are divided into small, heterogeneous groups, where each group member has the responsibility to assist each other in understanding the material being studied. This model allows students to learn collaboratively, discuss, and give feedback to each other, so they can understand the concept more deeply. With the interaction between students, the understanding of concepts becomes better because they not only learn from teachers but also from peers.

The STEM approach in science learning emphasizes the integration of science, technology, engineering, and mathematics to solve real problems (Ali, 2024). In the context of science learning, STEM approaches provide opportunities for students to relate the theories they learn to their practical applications in everyday life. For example, in understanding the concepts of force and motion, students are not only given theoretical explanations, but are also invited to conduct experiments or projects involving engineering and mathematical principles. Thus, they can see how science works in the real world, so that their understanding becomes deeper and more meaningful. The combination of the STAD learning model and the STEM approach in science learning can provide many benefits for students. First, this model encourages students to think critically and creatively in solving problems, as they engage in hands-on exploration and experimentation. Second, this model improves collaboration and communication skills, as students work in groups to understand concepts and complete tasks together. Third, this approach can increase students' motivation to learn, as they are more active in learning and feel more challenged to explore the concepts they are learning.

The integration of STAD and STEM also provides a more enjoyable learning experience for students. Learning based on direct experience and teamwork can create a more dynamic and interactive classroom atmosphere (Capone, 2022). Students learn not only from the teacher's books or lectures, but also from their own experiences and from their peers. Thus, their understanding of the concept of science not only increases, but also lasts longer in their memory. By implementing the STEM-based STAD model, teachers can more easily build a challenging and meaningful learning environment. Teachers can design learning activities that involve STEM-based projects or experiments that are appropriate to the student's developmental level. In addition, teachers can also facilitate discussions and reflections so that students can understand the relationship between the concepts they learn and the real world. This will help students to better understand the concept of science in a more in-depth and applicable way.

In the modern education era, the application of innovative learning models such as STEM-based STAD is very important. Science learning that only focuses on memorizing concepts is no longer relevant to the needs of the times. Students need to be equipped with critical thinking, analytical, and problem-solving skills so that they are ready to face future challenges (Shanta & Wells, 2022). Therefore, a learning approach based on direct experience, teamwork, and the integration of various disciplines such as STAD and STEM is the right solution in improving the quality of science learning in elementary schools. The application of the STEM-based STAD model in science learning provides many benefits for students. Not only does it improve their understanding of science concepts, but it also helps them develop critical, creative, and collaborative thinking skills. By adopting this approach, it is hoped that science learning in elementary schools can be more effective, interesting, and meaningful for students, so that they can be better prepared to face future challenges.

Research's State of the Art

Previous research has examined the effectiveness of cooperative learning in improving student understanding. The STAD model has been proven effective in improving student learning outcomes in various subjects, including science. In addition, STEM approaches have also been studied and proven to improve students' critical thinking and problem-solving skills. STAD has been associated with a significant improvement in student achievement, as evidenced by a study that reported a dramatic increase in A grades among students using this model (Shafiee Rad et al., 2023). Furthermore, other research shows that STAD improves self-efficacy and conceptual understanding, especially in complex subjects such as thermochemistry (Sani & Arianingrum, 2024). STEM methodologies have been shown to foster critical thinking and problem-solving skills, essential for understanding scientific concepts (Hebebci & Usta, 2022). The combination of cooperative learning and STEM approaches can further enhance these skills, leading to better learning outcomes in science education. Several studies have shown that the effectiveness of cooperative learning models can be hampered by factors such as group dynamics and various student abilities (Qureshi et al., 2023). The need for optimal implementation and a supportive environment is essential to maximize the benefits of this educational strategy.

Novelty, Research Gap, & Objective

Although there have been many studies proving the effectiveness of STAD and STEM separately, there are still few studies that integrate these two approaches in science learning in primary schools. Most research still focuses on higher levels of education, such as junior high and high school. In addition, most of the existing research emphasizes more on improving learning outcomes without digging deeper into the understanding of concepts obtained by students. Thus, this study aims to bridge the research gap by examining how the combination of STAD and STEM can improve the understanding of science concepts in elementary school students. The novelty in this study lies in the application of the STAD learning model integrated with STEM approaches in the context of science learning in elementary schools. This study not only assesses the effectiveness of the model in improving learning outcomes, but also explores the extent to which students' understanding of science concepts improves through this approach. Thus, this research makes a new contribution in the field of education, especially in more effective and innovative science learning strategies.

METHOD

Type and Design

This type of research is experimental research, which is a research method used to find the effect of certain treatments on others under controlled conditions (Thomas, 2021). The research design uses a pretest-posttest control group design which aims to obtain differences in students' understanding of science concepts between the experimental and control classes, the design of this study is illustrated in the following table:

All figures and tables should be cited in the main text as Figure 1, Table 1, etc.

Table 1. Pretest-Posttest Control Group Design

Group	Pretest	Treatment	Posstest
Eksperimen	O1	X	O2
Control	O1	-	O2

Information:

O1 = Pretest administration in the experimental and control groups

O2 = Giving postest to experimental and control groups

X = Perlakuan berupa penggunaan pembelajaran STAD bebasis STEM kelas eksperimen

- = Treatment in the form of the use of STAD free STEM learning in experimental classes

The sampling technique used is cluster random sampling. Through cluster random sampling, two classes were randomly selected. Then, from the two classes, they were randomized again to choose the experimental class and the control class. The data collection technique was carried out by a test method using a science concept comprehension test.

RESULTS

The results showed that there was a significant increase in students' understanding of science concepts in the experimental class compared to the control class. Students who learned using the STEM-based STAD model showed a deeper understanding of science concepts, which was demonstrated by higher posttest scores compared to the control group.

Table 2. Recapitulation of Pretest Data in Both Sample Classes

Component	**Data on the Results of Understanding the Concept of Science**	
	Experimental Classes	**Control Classes**
Number of Students	36	35
Lowest Score	64	53
Highest Value	13	12
Average	31,97	28,51
Standard deviation	9,78	9,34
Homogeneity Test	Homogeneous	

The data from the pretest results showed that the average score of the initial test of students in the two samples was 31.97 for the control class and 28.51 for the experimental class with an average difference of 3.46. It shows that the experimental class and the control class are homogeneous, which means that both sample classes have the same initial ability to understand science concepts. Based on these results, the effect of treatment was carried out by analyzing posttest data. After the pretest, then the two sample classes were given different treatments, then the posttest was carried out. The data from the posttest of understanding the concept of science in the experimental class and the control class can be seen in the following table:

Table 2. Recapitulation of Pretest Data in Both Sample Classes

Component	**Data on the Results of Understanding the Concept of Science**	
	Experimental Classes	**Control Classes**
Number of Students	36	35
Lowest Score	82	63
Highest Value	34	26
Average	56,47	43,77
Standard deviation	10,56	8,56
Normality Test	Normal	
Homogeneity Test	Homogeneous	
Uji Hipotesis	-ttable<tcal>+ttable, H0 rejected and Ha accepted	

In the table above, it can be seen that the average score of the experimental class after the posttest is also higher than that of the control class, namely the average score of the experimental class is 56.47 and the average score of the control class is 43.77, with a larger average difference from the pretest results, which is 12.70. Based on the results of the posttest, the experimental and control classes have increased, which shows an increase in students' understanding of science concepts. The experimental class experienced an increase in the average score of 24.5, while the control class experienced an increase of 15.26. The above results show that the increase in the average score experienced by the experimental class is higher than the increase in the average score of the control class.

Based on the results of the normality and homogeneity test of posttest data, it shows that the data is distributed normally and homogeneously, so that the influence of STEM integration STAD learning through this experimental method is tested using the t-test polled variance formula. After the data was analyzed using the t-test polled variance, the results of tcount = 5.38 and ttable = 1.99 were obtained at 69 degrees of freedom with a significance level of 5%. The results of the calculation with the criteria of the two-party test show that the tcount value is greater than +ttable and - ttable, which is -1.99 < 5.38 > +1.99. Based on the two-party test criteria that if -ttable ≤ tcal ≤ +ttable, then H0 is accepted and Ha is rejected, then the results of the above test show the influence of STEM integration STAD learning through experimental methods on students' understanding of science concepts.

DISCUSSIONS

Teamwork is one of the key elements in the STEM-based STAD-type cooperative learning model which has a significant impact on students' understanding of science concepts. In this model, students work in small, heterogeneous groups to achieve common learning goals. Each group member has the responsibility to help each other in understanding the material, discussing concepts, and providing feedback on each other's understanding. The social interactions that occur in groups allow students to learn from different perspectives, thus enriching their understanding of the concepts learned. According to Ghufron (2023), cooperative learning such as STAD improves student learning outcomes because it allows them to actively construct knowledge through discussion and cooperation, compared to an individualized learning approach. In addition, (Silva et al., (2021) emphasized that social interaction in cooperative learning can improve students' conceptual understanding through the exchange of ideas and the strengthening of understanding collectively.

In addition to providing opportunities for students to discuss and work together, the STAD model also encourages them to develop critical thinking skills. In groups, students are challenged to explain concepts to their classmates, analyze problems, and find solutions together. This process is in line with the theory of constructivism put forward by Vygotsky (Suwastini et al., 2021), which states that learning occurs optimally through social interaction and scaffolding from peers or teachers. In the context of science learning, students who work in groups tend to understand abstract concepts more easily, because they can discuss and test their understanding directly with their peers. A study by Ali (2024), demonstrates that cooperative learning not only improves students' academic understanding, but also develops critical thinking, problem-solving, and communication skills, which are crucial in STEM-based learning.

The contextual approach also plays an important role in improving students' understanding of science concepts in STEM-based STAD learning. The STEM approach emphasizes the integration of science, technology, engineering, and mathematics in real problem-solving. In the context of science learning, this approach helps students to understand that science is not just a theory learned in class, but also has real applications in daily life. For example, in learning about energy and force, students can conduct simple experiments using technological devices or small engineering projects to understand how the laws of physics work in everyday life. According to Hsiao et al., (2022), STEM approaches can increase student engagement and understanding because they learn through hands-on experiences that are relevant to the real world.

In addition to increasing student engagement, contextual approaches in STEM-based learning can also reinforce conceptual understanding through experiments and projects. A study conducted by Wilson (2021), found that project-based learning in STEM contexts allows students to develop a deeper understanding of science concepts, as they not only learn through texts or lectures, but also through exploration and hands-on practice. Furthermore, Payne & Costas (2021) stated that experiential learning provides opportunities for students to make connections between theory and its application in the real world, thereby improving their memory and understanding of the material being studied.

The active involvement of students in STEM-based STAD learning is also the main factor that supports the improvement of understanding of science concepts. This learning model requires students to actively participate in the exploration of concepts through experiments, discussions, and problem-solving in groups. In contrast to conventional learning methods that often place students as passive recipients of information, this approach encourages them to become active participants in the learning process. Sari et al., (2025) in their research on the effectiveness of interactive learning showed that students who learn through active methods, such as group discussions and experiments, gain a higher understanding of concepts compared to students who only learn through lecture methods. Furthermore, students' active involvement in STEM-based learning can also increase their motivation to learn. According to research conducted by Capone (2022), active learning methods, such as groupwork in STAD and exploration in STEM, can improve student learning outcomes and engagement in the classroom. Students who are actively involved in the learning process tend to have a higher level of understanding because they experience firsthand how a concept works in real-life situations. When students are given the opportunity to explore concepts through experimentation and project-based problem-solving, it is easier for them to understand the linkages between theory and practice, ultimately strengthening their understanding of the material being studied.

STEM-based active learning also allows students to develop 21st-century skills, such as critical thinking, creativity, and collaboration. According to research conducted by Nurmaliah et al., (2021), STEM-based learning that involves students in projects and problem-solving can help them develop skills that are much needed in the world of work and daily life. Thus, STEM-based STAD learning not only improves students' understanding of science concepts, but also equips them with relevant skills for the future. The combination of teamwork, contextual approach, and active involvement in STEM-based STAD learning has proven effective in improving students' understanding of science concepts. Teamwork allows students to discuss, exchange ideas, and build understanding collectively. The contextual approach helps students see the relevance of science concepts in daily life, so that they can better understand and remember the material. Meanwhile, active engagement through experimentation and exploration provides a more enjoyable and meaningful learning experience, ultimately reinforcing their understanding of the concepts learned. With the support of various studies that have been conducted, the application of STEM-based STAD in science learning can be an effective strategy in improving the quality of education at the elementary school level.

CONCLUSION

The findings of this study indicate that the implementation of a STEM-based Student Teams Achievement Division (STAD) cooperative learning model has a significant and positive effect on elementary school students' understanding of science concepts. In contrast to conventional instructional approaches, this model promotes greater student engagement through collaborative group discussions, concept exploration, and the practical application of learning materials to real-world contexts. The STEM-based STAD approach not only enhances conceptual comprehension but also supports the development of students' critical thinking and cooperative learning skills. Within the STAD framework, students work in small, heterogeneous groups, enabling peer-assisted learning and mutual support in grasping complex scientific ideas. The integration of STEM components into instruction fosters a more engaging and meaningful learning environment, as students are encouraged to deepen their understanding through hands-on experiments, project-based learning, and the use of relevant technological tools. As such, this model presents a promising strategy for enriching science education in elementary classrooms.

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