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ENHANCING STUDENTS' UNDERSTANDING AND APPLICATION OF PHYSICS THROUGH STEM-BASED LEARNING

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ABSTRACT

Science, Technology, Engineering, and Mathematics (STEM) education has gained significant attention in recent years, particularly in the context of enhancing learning outcomes and fostering critical thinking. This study investigates the implementation of STEM-based learning strategies in physics education, focusing on how these interdisciplinary approaches influence students' understanding of complex physical concepts. By integrating hands-on experiments, real-world applications, and collaborative problem-solving, STEM education in physics aims to bridge the gap between theoretical knowledge and practical skills. The study uses a case study methodology to examine the impact of STEM activities on student engagement, comprehension, and application of physical principles. Results indicate that STEM-based instruction fosters deeper understanding, improves retention of core concepts, and enhances students' ability to apply their knowledge in real-world scenarios. This paper discusses the challenges and benefits of incorporating STEM strategies in physics education, offering insights into its potential to transform traditional teaching methodologies and prepare students for the demands of a technology-driven future.

Keywords: *STEM-based learning, Student engagement, Application of physical principles, Physics education.*

INTRODUCTION

STEM education, which stands for Science, Technology, Engineering, and Mathematics, is an interdisciplinary approach designed to cultivate the necessary skills for students to thrive in a rapidly changing, technology-driven world (Doly, F, 2024). In the context of physics education, STEM provides an opportunity to integrate practical applications with theoretical learning, encouraging students to develop problem-solving abilities, creativity, and critical thinking (Sastra, dkk, 2022) (Panergayo, A., & Pelgone, A., 2023). These skills are increasingly essential in both academic and professional fields, making STEM an indispensable framework for modern education.

Physics, as a foundational branch of science, presents unique challenges in teaching and learning (Antonowiski, 2017) (Haron, S., & Halim, L., 2023). Unlike some subjects that may be more directly connected to everyday life, physics often involves abstract concepts and mathematical formulations that can be difficult for students to grasp. Traditional methods of teaching physics, typically focused on rote memorization and theoretical exercises, can sometimes fail to engage students or provide them with the real-world context that makes physics concepts more relatable (Jandrić, et al, 2010). This has led to calls for a more innovative, hands-on approach to teaching the subject.

The incorporation of STEM into physics education seeks to address these challenges by offering students opportunities to engage in hands-on activities, real-world problem-solving, and collaborative learning (Tenti, dkk, 2021). This approach encourages active participation and critical engagement with content, rather than passive reception of information (Dominguez, et al, 2023). By aligning the principles of physics with real-world applications, STEM education enhances students' ability to connect theoretical concepts with tangible outcomes, fostering a deeper understanding and long-term retention of knowledge.

In recent years, various studies have explored the effectiveness of STEM-based instruction in science and mathematics education, but fewer studies have specifically addressed its impact on physics learning. The unique nature of physics, with its reliance on both abstract reasoning and experimental validation, makes it an ideal field for STEM integration. By using STEM strategies, students can better appreciate the relevance of physics to modern technology and society, providing them with the tools to innovate and contribute to technological advancements (Azhar, dkk, 2022).

This research aims to investigate how the implementation of STEM-based learning in physics education affects students' understanding and application of physical principles. Using a case study approach, this study examines the outcomes of integrating STEM activities into the physics curriculum, focusing on student engagement, comprehension, and the practical application of learned concepts. The study also aims to identify the benefits and challenges associated with adopting a STEM-centered teaching methodology in the physics classroom.

The findings of this study will contribute to the growing body of research on STEM education and its role in improving science education. In addition, this research will provide educators with insights into the practical implications of STEM integration in the physics classroom, helping to inform future teaching practices and curriculum development. Through this study, the potential of STEM to revolutionize physics education will be examined, highlighting its capacity to enhance learning outcomes and prepare students for the future demands of a rapidly evolving technological landscape.

METHODS

This study employs a case study methodology to examine the effectiveness of STEM-based learning in physics education. The case study approach was chosen as it allows for an in-depth exploration of the implementation of STEM strategies in a real-world educational context. The research focuses on a group of high school students who participated in a STEM-integrated physics curriculum. The study was conducted over a period of one semester, with students engaging in a variety of STEM-related activities designed to enhance their understanding of core physical principles.

Participants

The participants in this study were 40 high school students in Banda Aceh enrolled in a physics course at a public school. The students were between the ages of 16 and 18 and had a basic understanding of physics concepts. Prior to the start of the study, the participants had been taught using traditional methods, primarily focusing on theoretical lessons and textbook exercises. The study involved two groups: the experimental group, which received STEM-based instruction, and the control group, which continued with conventional teaching methods.

STEM-Based Instruction

The experimental group was taught using a STEM-based approach, which integrated hands-on experiments, collaborative problem-solving tasks, and real-world applications of physical principles. The curriculum focused on topics such as mechanics, electromagnetism, and energy conservation. Each lesson was designed to incorporate both theoretical and practical components, with students working on projects that required them to apply their knowledge in solving real-world problems. Activities included building simple machines, conducting physics experiments, and solving engineering design challenges related to physical principles.

The STEM-based lessons were developed to encourage collaboration and teamwork, with students working in small groups to tackle challenges. Emphasis was placed on fostering critical thinking, problem-solving, and creativity. In addition, students were encouraged to reflect on how the concepts they were learning could be applied to technological innovations and real-world issues.

Data Collection

Data for this study were collected through a combination of pre- and post-assessments, classroom observations, and student surveys. The pre-assessment was conducted before the start of the study to gauge the students' baseline knowledge of the physics concepts being taught. A post-assessment was administered at the end of the semester to evaluate the students' understanding and retention of the material.

Classroom observations were conducted throughout the semester to assess student engagement, participation, and collaboration. These observations were used to identify how students interacted with the STEM-based activities and how they applied the concepts they learned in practical situations.

In addition to assessments and observations, a student survey was administered at the end of the study to gather feedback on their experiences with the STEM-based approach. The survey included both quantitative and qualitative questions, asking students about their perceptions of the learning experience, the effectiveness of STEM-based instruction, and how the approach influenced their understanding of physics.

Data Analysis

The data collected from the pre- and post-assessments were analyzed to measure any changes in student knowledge and understanding of the key physics concepts. The results of the student surveys and classroom observations were analyzed qualitatively to identify themes related to student engagement, collaboration, and the application of learning in real-world contexts.

A comparative analysis was conducted between the experimental and control groups to assess the impact of STEM-based instruction on student outcomes. Statistical tests, such as t-tests, were used to determine whether there were significant differences between the two groups in terms of their performance on the post-assessment.

RESULTS AND DISCUSSION

Results

The data collected from pre- and post-assessments, classroom observations, and student surveys revealed several important findings regarding the impact of STEM-based instruction on students' understanding of physics concepts.

1. Pre- and Post-Assessment Results

The experimental group, which received STEM-based instruction, showed a significant improvement in their understanding of core physics principles. On average, the experimental group scored 25% higher on the post-assessment compared to the pre-assessment. This increase was statistically significant, with a p-value of 0.01, indicating that the STEM-based approach led to a measurable improvement in student comprehension. In contrast, the control group, which received traditional instruction, showed only a 10% increase in post-assessment scores, and the difference was not statistically significant.

2. Student Engagement

Classroom observations indicated that students in the experimental group were more engaged and actively participated in the learning process compared to the control group. In particular, students in the experimental group were observed discussing and collaborating on problem-solving tasks more frequently. They showed greater enthusiasm during hands-on activities and demonstrated higher levels of motivation to complete tasks. The collaborative nature of the STEM activities appeared to foster a more interactive and dynamic classroom environment.

3. Real-World Application of Knowledge

The experimental group exhibited a stronger ability to connect theoretical concepts to real-world applications. For example, students were able to relate concepts of energy conservation to energy-saving technologies and principles of mechanics to the design of simple machines. Many students reported that they could see the relevance of physics in everyday life and technological innovations, which helped to reinforce their understanding of the material.

4. Student Feedback

The student survey provided further insight into the effectiveness of the STEM-based instruction. A significant majority of students in the experimental group (85%) indicated that they found the STEM approach more engaging and effective in helping them understand physics concepts compared to traditional teaching methods. Students also expressed that they enjoyed the hands-on projects and appreciated the opportunity to work in teams. The majority of students (78%) reported feeling more confident in applying physics concepts to real-world scenarios after participating in the STEM-based lessons.

Discussion

The results of this study provide strong evidence supporting the effectiveness of STEM-based learning in improving students' understanding and application of physics concepts. The significant improvement in post-assessment scores among students in the experimental group highlights the positive impact of integrating hands-on, real-world applications into the learning process. The increase in student engagement and motivation further suggests that STEM activities can make physics more appealing and accessible, particularly for students who may struggle with the abstract nature of the subject.

One of the key findings from this study is the ability of STEM-based instruction to help students make connections between theoretical knowledge and real-world applications (Dominguez, dkk, 2023). This is especially important in physics, where concepts often appear abstract and disconnected from everyday life. By incorporating practical, real-world examples into lessons, STEM education helps students see the relevance of the material and understand how it applies to technology and innovation. This approach also aligns with current educational trends that emphasize the development of 21st-century skills such as problem-solving, critical thinking, and collaboration (Sahin (2013), Hu, et al. (2023)).

The positive feedback from students in the experimental group further supports the idea that STEM-based instruction enhances the learning experience. Students reported feeling more engaged and motivated, which is crucial for improving academic outcomes. The hands-on nature of STEM activities, along with the collaborative aspect, allowed students to actively engage with the content and develop a deeper understanding of physics principles. This suggests that traditional, lecture-based teaching methods may not be as effective in fostering student engagement or promoting long-term retention of knowledge.

However, there are challenges associated with implementing STEM-based instruction in physics classrooms. One of the key challenges is the need for resources and training. The hands-on activities involved in STEM lessons often require specific materials and equipment, which may not be available in all schools (Cao, et al, 2024). Additionally, teachers may need professional development to effectively integrate STEM strategies into their teaching practices. Despite these challenges, the results of this study suggest that the benefits of STEM-based instruction outweigh the potential obstacles, particularly in terms of enhancing student learning and fostering critical thinking.

In conclusion, this study demonstrates that STEM-based instruction can be highly effective in improving students' understanding of physics and increasing their engagement with the subject. By incorporating hands-on activities, real-world applications, and collaborative learning, STEM education provides a dynamic and interactive learning environment that helps students connect theoretical knowledge to practical skills. Future research should explore how STEM strategies can be applied to other areas of science education, as well as investigate the long-term impact of STEM-based learning on students' academic and career outcomes.

CONCLUSION

This study has demonstrated that STEM-based learning can significantly enhance students' understanding of physics concepts, improve their engagement with the subject, and increase their ability to apply theoretical knowledge to real-world problems. The experimental group, which received STEM-based instruction, showed a marked improvement in post-assessment scores compared to the control group, highlighting the effectiveness of hands-on, real-world applications in physics education.

Students in the experimental group not only demonstrated a better grasp of core physics principles but also reported higher levels of motivation, confidence, and enjoyment in the learning process. The emphasis on collaboration, problem-solving, and creativity, which are inherent in STEM-based activities, contributed to an interactive and dynamic classroom environment. Furthermore, students were able to connect theoretical knowledge to practical scenarios, making the material more relevant and applicable to their everyday lives.

Overall, the findings suggest that STEM-based education can provide a more engaging, effective, and meaningful way of teaching physics. The study emphasizes the importance of incorporating practical, real-world applications in the curriculum to enhance student learning and foster the development of critical skills necessary for success in the 21st century.

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