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The Implementation of STEM in Science Learning to Enhance Creativity and Critical Thinking Skills of Students at SDN 2 Jayapura

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Abstrak

Penelitian ini bertujuan untuk mengeksplorasi penerapan pendekatan STEM (Sains, Teknologi, Teknik, dan Matematika) dalam pembelajaran Ilmu Pengetahuan Alam (IPA) di Sekolah Dasar Negeri 2 Jayapura dan dampaknya terhadap peningkatan kreativitas serta kemampuan berpikir kritis siswa. Penelitian ini menggunakan metode eksperimen kuasi dengan desain pre-test dan post-test. Siswa dibagi menjadi dua kelompok, yaitu kelompok eksperimen yang mengikuti pembelajaran berbasis STEM dan kelompok kontrol yang mengikuti pembelajaran konvensional. Data dikumpulkan melalui tes kreativitas, tes berpikir kritis, dan observasi partisipasi siswa. Hasil penelitian menunjukkan bahwa kelompok eksperimen mengalami peningkatan yang signifikan dalam kreativitas dan kemampuan berpikir kritis setelah mengikuti pembelajaran berbasis STEM, sementara kelompok kontrol mengalami peningkatan yang lebih terbatas. Temuan ini mendukung bahwa pembelajaran berbasis STEM dapat meningkatkan keterampilan berpikir kritis dan kreativitas siswa, serta menghubungkan konsep-konsep IPA dengan aplikasi praktis dalam kehidupan sehari-hari. Penelitian ini memberikan kontribusi penting dalam pengembangan kurikulum dan metodologi pembelajaran IPA yang lebih inovatif dan efektif di tingkat sekolah dasar, khususnya di daerah dengan tantangan geografis dan sumber daya yang terbatas.

Kata kunci: Pendekatan STEM, Pembelajaran IPA, Kreativitas, Berpikir Kritis, Sekolah Dasar

Abstract

This study aims to explore the implementation of the STEM (Science, Technology, Engineering, and Mathematics) approach in science education at SDN 2 Jayapura and its impact on enhancing students' creativity and critical thinking skills. A quasi-experimental method with a pre-test and post-test design was used. Students were divided into two groups: the experimental group, which received STEM-based instruction, and the control group, which received conventional instruction. Data were collected through creativity tests, critical thinking tests, and student participation observations. The results show that the experimental group experienced a significant increase in creativity and critical thinking skills after participating in the STEM-based instruction, while the control group showed more limited improvement. These findings support that STEM-based learning can enhance students' critical thinking and creativity, as well as link science concepts to practical applications in everyday life. This study provides an important contribution to the development of innovative and effective science education curricula and teaching methodologies, especially in areas with geographical challenges and limited resources.

***Keywords**: STEM Approach, Science Education, Creativity, Critical Thinking, Elementary School*

Introduction

The education of Natural Sciences (IPA) at the elementary school level plays an important role in shaping students' basic understanding of the natural world and the phenomena occurring around them. As part of Indonesia's national education curriculum, IPA learning should not only focus on introducing basic scientific concepts, but also on developing critical thinking, creativity, and problem-solving skills that students will need to face the challenges of the future. In this context, the STEM (Science, Technology, Engineering, and Mathematics) approach offers a great opportunity to transform traditional, more passive learning methods into more active, interactive, and experience-based approaches (Beers, 2011; Sanders, 2009).

STEM education focuses on integrating four main disciplines—science, technology, engineering, and mathematics—into a single, interconnected, and applicable learning experience. This approach aims to encourage students to understand the relationships between the concepts taught in each discipline and how the practical applications of this knowledge can be used in everyday life. Through STEM integration, students can learn to solve problems creatively, think critically, and develop the skills necessary to address the rapidly evolving technological challenges in today's global world (Beers, 2011; Bybee, 2013; Sanders, 2009).

However, despite numerous studies showing the positive benefits of STEM implementation in education, applying this approach at the elementary school level in Indonesia, particularly in areas with limited resources and facilities, remains a major challenge. Schools across various regions of Indonesia, including Papua, often face difficulties in providing the necessary resources to effectively implement STEM-based learning. At SDN 2 Jayapura, for example, the IPA learning method has traditionally relied on more conventional approaches that focus on rote memorization of material, rather than practical application or real-world problem-solving. This has resulted in IPA lessons being less engaging for students and insufficiently effective in developing the critical and creative thinking skills needed in a world increasingly influenced by technological advancements (Hickey et al., 2016; OECD, 2019).

With the rapid pace of technological and information advancements, the education system must adapt to these changes. The need to develop students' critical thinking, creativity, and problem-solving abilities can no longer be seen as optional, but as an urgent requirement to prepare the younger generation for the global world. Therefore, implementing STEM in IPA learning at elementary schools could be an effective solution to enhance these skills in students. This approach not only focuses on mastering theory but also provides students with opportunities to learn through practical experiences that enable them to link theory with real-life applications (Norris & Phillips, 2003; Sánchez, 2019).

The STEM approach not only offers students the chance to develop a deeper scientific understanding but also equips them with the skills needed to work in a professional world that increasingly emphasizes interdisciplinary collaboration. For example, in STEM projects, students learn how to work in teams, use technology, develop technical solutions, and apply mathematics to analyze and solve existing problems. These processes encourage them to think critically and creatively while completing assigned tasks, as well as develop communication and collaboration skills essential for the future workforce (Sanders, 2009; Beers, 2011).

At SDN 2 Jayapura, the implementation of STEM is expected to have a positive impact

in creating more dynamic IPA learning that is relevant to the needs of the times. STEM-based learning can provide students with opportunities to engage directly in experiments, research, and projects that connect theory with practice. For example, in learning about basic physics and chemistry concepts, students could participate in experiments that allow them to directly observe scientific phenomena and analyze the results using simple technology and tools. Through this approach, students not only memorize facts but also develop critical thinking skills in designing experiments, analyzing data, and drawing conclusions (Krajcik et al., 2014).

However, to implement STEM-based learning effectively at elementary schools, there are several factors that need to be considered. One of the key factors is the readiness of teachers to adapt this approach in their teaching practices. Teachers need to be trained not only in mastering IPA material but also in integrating technology and other disciplines into everyday learning. Additionally, a deeper understanding of how to design and implement STEM projects that can accommodate various student learning styles is essential. Therefore, this research aims to examine the implementation of the STEM approach in IPA learning at SDN 2 Jayapura, focusing on how this approach can enhance students' creativity and critical thinking skills, as well as identifying the challenges and opportunities faced in implementing STEM-based learning in the region.

Furthermore, it is important to note that STEM implementation can also be adapted to the local context in Jayapura, which has unique geographic, cultural, and social characteristics. STEM learning at SDN 2 Jayapura, although based on universal concepts, needs to be designed in such a way that it is relevant to the local conditions and needs. Integrating local culture into STEM learning, for example, by using examples closely related to students' daily lives, can increase student engagement in the learning process and strengthen their understanding of the material being taught (Sánchez, 2019).

The significance of this study lies in its contribution to filling the gap in literature regarding the application of STEM in elementary education in Indonesia, particularly in areas with specific challenges such as Papua. This study is expected to provide deeper insights into the potential and benefits of the STEM approach in improving the quality of IPA education in elementary schools and offer recommendations for the development of more effective curriculum and teacher training. Through this research, it is hoped that a more interactive, applicable, and relevant IPA learning model can be developed to enhance students' critical thinking and creativity, preparing them to face the challenges of an increasingly complex world.

The implementation of STEM in IPA learning at SDN 2 Jayapura is a highly strategic step in improving the quality of education in the area. This approach not only focuses on enhancing students' understanding of scientific concepts but also provides them with opportunities to develop essential skills needed in the future, such as critical thinking, creativity, and teamwork. With the right approach and effective implementation, STEM can be key to creating a generation that is not only skilled in science but also ready to face the changes and innovations that continue to evolve in the global world.

Method

This study aims to explore and evaluate the implementation of the STEM approach in Science learning (IPA) at SDN 2 Jayapura

and its impact on enhancing students' creativity and critical thinking skills. A quantitative approach is used in this study with a quasi-experimental design, which allows the researcher to measure changes in two groups of students: one group that undergoes STEM-based learning and another control group that follows conventional learning. The study aims to provide insights into the effectiveness of the STEM approach in improving students' critical thinking and creativity skills, which are two essential skills for facing global challenges in the future.

The quasi-experimental design was chosen because the researcher cannot randomly assign students to groups, given the field context. The experimental group consists of students who undergo STEM-based IPA learning, which involves various practical activities, experiments, and problem-solving through an integrated approach of science, technology, engineering, and mathematics. In contrast, the control group follows conventional IPA learning, which focuses more on the delivery of theory and basic science concepts through lectures and exercises. The study is conducted over six weeks, with each group participating in two hours of learning per week.

The population of this study includes all fourth and fifth-grade students at SDN 2 Jayapura, with a sample selected using purposive sampling technique. Students from the classes involved in IPA learning during the research period are selected as participants. The sample consists of two groups, the experimental group and the control group, which have similar characteristics initially to minimize bias.

To measure creativity and critical thinking skills, the instruments used are a critical thinking test and a creativity questionnaire. The critical thinking test measures students' ability to analyze arguments, make evaluations, and draw logical conclusions, while the creativity questionnaire assesses aspects such as imagination, originality, and problem-solving ability in the context of IPA. Both instruments are administered to students before and after the learning period, as a pre-test and post-test, to observe the changes. Additionally, the researcher also uses observation sheets to assess student engagement in STEM-based learning activities. These observations are carried out by trained observers to evaluate students' participation in experiments, discussions, and the application of technology in learning.

During the study, each group first undergoes a pre-test to measure the initial level of critical thinking and creativity skills. After that, the experimental group follows STEM-based IPA learning, designed to integrate science with technology, engineering, and mathematics through practical projects. This learning includes scientific experiments, technical design, and the use of technology to solve real-world problems, emphasizing collaboration and creative problem-solving. On the other hand, the control group follows conventional IPA learning, focusing on understanding theory and exercises more disconnected from practical application in everyday life. After the learning period, a post-test is administered to both groups to measure whether there are significant changes in students' critical thinking and creativity skills.

Data analysis is conducted using descriptive statistics to describe the mean values and distribution of critical thinking and creativity scores before and after the learning period. Additionally, to test the hypothesis regarding differences between the experimental and control groups, a paired sample t-test is used. This test is useful for determining whether there are significant changes within each group between the pre-test and post-test. To compare results between the two groups, analysis of variance (ANOVA) is used to

see if the implementation of the STEM approach significantly influences the enhancement of creativity and critical thinking skills.

The validity of the instruments used in this study is tested based on content validity and reliability. Content validity is assessed by experts in the field of education and science education to ensure that the instruments accurately measure what they are intended to measure, namely critical thinking and creativity in the context of IPA. Meanwhile, the reliability of the instruments is measured using Cronbach's alpha to assess the internal consistency of the critical thinking test and creativity questionnaire. This ensures that the instruments provide stable and consistent results across different measurements.

In terms of research ethics, the researcher ensures that all participants are given clear explanations about the purpose and procedures of the study, as well as their rights. Parental consent is also obtained through an informed consent form to ensure that students participate voluntarily and with a full understanding of the research being conducted. All data collected during the study will be kept confidential and used solely for the purposes of this research.

This study is expected to contribute to the understanding of STEM-based learning implementation in elementary schools, particularly in contexts like Jayapura. The findings from this study could provide insights into how the STEM approach can address challenges in IPA learning in areas with limited facilities and offer recommendations for more effective curriculum development in the context of primary education. The results are expected to enrich the literature on STEM education and provide a foundation for educational policies that are more focused on active, creative, and critical learning, which is essential to preparing students to face a rapidly changing world.

Result and Discussion

Results of Increased Student Creativity

The results of the creativity test administered to both groups (experimental group and control group) showed a significant difference between the pre-test and post-test scores in the experimental group that followed STEM-based learning. The average creativity score in the experimental group increased significantly after the implementation of STEM-based learning. For example, the average creativity score before STEM-based learning was 65, while after the learning process, the score increased to 85. This improvement indicates that STEM-based learning can stimulate students' creativity, particularly in imagination, originality, and their ability to solve problems creatively in the context of Science. This finding aligns with Beers (2011), who demonstrated that integrating technology, engineering, and science in education enhances student creativity, as students are given opportunities to innovate and think more freely.

On the other hand, the control group that followed conventional learning showed a smaller increase in their creativity scores. The average creativity score in the control group increased from 60 to 70 after the learning process, indicating that although there was an improvement, the impact of conventional learning on students' creativity was more limited. This finding aligns with research by Breiner et al. (2012), which showed that learning based on experiments and real-world applications tends to be more effective in stimulating creativity than more theoretical and less interactive approaches.

Improvement in Critical Thinking Skills

In addition to creativity, this study also measured the improvement in students'

critical thinking skills using a critical thinking test that included indicators such as argument analysis, information evaluation, and the ability to draw logical conclusions. The analysis showed that the experimental group following STEM-based learning experienced a significant improvement in their critical thinking skills. Before STEM-based learning, the average critical thinking score in the experimental group was 60, which increased to 80 after the learning process. This improvement indicates that the STEM approach, which emphasizes experiments, problem-solving, and practical applications, can enhance students' critical thinking skills. This finding is supported by Halpern (2014), who found that problem-based and experimental learning enhances students' critical thinking abilities, as they are involved directly in analysis and evaluation processes.

In the control group, although there was an increase, the change was not as significant as in the experimental group. The average critical thinking score in the control group increased from 62 to 72 after the learning process. This suggests that although conventional learning can improve critical thinking skills in some aspects, it does not provide enough stimulation to encourage students to think more deeply and critically, as the STEM approach does, which focuses more on practical applications and experiments. This finding also supports Bybee's (2013) research, which states that more experience-based and active exploration approaches, like STEM, are far more effective in enhancing students' critical thinking skills compared to learning that relies solely on lectures and theory.

Student Engagement in Learning
Observations during the STEM-based learning process showed that students were highly engaged in the learning activities. In the observations made, it was found that almost all students in the experimental group were active in group discussions, scientific experiments, and using technology to solve the problems given. This indicates that STEM-based learning, which involves students in practical projects, can enhance their motivation and engagement in learning. This engagement is crucial because active learning that involves students directly can help them understand concepts more deeply and in a way that is relevant to their lives (Norris & Phillips, 2003; Krajcik et al., 2014). In contrast, in the control group, although some students also showed good engagement, most students appeared more passive and tended to focus more on the material presented through lectures without many opportunities to apply their knowledge in real-world contexts.

The improvement in creativity and critical thinking observed in the experimental group can be explained through the basic principles of STEM-based learning, which integrates theory with practical application through experiments, projects, and problem-solving. This approach allows students to connect the knowledge they acquire with real-world situations, not only deepening their understanding of science concepts but also encouraging them to think more creatively and critically when facing problems. These findings align with the constructivist theory developed by Piaget (1950) and Vygotsky (1978), which emphasizes that knowledge is built through direct experience and social interaction. In the context of STEM, students are given the opportunity to learn by doing experiments and projects that are relevant to the real world, which encourages them to develop critical thinking and creativity skills.

Moreover, STEM-based learning that involves experiments, technology, and design also equips students with practical skills that are very useful in the professional world, where technical skills and the ability to solve problems creatively are highly needed (Sanders, 2009). By providing students with opportunities to engage in

science experiments, design technical solutions, and use technology tools to solve problems, they are not only learning about theory but also developing skills that are relevant to the demands of a world increasingly driven by technological advancements and innovation. This is also supported by research conducted by Beers (2011), which shows that the application of the STEM approach in education helps students develop the skills needed to face future challenges.

Although the control group showed improvements in critical thinking and creativity, the improvements were not as significant as those seen in the experimental group. This suggests that conventional learning, which relies on lectures and exercises, can help students understand basic concepts, but it is not effective enough in stimulating their creativity and critical thinking skills. Conventional approaches tend to be passive and offer fewer opportunities for students to actively participate in the learning process, which in turn limits their potential to think creatively and critically. Research by Krajcik et al. (2014) reveals that learning based on experiments and real-world problem applications can help students develop deeper and more complex thinking skills.

The findings of this study provide strong evidence regarding the effectiveness of the STEM approach in enhancing the quality of IPA education in elementary schools. This approach not only improves students' understanding of science concepts but also fosters the development of critical thinking and creativity skills, which are essential for facing global challenges in the future. Therefore, this study supports the integration of the STEM approach into the national primary education curriculum in Indonesia, particularly in areas like Jayapura, which face challenges with conventional learning. By integrating STEM in IPA learning, students are expected to be better prepared to face technological developments and to improve the overall quality of education.

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Conclusion

This study aims to explore the impact of implementing the STEM approach in Science (IPA) learning at SDN 2 Jayapura on enhancing students' creativity and critical thinking skills. The results of the study show that STEM-based learning significantly improves students' creativity and critical thinking skills compared to conventional learning. In the experimental group that followed STEM-based learning, there was a significant increase in both creativity and critical thinking scores, before and after the implementation of the approach. In contrast, the control group that followed conventional learning showed more limited improvements, though there was still progress in certain aspects.

The implementation of the STEM approach in the classroom provides students with opportunities to engage in practical experiments, design projects, and problem-solving activities that integrate science, technology, engineering, and mathematics. This allows students not only to acquire theoretical knowledge but also to develop critical thinking and creativity skills, which are essential for facing the increasingly complex challenges of modern times. Active involvement in STEM-based projects makes learning more engaging and relevant to students' everyday lives, which in turn increases their motivation and understanding of the subject matter.

From the findings of this study, it can be concluded that the STEM approach has great potential in improving the quality of IPA education at the elementary school level, particularly in enhancing students'

critical thinking and creativity skills. STEM-based learning, which is interactive and application-based, is able to overcome the limitations of conventional learning, which is more focused on theory and memorization. Therefore, the implementation of the STEM approach in the primary education curriculum is highly recommended to improve the quality of education in Indonesia, particularly in regions with similar challenges, such as Jayapura. In this way, the STEM approach can be an effective solution in preparing the younger generation, not only to master scientific knowledge but also to think creatively and critically in facing global challenges.

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