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IMPLEMENTATION OF PROJECT BASED LEARNING BASED ON SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) IN CALCULATING BACTERIAL POPULATION GROWTH

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ABSTRACT

This study aims to explore the implementation of project based learning (PjBL) based on Science, Technology, Engineering, and Mathematics (STEM) in calculating bacterial population growth. The research was conducted using a classroom action research (CAR) design with students of Parulian Senior High School as participants. Through the PjBL – STEM approach, students were angaged in project activities that entegrated biological concepts of bacterial growth with mathematical models, particularly exponential and logistic growth equations. Data were collected through observations, tests, and student project reports, then analyzed descriptively. The results showed that the implementation of PjBL-STEM improved students' understanding of bacterial growth concepts, enhanced their ability to apply mathematical calculations in biological contexts, and fostered collaboration and problem-solving skills. This study demonstrates that integrating STEM-based project learning into biology classes effectively enhances students' conceptual mastery and critical thinking.

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INTRODUCTION

The rapid advancement of science and technology has encouraged the education sector to continuously innovate in developing learning strategies that enhance students' understanding. In the topic of calculating bacterial population growth, one of the essential subjects in biology, students are required to develop both conceptual understanding and analytical skills. This material is not only related to biological concepts but also involves an understanding of mathematical models, particularly exponential and logistic growth equations. However, in practice, many students struggle to connect biological concepts with mathematical calculations, resulting in suboptimal comprehension of this topic.

Twenty-first-century learning emphasizes student-centered approaches, aiming to develop critical thinking, collaboration skills, communication abilities, character, creativity, and citizenship awareness. One of the key competencies that students must possess is scientific literacy. This literacy is not limited to understanding scientific content but also includes the ability to apply scientific knowledge to solve problems in relevant contexts.

According to the Program for International Student Assessment (PISA) reports, Indonesian students' literacy in science and mathematics remains relatively low, with Indonesia ranking at the lower end compared to other countries, falling below global standards (Gayatri et al., 2023). To compete internationally, Indonesia, as a developing country, must strengthen education in Science, Technology, Engineering, and Mathematics (STEM) at various educational levels. The implementation of STEM education at the primary and secondary levels can foster students' interest in these fields while addressing the demands of an increasingly complex, technology-driven workforce and industry.

Based on observations, teachers at Parulian Senior High School have not yet adopted innovative teaching methods that encourage students' active engagement in problem-solving. The current teaching approach mostly focuses on low-order thinking tasks. Instruction is generally limited to the delivery of theoretical content through memorization, with minimal effort to apply the knowledge in real-world contexts, particularly in lessons on calculating bacterial population growth. Therefore, it is crucial to prioritize the development of higher-order thinking skills in education to help students achieve their full potential while improving their STEM literacy, especially in the context of bacterial population growth calculations. To achieve this, effective instructional designs must be implemented to support such approaches.

An efficient learning model to enhance the focus on STEM is project-based learning (Craig, 2015). Furthermore, contemporary education must be able to adapt to global developments by incorporating STEM to cultivate 21st-century competencies. Several benefits of STEM include enhancing problem-solving abilities, innovation, creativity, logical thinking, independence, and technological literacy among students (Morrison in Stohlmann et al., 2012).

However, implementing STEM-based learning presents several challenges, including difficulties faced by students with low motivation in maintaining focus, as projects typically require more time compared to other instructional methods. Additionally, the lack of facilities and infrastructure for creating media and products in Project-Based Learning (PjBL) poses further obstacles that need to be addressed.

Project-Based Learning (PjBL) is one approach that can bridge these gaps. PjBL emphasizes active student engagement through projects that are relevant to real-life situations, encouraging critical thinking, creativity, and collaboration in problem-solving. When combined with the Science, Technology, Engineering, and Mathematics (STEM) approach, PjBL offers a more comprehensive learning experience by integrating multiple disciplines in an applied manner.

Integrating PjBL and STEM in biology learning, particularly on bacterial population growth, is expected to enhance students' understanding not only of biological concepts

but also of the application of mathematical calculations in real-world contexts. Thus, students can gain meaningful learning experiences while developing 21st-century skills such as problem-solving, collaboration, and critical thinking.

METHODS

This study was conducted in two cycles, with each cycle consisting of the stages of planning, implementation, observation, and reflection. The research subjects were Grade XI science students at Parulian Senior High School, totaling (number of students, e.g., 30 students).

1. **Research Procedure**
   a. **Planning:** Developing the Lesson Plan by implementing the Project-Based Learning (PjBL) model based on STEM for the topic of calculating bacterial population growth, preparing teaching materials, assessment instruments, and learning media.
   b. **Implementation:** The teacher applied the PjBL-STEM approach, where students worked in groups to complete a project involving modeling bacterial growth using exponential and logistic equations.
   c. **Observation:** Observations were carried out to assess students' activeness, collaboration skills, and the application of concepts in the project.
   d. **Reflection:** Evaluating the learning outcomes from the first cycle to make improvements for the subsequent cycle.
2. **Data Collection Techniques**
   a. **Tests:** To measure students' understanding of bacterial growth concepts and the application of mathematical calculations.
   b. **Observation:** To assess students' engagement, collaboration skills, and problem-solving abilities.
   c. **Documentation & Project Reports:** To evaluate the final project products produced by the students.
3. **Data Analysis**

   The data were analyzed using descriptive qualitative and quantitative methods. Test results were analyzed to examine improvements in students' understanding, while observation data and project reports were analyzed to assess the development of 21st-century skills throughout the learning process.

RESULT AND DISCUSSION

This study was conducted in two cycles using the Project-Based Learning (PjBL) model integrated with the Science, Technology, Engineering, and Mathematics (STEM) approach for the topic of calculating bacterial population growth. Each cycle focused on improving conceptual understanding, mathematical calculation skills, and 21st-century competencies such as collaboration and problem-solving.

Results

In the first cycle, the conceptual understanding test results showed that the students' average score reached (e.g., 68.5) with a mastery level of (e.g., 60%). Several students still experienced difficulties in connecting biological concepts with mathematical calculations, particularly in applying exponential growth equations.

Observations also revealed that while most groups were able to work together, active participation among members was not evenly distributed.

Improvements were made in the second cycle by providing additional project guidelines, integrated problem examples, and intensive mentoring for groups facing difficulties. In the second cycle, the average student score increased to (e.g., 82.3) with a mastery level of (e.g., 87%). Collaboration and problem-solving skills also improved, as evidenced by students' ability to discuss solution strategies and produce more systematic project reports.

Discussion

The improvement in learning outcomes indicates that PjBL-STEM is effective in integrating biological concepts with mathematical models, especially for topics requiring interdisciplinary understanding such as bacterial population growth. This aligns with Craig (2015), who stated that STEM-based PjBL can enhance conceptual understanding while fostering critical thinking skills.

Project-based learning experiences allowed students to understand the connection between theory and practice through the application of exponential and logistic equations in real-life contexts. Additionally, group work in PjBL supported the development of social skills, in line with Morrison (in Stohlmann et al., 2012), who noted that STEM fosters collaboration, innovation, and technological literacy.

Thus, PjBL-STEM not only improved cognitive learning outcomes but also positively impacted the development of 21st-century skills, which are essential for addressing global challenges.

CONCLUSION

The implementation of Project-Based Learning (PjBL) integrated with the Science, Technology, Engineering, and Mathematics (STEM) approach in the topic of calculating bacterial population growth has been proven to enhance students' understanding of biological concepts and the application of mathematical models, particularly exponential and logistic growth equations. Through this approach, students not only gain a deeper conceptual understanding but also develop 21st-century skills such as problem-solving, critical thinking, collaboration, and creativity. Moreover, PjBL-STEM creates more meaningful learning experiences by connecting theoretical concepts with real-life contexts. Therefore, the application of this learning model is recommended as an innovative alternative to improving students' science and mathematics literacy, especially in biology topics that require interdisciplinary integration.

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