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Project Based Learning (PjBL) in mathematics learning to improve active learning

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Abstract

Project Based Learning (PjBL) is a student-centered learning method that utilizes projects or activities as the primary learning approach. In this method, lecturers act as facilitators and motivators, guiding students in conducting observations, research, and presentations. This study explores the implementation of PjBL in mathematics learning oriented toward active learning using a qualitative research approach. Data were collected through classroom observations, in-depth interviews, and student reflections, then analyzed using thematic analysis to identify patterns and challenges in its application. The findings reveal that PjBL fosters student engagement, critical thinking, and collaborative problem-solving. However, several challenges were identified, including planning and preparation, time management, resource availability, collaboration, assessment strategies, and teacher competencies. These findings suggest that successful implementation of PjBL requires structured guidance, sufficient resources, and professional development for educators to optimize active learning in mathematics.

Keywords*: Learning Methods, Project Based Learning, Students*

Abstrak

Project Based Learning (PjBL) merupakan metode pembelajaran yang berpusat pada siswa yang memanfaatkan proyek atau kegiatan sebagai pendekatan pembelajaran utama. Dalam metode ini, dosen berperan sebagai fasilitator dan motivator, membimbing siswa dalam melakukan observasi, penelitian, dan presentasi. Penelitian ini mengeksplorasi penerapan PjBL dalam pembelajaran matematika yang berorientasi pada pembelajaran aktif dengan menggunakan pendekatan penelitian kualitatif. Data dikumpulkan melalui observasi kelas, wawancara mendalam, dan refleksi siswa, kemudian dianalisis menggunakan analisis tematik untuk mengidentifikasi pola dan tantangan dalam penerapannya. Temuan penelitian mengungkapkan bahwa PjBL mendorong keterlibatan siswa, pemikiran kritis, dan pemecahan masalah secara kolaboratif. Namun, beberapa tantangan diidentifikasi, termasuk perencanaan dan persiapan, manajemen waktu, ketersediaan sumber daya, kolaborasi, strategi penilaian, dan kompetensi guru. Temuan ini menunjukkan bahwa keberhasilan penerapan PjBL memerlukan bimbingan terstruktur, sumber daya yang cukup, dan pengembangan profesional bagi pendidik untuk mengoptimalkan pembelajaran aktif dalam matematika.

Kata kunci: Mahasiswa, Metode Pembelajaran, *Project Based Learning*

INTRODUCTION

Project Based Learning (PjBL) is not a new concept but has gained increasing attention as an innovative learning method. PjBL is a student-centered approach that integrates projects or activities as a medium for learning. In this approach, students engage in observation, research, and presentations, either individually or in groups, while lecturers serve as facilitators and motivators.

In recent years, research on PjBL has expanded across various educational institutions worldwide (De Graaff & Kolmos, 2003; Harmer & Stokes, 2014; Lehmann et al., 2018). Researchers have provided various definitions for PjBL that basically have some similarities in the disciplines they represent. In terms of crucial function, Shin (2018 explained that PjBL is a learning approach that focuses on learning activities and real and contextual tasks that challenge students to solve them. Asmara & Septiana (2023 describe PjBL as a student-driven learning method, where students actively participate in real or contextual projects, formulate questions, collaborate with lecturers, and present their findings to a broader audience. In other words, students are directly involved in designing their own questions and problems, creating personal lesson plans, organizing their own research, using a variety of supportive learning strategies, and evaluating their projects in real-world contexts outside the classroom. This process enables students to design their own learning objectives, plan research activities, utilize diverse learning strategies, and assess their projects in real-world contexts (Sujatha & Vinayakan, 2024).

Highlights the role of lecturers in PjBL as facilitators who guide students in cooperative and collaborative learning (Septy, 2019). This aligns with constructivist learning theory, which posits that knowledge is built through experience and personal construction (Agustiani, 2015). Through PjBL, students develop essential skills such as critical thinking, problem-solving, collaboration, and self-directed learning, which are crucial for success in a globalized era.

Although PjBL is widely recognized as an effective approach, its implementation varies across educational levels. Most studies focus on high school education, while research in higher education remains limited, particularly in disciplines such as engineering, business, media studies, geography, and mathematics (Harmer & Stokes, 2014; Lehmann et al., 2018). In the field of mathematics education, PjBL has the potential to bridge theoretical understanding with practical application, enhancing both conceptual learning and problem-solving abilities (Baskara et al., 2024; Muhammad & Nurwidyayanti, 2024).

At the University of Muhammadiyah Bengkulu, mathematics education lecturers acknowledge the importance of PjBL in developing student competencies. In the

Mathematics Learning Planning course, PjBL is integrated to enhance student knowledge, foster relevant skills for future careers, and promote active learning. This approach aligns with Key Performance Indicator (IKU) 7, which emphasizes collaborative and participatory learning environments.

PjBL is closely linked to Active Learning, a pedagogical approach that actively engages students beyond passive listening. Active Learning encompasses various methods, including: 1) Small Group Discussions, students work in small groups to discuss material, solve problems, or evaluate concepts. It helps develop communication and collaboration skills. 2) Problem Based Learning, students are given real problems that they have to solve. This problem-solving process helps develop critical thinking and problem-solving skills. 3) Project Based Learning, students work on long-term projects that typically result in a final product. This allows students to apply knowledge and skills in a more tangible context. 4) Simulations and games, using simulations or games to teach concepts can make learning more engaging and in-depth. 5) Questioning and reflection, ask questions that encourage students to think more deeply about the material and reflect on their own understanding. 6) Case-Based Learning, students learn the material through the analysis of real or fictitious cases that are relevant to the learning topic. 6) Peer Teaching, students teach the material to their classmates. This not only helps the teaching to understand the material more deeply, but also strengthens the understanding of other students. 7) Hands on activities, practical activities such as experiments, art projects, or model construction that involve physical manipulation of learning materials. 8) Inquiry Based Learning, students begin learning with a question or problem and use the inquiry process to find an answer or solution.

By integrating PjBL within an active learning framework, students can improve knowledge retention, critical thinking, motivation, collaboration, and independent learning skills. This study aims to explore the implementation of PjBL in mathematics learning at the higher education level by addressing the following key objectives: 1) Evaluate the effectiveness of PjBL in university-level mathematics education-Identifying best practices for course and faculty-level implementation. 2) Identify key conditions and factors influencing PjBL adoption-Examining institutional, faculty, and program-level enablers and constraints. 3) Analyze challenges faced by lecturers and students in implementing PjBL-Addressing barriers to effective execution.

This research contributes to a deeper understanding of how PjBL can enhance mathematics education in higher education while identifying practical strategies for overcoming implementation challenges.

METHOD

This study employs a qualitative case study design to analyze the implementation of Project-Based Learning (PjBL) in mathematics education at the Mathematics Education Program, University of Muhammadiyah Bengkulu. The research focuses on students' experiences in developing contextual mathematics learning modules, their interactions during the learning process, and the impact of PjBL on their pedagogical skills. The research subjects consist of students enrolled in the Mathematics Learning Planning course, the lecturer as a facilitator, and optionally, school students involved in module trials. The sample is selected using purposive sampling, involving students actively participating in module development throughout the semester.

Data collection techniques include participatory observation, in-depth interviews, document analysis, and focus group discussions (FGD). Observations focus on student engagement, creativity, and collaboration, while interviews explore their experiences and challenges in implementing PjBL. Document analysis assesses the quality of the developed modules, including completeness, clarity, creativity, and effectiveness. FGDs are conducted to deepen insights into students' perceptions of PjBL and its impact on their learning.

The research instruments include observation guidelines, interview protocols, module evaluation rubrics, and student reflection sheets. The research procedure consists of five stages: 1) Planning, topic selection and initial research; 2) Module development, designing engaging and interactive learning materials; 3) Implementation and data collection, testing modules and gathering feedback through observation and interviews; 4) Analysis and revision, refining modules based on collected data; and 5) Presentation and reflection, presenting the final modules and analyzing the learning process.

Data analysis follows the thematic analysis method, involving data reduction, categorization, interpretation, and validation through triangulation. This approach ensures a comprehensive understanding of how PjBL enhances students' mathematical and pedagogical competencies.

RESULTS AND DISCUSSION

Topic and Class Selection

The topics selected for each educational level (elementary, junior high, and high school) were identified based on their relevance and difficulty. The chosen topics were Curved Side Space (elementary), Equation of Functions of Virtue (junior high), and Trigonometry (high school). These topics were selected due to their complexity and their importance in developing a strong understanding of mathematical concepts.

Figure 1. Topic and Class Selection

Initial Research

Figure 2. Initial Research

Initial research was conducted by gathering feedback from mathematics teachers at elementary, junior high, and high school levels regarding the most challenging mathematical topics for students. The findings revealed the following:

Elementary Level

Students struggled primarily with understanding the volume and area of curved side spaces. This difficulty was attributed to ineffective learning strategies, with 80% of teachers reporting issues with comprehension and memorization of formulas.

Junior High Level

The equation of functions of virtue, especially quadratic equations, presented challenges. 70% of students could not represent problems in algebraic form, and 65% lacked contextual understanding of quadratic equations.

High School Level

Trigonometry posed significant difficulties, with 75% of teachers highlighting that the limited time available and frequent holidays impeded effective teaching. Students had difficulty grasping the core concepts due to insufficient time for explanation and practice.

Module Design

The development of teaching modules was guided by the lecturers, who provided specific instructions and frameworks for students. The designed modules incorporated real-world contexts to engage students and make the learning process more relatable and effective.

Material Development

Material development in Project-Based Learning (PJBL) requires careful and structured planning to ensure that the project designed is relevant, engaging, and in accordance with the learning objectives.

Testing & Feedback

Testing the modules revealed that 85% of students found the modules engaging and helpful in understanding difficult concepts. Continuous feedback was provided throughout the project to help students refine their work. Feedback focused on strengthening areas where students struggled, such as improving clarity in instructions and increasing contextual relevance.

Tabel 1. Feedback Results

Feedback Category	Percentage of Positive Feedback
Engagement with the material	85%
Clarity of the module content	75%
Relevance to real-life context	80%
Effectiveness in improving understanding	70%

Reflection

Reflection sessions showed that 90% of students expressed greater confidence in their ability to teach mathematical concepts using project-based learning. These reflections also helped students recognize areas for improvement, particularly in time management and clearer communication of concepts.

This discussion will discuss the main features of Project-Based Learning (PjBL) and the tasks given to students in the Mathematics Learning Planning course at the Mathematics Study Program, University of Muhammadiyah Bengkulu.

Key Features of Project Based Learning (PjBL)

Some of the main characteristics of PjBL are identified through the literature to distinguish its approach from similar pedagogical such as problem-based learning, inquiry -based learning. There are seven main aspects that distinguish Project-based learning as follows:

Active Learning

PjBL emphasizes active learning, which is a central concept in constructivist learning theories (Alawi & Soh, 2019). By engaging students in hands-on activities, PjBL aligns with the principles of experiential learning where students learn by doing rather than passive listening. Studies by (Sari et al., 2024) also suggest that students in PjBL settings demonstrate higher engagement levels as they take responsibility for their learning through real-world problem-solving activities. This concept is reinforced by findings in our study, where students actively designed, planned, and evaluated their projects, thus solidifying their understanding of mathematical concepts.

Real World Problems

The use *of* real-world problems in PjBL has been widely supported by research (Aksela & Haatainen, 2019). According to these studies, authentic content increases students' motivation by linking academic goals with real-life situations. This study corroborates this idea, as students were highly engaged when allowed to choose topics relevant to their daily lives. By allowing students to address social and practical problems, PjBL fosters a deeper understanding of the material and enhances its relevance. (Gazali, 2016) also emphasizes that students' choice of a topic is based on questions that arouse their natural curiosity. This task provides an opportunity for project teams to be more responsible in selecting and structuring their projects as they research real-world questions, propose solutions to real-world problems, and design real-world products in an in-depth way.

The Role of Lecturers as "Supervisors"

As a student-driven approach, the role of lecturers in PjBL has shifted from 'sage-on the stage' to 'guide-on-the-side' (Hoidn & Klemenèiè, 2020). Lecturers work as facilitators or mentors who oversee the entire project implementation process. This poses many challenges for lecturers, who need additional training, support, and resources. As explained by Khusna et al. (2022), the role of lecturers changes from knowledge distributors to process managers, assisting students in their learning process by initiating a process of reflection and supporting them, if necessary, regarding substantive matters. Therefore, in PjBL students will be more responsible for their own learning, they will have to decide on topics, methods, and determine their own learning needs, all of which are considered to be the main characteristics of PjBL.

Interdisciplinary

The next key feature of PjBL is the emphasis on an interdisciplinary approach. In fact, to complete a project, students need knowledge and skills from a variety of disciplines, from mathematics and physical sciences to natural sciences and social

sciences (Zubaidah, 2019). This feature means that schools and lecturers must equip students with adaptability and holistic thinking to address problems from a variety of disciplines.

Cooperative Learning

PjBL is innovative with its emphasis on collaboration and teamwork, which is at the heart of the overall approach, student activities revolve around a complex set of interactions between team members over time, utilizing a key set of transferable skills such as communication, planning, and teamwork. Students plan learning together with faculty support, research literature, and if necessary, meet with experts, help with prototypes, and conduct surveys and experiments among other learning activities. This approach empowers students to collaborate in teams with the guidance of their lecturers. Collaborations can also involve partners outside of academia, such as community groups, corporations, or even overseas consulates, thus developing further professional skills, behaviors, and networks. However, in addition to these valuable skills, group work is also considered problematic if it contains potential conflicts and student dissatisfaction (Ahkami et al., 2025).

Final Products

In the PjBL approach, students and lecturers are involved in a project, so that in the end it is the students who create tangible results to represent what they have learned. (Kahar & Ili, 2022 states that quality products are a distinguishing feature of PjBL that drives project planning, production, and evaluation. The types of outputs are very diverse, ranging from dissertations or standard academic presentations, professional consultant reports, to exhibitions such as fashion shows, reality TV shows, music videos, board games, and viral video productions for external business clients.

PjBL Effectiveness

Incorporating projects into the curriculum is not new or revolutionary. However, the benefits cannot be avoided in the teaching and learning process. A lecturer in Washington State who has used project-based teaching in math and science classes reported that many students find meaning and justification for learning by working on projects after long periods of struggle in most academic settings. He also stated that by facilitating the learning of knowledge content as well as reasoning and problem-solving skills, project-based learning can help students to prepare for state assessments and meet state standards. (Valle et al., 2016) shows that the involvement and motivation of PjBL results in high achievement. They also agreed that PjBL provides one way to introduce broader learning opportunities in the classroom. In general, there are six benefits that the author thinks are most significant for students after introducing PjBL in the teaching and learning process,

namely: 1) Student academic achievements, 2) Students' understanding of the subject matter, 3) Improving students' understanding of skills and strategies in the 21st century, 4) Positive attitude of students towards learning, 5) Perceived changes in work habits and other PjBL process behaviors, and 6) Project-based learning in mathematics teaching and learning.

Project-Based Learning Challenges (PjBL)

The challenges of PjBL cover various aspects that can affect the effectiveness and implementation of these methods in the classroom as follows:

Planning and Preparation

Creating a good and structured lesson plan is essential in PjBL. Teachers must be able to design projects that are relevant, engaging, and in accordance with the curriculum.

Time Management

Projects often take longer compared to traditional learning methods. Managing time well so that all students can complete the project on schedule is a big challenge.

Resources and Materials

Projects require a variety of resources, such as materials, technology, and access to information. Limited resources can hinder the implementation of PjBL.

Collaboration and Cooperation

PjBL often involves group work. Managing group dynamics, ensuring all members contribute, and resolving conflicts are challenges in themselves.

Valuation

Assessing the learning outcomes of a project can be more complex than traditional assessments. Teachers should design a clear and objective assessment rubric to measure different aspects of the skills and knowledge that students acquire.

Teacher Skills

Teachers need to have specific skills to implement PJBL effectively. Continuous professional training and development is indispensable.

The findings of this study suggest both theoretical and practical implications. Theoretically, PjBL aligns with constructivist theories of learning, emphasizing student-centered approaches and the application of knowledge in real-world contexts. Practically, the implementation of PjBL can lead to more engaged students and better learning outcomes, especially when teachers have the right skills and resources. However, the study is limited by its small sample size and the lack of a control group for comparison. Future research should focus on exploring the long-term effects of PjBL and examining

the impact of different types of projects on student learning across diverse educational settings.

CONCLUSION

Project-Based Learning (PjBL) significantly enhances student independence, critical thinking, and collaboration skills, making it an effective approach in mathematics education. This study addresses how PjBL fosters student engagement and prepares them for future careers by developing essential skills like problem-solving and teamwork. Lecturers also benefit by improving their professional development and expertise. While the implementation of PjBL presents challenges such as time management and resource limitations, clear role definitions for students and lecturers can help overcome these obstacles. Future research should explore PjBL's long-term effects on student achievement and its application across various disciplines, while educational policies should focus on providing training, resources, and technological support to facilitate successful PjBL integration.

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