

The Effectiveness Motivation of Project-Based Learning on Student Learning Outcomes in Soil Mechanics Practicum in the Civil Engineering Laboratory

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Abstract

The objective of this research is to analyze the effectiveness of implementing Project-Based Learning (PjBL) model in improving student learning outcomes in soil mechanics practicums in the Civil Engineering Laboratory. The evaluation focuses on conceptual mastery for cognitive mastery, laboratory technical skills for psychomotor skills, and student perceptions of the learning experience. The study design used was a quasi-experimental study with a pretest-posttest non-equivalent control group. A sample of 100 students was divided into two groups: an experimental group that received PjBL intervention and a control group that followed conventional learning methods. Results indicated a significant rise in posttest cognitive scores among students in the experimental group (82.7), compared to those in the control group (73.1), with $p < 0.01$. In the psychomotor domain, the PjBL group performed higher with $p < 0.05$. Student perceptions of PjBL were also very positive, with average scores above 4.30 in the aspects of engagement, collaboration, conceptual understanding, and readiness to face professional challenges in the workplace. These findings confirm the pedagogical effectiveness of PjBL integration in civil engineering laboratory learning. The implementation of PjBL not only improves learning outcomes quantitatively, but also develops soft skills in the field of civil engineering.

Keywords: *Project Based Learning, Learning Outcomes, Learning Evaluation, Soil Mechanics Lab, Civil Engineering Laboratory*

INTRODUCTION

The Project-Based Learning (PjBL) is a teaching method which emphasizes student-centered learning through the execution of authentic and complex projects within a specific period of time. PjBL involves in-depth exploration of a real-world problem, cross-disciplinary integration, group collaboration, and the delivery of a final product in the form of a presentation or project report (Krajcik & Blumenfeld, 2006). The implementation of PjBL supports the principles of educational psychology as it allows students to engage in opportunities to: a) Take control of their learning process b) Develop a sense of ownership of academic tasks c) Experience high emotional and intellectual engagement d) Practice in a social context that supports collaboration and interaction Involvement in authentic projects also increases students' intrinsic motivation. The Self-Determination Theory by Ryan & Deci (2000) emphasizes that motivation increases when the needs for autonomy, competence, and social relatedness are met, dimensions inherently facilitated in PjBL.

Civil engineering education demands a balance between mastery of theoretical concepts and practical skills. One of the essential courses in the civil engineering curriculum is soil mechanics, which forms the basis for the analysis and design of foundations, slope stability, and other underground structures (Das & Sobhan, 2018). Soil mechanics practicums are a crucial component because they provide an applied understanding of the physical and mechanical properties of soil, which directly impact the design and implementation of geotechnical projects.

A study by the OECD (2018) confirms that a learning approach that positions students as active participants can improve higher-order thinking skills, teamwork, and creativity. This is crucial in civil engineering education, which demands students' readiness to face the dynamics of the field and the complexity of construction projects. In the context of a soil mechanics laboratory,

the application of PjBL is expected learners to connect academic concepts with practice and develop comprehensive technical and professional competencies.

To address these challenges, PjBL approach is a promising alternative strategy. In this approach, students not only conduct experiments but also engage in project development that integrates planning, implementation, data analysis, and reporting results in a collaborative and contextual manner. Ratih, Festiyed, & Arsih (2024) states that PjBL encourages active learning and is oriented toward solving real-world problems, while Bell (2010) emphasizes the benefits of PjBL in increasing motivation, emotional engagement, and mastery of 21st-century skills such as collaboration, critical thinking, and effective communication.

The practicum experience enables students to understand soil characteristics through standardized tests such as Atterberg limits, direct shear tests, Proctor compaction tests, and consolidation tests. However, based on initial observations at the Civil Engineering Laboratory at the State University of Malang, several obstacles remain in the implementation of these practicums, including low student motivation, minimal active involvement in the practicum process, and difficulty relating experimental results to field applications. Conventional instructional strategies, including demonstrations and direct instruction, typically emphasize procedures rather than fostering critical thinking and the ability to solve problems (Prince & Felder, 2013). Students often simply execute instructions without fully understanding the purpose of the experiment or relating it to real-world construction problems. This results in poor conceptual mastery, technical skills, and reflective thinking about experimental results.

In the context of engineering education, developing these skills becomes increasingly relevant as graduates are required to integrate cross-disciplinary knowledge, work in multidisciplinary teams, solve complex problems, and adapt to new technologies and changing work environments. Therefore, engineering higher education institutions are required to design learning systems that focus not only on mastering theory but also on the balanced development of generic and professional competencies. A soil mechanics practicum, a PjBL approach, helps students integrate classroom theory with laboratory practices, such as soil consistency testing, direct shear, compaction, and consolidation. Through the project, students can understand the relationship between laboratory test data and real-world applications in civil engineering design.

As a vital element in civil engineering education, the soil mechanics practicum offers students experiential learning to better grasp soil behavior and its physical-mechanical properties. This practicum is designed to integrate classroom theory with the technical skills needed in the field (Wisudawan & Wiyono, 2021). Implementing the soil mechanics practicum as a PjBL requires the development of learning instruments and systematic, context-based planning (Elvarita, Iriani, & Handoyo, 2020). Each project is designed to support the achievement of learning objectives according to the type of laboratory test conducted.

Therefore, the objective of this research is to evaluate how effective PjBL is in soil mechanics practicum at the Civil Engineering Laboratory of the Faculty of Engineering, with a focus on four types of laboratory tests: soil consistency, direct shear test, soil compaction test (Proctor), and consolidation test. It is anticipated that the results of this research will help shape a more relevant and impactful practicum approach tailored to the requirements of today's civil engineering workforce.

RESEARCH METHODS

This study employed a quasi-experimental research approach, predominantly using quantitative methods. This type of research was chosen because the researcher lacked full control over the independent variables (such as group randomization), but still allowed to test the impact of a treatment or learning intervention under conditions that approximated field reality (quasi-

experimental). Quasi-experiments are suitable for educational contexts, where full randomization is often impossible due to practical limitations, such as pre-scheduled class assignments (Sugiyono, Metodologi Penelitian Kuantitatif, Kualitatif dan R&D, 2019). A quasi-experimental method, specifically the pretest-posttest non-equivalent control group design, was utilized in this research, which is frequently applied in educational settings.

A quasi-experimental method, specifically the pretest-posttest non-equivalent control group design, was utilized in this research, which is frequently applied in educational settings. Two groups of students, chosen through a non-random process, were administered a pretest before the intervention and a posttest after its implementation. The treatment applied to the experimental group involved the form of PjBL, while the control group followed conventional learning methods commonly used in civil engineering laboratories.

This design aimed to compare the effectiveness of PjBL implementation with conventional learning in a Soil Mechanics practicum. Measurements were conducted using the same instruments before and after the treatment (pretest and posttest) to assess the extent to which students' cognitive and psychomotor abilities improved as a result of the treatment. This design allows for a more comprehensive analysis of differences in learning outcomes between groups, both before and after the treatment, allowing for objective measurement of the effectiveness of PjBL method. Although the primary approach in this study was quantitative, students' perceptions of the implementation of PjBL were also examined using a questionnaire, which was analyzed descriptively and qualitatively as supporting data. Therefore, employing a quasi-experimental approach, this study is mainly quantitative in nature but integrates data triangulation from diverse sources to gain a more holistic view of how PjBL performs in the context of civil engineering laboratories. A total of 100 students participated in the study, divided non-randomly into two equal groups: one receiving project-based learning as the experimental group, and the other experiencing conventional learning as the control group.

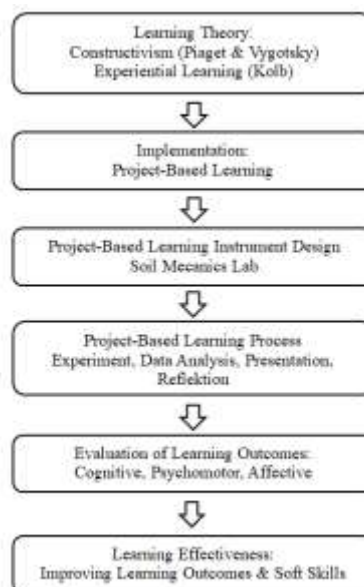


Figure 1. Research framework

RESULT AND DISCUSSION

This study was conducted over one semester in the 2024/2025 academic year at the Soil Mechanics Laboratory, Department of Civil Engineering and Planning, Faculty of Engineering, Universitas Negeri Malang. The study subjects consisted of 100 undergraduate Civil Engineering students divided into two treatment groups: an experimental group of 50 students who received the PjBL model, and a control group of 50 students who received conventional learning. In implementing the PjBL model, the experimental group conducted a project that included four main types of laboratory tests: 1. Soil consistency test, 2. Direct shear test, 3. Soil compaction test (proctor), and 4. Consolidation test.

Throughout the learning process, student activities were intensively monitored using observation instruments, psychomotor assessment rubrics, and activity documentation to record the development of technical skills, group collaboration, and concept application. This approach was designed to support a comprehensive analysis of the effectiveness of project-based learning compared to conventional methods in the context of Soil Mechanics practicums.

Measurement for Cognitive Mastery

To assess students' mastery of theoretical concepts in soil mechanics, all participants from both groups (experimental and control) were given cognitive tests in the form of pretests and posttests, administered before and after the treatment. The purpose of these tests was to determine the degree of improvement in students' understanding of basic principles after undergoing the respective learning method. Table 1 displays the mean scores from the pretest and posttest for each group.

Table 1. Pretest dan Posttest Cognitif Average

Team	Pretest (Mean ± SD)	Posttest (Mean ± SD)
Experiment	58.2 ± 6.5	82.7 ± 5.4
Control	57.9 ± 7.1	73.1 ± 6.2

Source: Data Processed (2025)

An independent samples t-test revealed a statistically significant disparity in posttest results between both groups ($p < 0.01$). These results suggest that applying the Project-Based Learning (PjBL) approach led to a notable enhancement in students' grasp of concepts within the Soil Mechanics course. The greater score increase observed in the experimental group (24.5 points) compared to the control group (15.2 points), indicates that the PjBL approach has a strong and positive impact on students' mastery of theoretical concepts.

Psychomotor Observation Test

Psychomotor aspects were evaluated through a performance observation rubric that included procedural, technical, and occupational safety indicators during the practicum. Table 2 presents the average observation scores from the observations.

Table 2. Average Value of Practical Performance (Psychomotor)

Types of Soil Tests	Experiment Team	Control Team
Consistency Test	86.5	75.4
Direct Shear Test	88.1	76.2
Compaction Test (Proctor)	85.7	73.9
Consolidation Test	87.3	74.8

Source: Data Processed (2025)

A statistically significant difference ($p < 0.05$) was observed in the average psychomotor scores between the experimental and control groups. The data showed that the experimental group consistently scored higher in all four types of laboratory tests—consistency, direct shear,

compaction, and consolidation—compared to the control group. The results suggest that applying the Project-Based Learning (PjBL) model not only positively impacts conceptual understanding but also significantly improves students' technical skills in conducting laboratory experiments. Results of Student Perceptions of Project-Based Learning (PjBL)

Assessment of student perceptions of the learning model was conducted using a 5-point Likert-scale questionnaire, designed to measure responses to various aspects of the implementation of Project-Based Learning (PjBL). Results of data processing showed a very positive average score of perceptions towards this approach, reflecting high levels of engagement, satisfaction, and relevance of learning according to students' views. Details of the results of student perceptions of PjBL are presented in Table 3 below:

Table 3. Average Score of Student Perceptions of PjBL

Rated Aspect	Score Average
Engagement in learning	4.45
Understanding concepts	4.35
Collaboration and communication	4.51
Readiness for work	4.42

Source: Data Processed (2025)

Students showed strong approval and positive attitudes toward the use of PjBL. Students reported feeling more active, engaged, and challenged in the learning process, with improved ability to connect practicum content to real-life civil engineering applications. The average perception score across all aspects was above 4.30, indicating that students not only felt more motivated and collaborative but also enhanced their readiness for workplace challenges.

Next, to gain a deeper understanding of the Project-Based Learning (PjBL) experience, semi-structured interviews were carried out with 10 students from the experimental group. Thematic analysis of the interview transcripts yielded the following key qualitative findings:

1. Improved Procedural and Conceptual Understanding Students stated that direct involvement in the lab projects helped them understand the logic, procedures, and objectives of each type of laboratory test more thoroughly. They felt better able to connect theory to practical application.
2. Improved Critical Thinking Skills Activities such as processing and analyzing experimental data encouraged students to develop scientific reasoning and critical thinking, particularly in interpreting test results and drawing conclusions based on empirical data.
3. Strengthening Soft Skills through Collaborative Challenges Several students stated that the main challenges they faced were not technical, but rather time management, task allocation, and coordination among group members. However, these challenges were seen as important learning opportunities for developing non-technical competencies including teamwork, leadership, and communication. These findings strengthen previous quantitative results, while providing a deeper qualitative context regarding the positive impact of PjBL implementation on student learning in Soil Mechanics practicums.

Research outcomes suggest that applying PjBL in Soil Mechanics practicum sessions significantly contributes to the improvement of students' learning achievements across various areas. Quantitatively, there were significant improvements in cognitive and psychomotor learning outcomes, supported by qualitative findings that indicated very positive student perceptions of this approach. Overall, the implementation of PjBL had tangible impacts in the following ways:

1. Improved students' in-depth conceptual understanding of the practicum material.
2. Strengthened technical skills, such as measurement accuracy and the use of test equipment.
3. Developed critical thinking, analytical skills, and problem-solving skills during the experimental process.

4. Enhanced soft skills, including teamwork, scientific communication, and time management.
5. Created meaningful, contextual learning experiences that are relevant to the needs of the civil engineering workforce. These findings align with previous research, such as that presented by Strobel & van Barneveld (2009) and Hmelo-Silver (2004), which emphasized the superiority of Project-Based Learning (PjBL) in enhancing students' conceptual understanding, higher-order thinking skills, and professional readiness. PjBL serves to connect theoretical knowledge with practical application by engaging students in authentic and demanding project-based activities.

The implication of these results is that the PjBL is worthy of recommendation as an alternative pedagogical strategy in civil engineering laboratory learning more broadly. However, for optimal implementation, several important adjustments are required, such as:

- a. Contextual and structured project design.
- b. Active support from lecturers and laboratory staff.
- c. Study group management that allows each student to contribute equally.

Thus, integrating PjBL into practicum activities enhances student learning while also fostering essential professional skills required in both present and future civil engineering workplace. Based on the outcomes of this study, PjBL proves to be a powerful method in promoting cognitive advancement, as evidenced by significant empirical improvements. This aligns with the findings of Strobel & Barneveld (2009) and Bell (2010), who stated that project-based learning is superior in fostering conceptual mastery and higher-order thinking skills compared to conventional methods. In terms of improving psychomotor skills, the PjBL approach, which requires students to actively manage projects from the planning stage to execution, provides a deeper learning environment for technical skills. Students not only imitate procedures but also take responsibility for the accuracy of data collection and processing, making the learning process more authentic. Meanwhile, insights from students' perspectives and emotional reactions show that PjBL serves as a powerful motivator and fosters deeper emotional engagement in learning. This affective aspect plays a vital role because it forms the foundation for developing professional attitudes in civil engineering students.

The outcomes are consistent with Ryan and Deci's (2000) Self-Determination Theory, which states that fulfilling the needs for autonomy, competence, and social relationships will increase students' intrinsic motivation. By connecting findings to the scope of civil engineering work, through the context of real-world projects (such as road subgrade analysis or foundation settlement prediction), Project-Based Learning (PjBL) provides a transformative learning experience. Students not only master concepts but also gain a practical understanding of the role of soil test data in geotechnical planning and design. This makes PjBL an adaptive approach to today's civil engineering competency needs.

CONCLUSION

This research, which examines the implementation of Project-Based Learning (PjBL) in a Soil Mechanics practicum, concluded that PjBL significantly improved students' cognitive learning outcomes. Students who participated in the PjBL approach achieved significantly higher cognitive posttest scores than their peers in the conventional learning group. This demonstrates that PjBL is effective in strengthening conceptual understanding, scientific reasoning, and mastery of basic soil mechanics principles. PjBL strengthens psychomotor skills in the practicum. Observations showed that the experimental group performed better in laboratory tests, particularly in terms of procedural accuracy, measurement precision, and tool mastery. This indicates that active involvement in the project directly impacts technical skill mastery.

Students responded very positively to project-based learning. Student perceptions indicated a high level of engagement, strong team collaboration, and a perception that PjBL is relevant to the needs of the civil engineering workforce. Qualitative findings from interviews also confirmed that this approach provides an applicable and contextual learning experience. PjBL also encourages the development of soft skills in civil engineering students. This approach develops essential non-technical skills such as teamwork, scientific communication, time management, and collective responsibility—critically needed in 21st-century engineering professional practice. The success of PjBL implementation is influenced by project design, the role of the facilitator, and group dynamics. The effectiveness of PjBL is largely depends on how well the project is designed, the instructor's readiness to facilitate the process, and the interactions that occur within the student group.

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