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From Theory To Practice: A Qualitative Exploration Of Project-Based Learning In Electrical Engineering University Students' Skills

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Abstract. The pressure to produce engineering graduates with practical skills has driven the implementation of Project-Based Learning (PBL) in electrical engineering education. This study aims to examine in depth how PBL affects the process of transferring knowledge from theory to practice for electrical engineering students. This qualitative research with a descriptive approach involved six students from the Electrical Engineering Study Program at Politeknik Negeri Sriwijaya who were interviewed using semi-structured interviews. Data were analyzed using coding techniques and member verification. The results show that PBL contributes to better academic understanding, development of technical skills, and improvement of critical thinking and problem-solving abilities. However, there are obstacles in the form of inactivity of some students, anxiety in using equipment, and limited laboratory facilities. The conclusion emphasizes that the effectiveness of PBL depends on the availability of resources, lecturer support, and adequate equipment access policies.

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INTRODUCTION

The pressure exerted on universities to produce engineers who not only excel theoretically but also possess practical skills and are flexible in their professional activities has risen sharply because of the intensive development of technologies and complexity of industries' demands. Better understanding of the theoretical concepts and cultivation of such soft skills as cooperation, communication, and problem-solving are ensured by Project-Based Learning which focuses specifically on practical projects and problem-solving (Faranita et al., 2017). Such a shift in pedagogy is particularly relevant to electrical engineering education. Lack of ability to utilize information to address the issues in engineering is common; additionally, sometimes, the mismatch between concepts and real-life application becomes the reason for boredom experienced by undergraduate students in the context of theoretical lectures at lower-level courses (Kunicina et al., 2024). Overcoming this issue is of professional rather than purely educational value (Song et al., 2016). The need to develop competencies apart from skills and knowledge combined with the common problem faced by engineering graduates during their transition to engineering practice becomes the basis for competency development research in engineering education (Purba

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et al., 2025). In this light, PBL may become a successful way of aligning professional engineering practice requirements and academic studies.

In the last few years, research related to Project-Based Learning (PBL) in engineering education has received immense attention. It was found out that PBL plays a significant role in developing students in many different areas. For example, there is evidence that PBL significantly helps to enhance academic results and retention of knowledge (Song et al., 2016; Kunicina et al., 2024; Zhang & Ma, 2023); develop technical skills in domain-specific engineering courses (Cobos-Torres et al., 2019; Viswambaran & Shafeek, 2019); higher-order thinking skills (HOTS) (Zhang & Ma, 2023; Hidayat et al., 2024); and build self-efficacy and motivation to stay in an engineering program (Wu et al., 2021). However, other researches concentrate on soft and transferable skills development such as communication and collaboration (Viswambaran & Shafeek, 2019; Husin et al., 2025; Chen et al., 2021); critical thinking and problem-solving (Husin et al., 2025; Lavado-Anguera et al., 2024); independent learning skills (Novalia et al., 2025); and work-related competencies (Naseer et al., 2025). Moreover, the other major gap in the existing knowledge base that should be addressed concerns the processes and mechanisms associated with developing skills via project-based learning in the domain of electrical engineering, as most of the research was conducted in regard to general engineering education and not the theory into practice transfer among electrical engineering students (Song et al., 2016; Cobos-Torres et al., 2019).

Eventhough many research demonstrated positive impact of PBL, other research also found negative impact of PBL. For instance, students little involved in class (Faranita et al., 2017); limited resources (Purba et al., 2025); when using electrical tools, learners could be worried and insecure, particularly if they are afraid of damaging the machinery (Prestado et al., 2025). The closure of higher education institutions caused by the COVID-19 epidemic significantly affected students' ability to conduct real lab experiments (Torres Lozano et al., 2022). Some students experienced difficulties in reading and interpreting circuit diagrams, which affected their ability to understand how the components were connected and how the system functioned (Wahyuni & Mukhaiyar, 2022). Electrical Engineering students, especially first-year students, face significant academic challenges due to the complexity of the field, which includes advanced mathematics, physics, and technical applications such as power systems, electronics, telecommunications, and control systems (BPIKA UMA, 2025).

Focusing on the process of the transition from theoretical to practical comprehension of knowledge, the current research is aimed at examining in depth how project-based learning affects the skill development among university students specializing in electrical engineering. The objective of this research is to highlight the complicated processes of skill acquisition in the field of electrical engineering where theory plays an integral part and sophisticated practical skills are required through the lens of student experience. Considering this aim, the study is guided by the following research question: How can students specializing in electrical engineering describe the process of applying project-based learning to transfer knowledge from theory to practice?

THEORETICAL BASIS

Project-Based Learning (PBL)—a key component of modern engineering education—effectively bridges theory with practical experience. By means of genuine projects, this method stresses participation, group work, and critical thinking development for students (Faranita et al., 2017). Students have to use theoretical ideas in real life circumstances instead of simply absorbing knowledge. Studies reveal that this practical approach improves cognitive development and technical skills as well as higher-level analytical and evaluative capacities required to solve difficult engineering problems (Song et al., 2016; Kunicina et al., 2024; Zhang & Ma, 2023; Hidayat et al., 2024).

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Researchers have also identified various categories of skills fostered through PBL in engineering education. Cobos-Torres et al. (2019) and Viswambaran & Shafeek (2019) divide these into technical and transferable skills. Technical abilities include particular competencies such circuit design, system analysis, and application of engineering tools. All of which are vital in engineering environments, communication, flexibility, and collaboration are transferable talents. Studies conducted by Husin et al. (2025) and Chen et al. (2021) also show that collaborative learning within project-based learning settings enhances pupils' teamwork abilities and their capacity to clearly express difficult ideas effectively. Similarly, as they are challenged open-ended issues mirroring actual-world industrial circumstances (Lavado-Anguera et al., 2024; Husin et al., 2025), students' critical thinking and problem-solving skills are much improved. Furthermore significant result of self-directed learning linked with PBL is self-directed learning. Novalia et al. (2025) underline how seeking resources, managing their time, and tracking their own development help PBL to inspire pupils to own their learning. Particularly in engineering fields where resilience is crucial, the studies of Wu et al. (2021) taken together with findings from Naseer et al. (2025) demonstrate that Problem-Based Learning (PBL) helps students to be more motivated and self-efficacious. Students so grow more confident in applying theoretical concepts in practical situations—a key for their professional development.

Though Project-Based Learning has many advantages, it also has several drawbacks. Students may find it challenging to adjust to learner-centered teaching techniques, especially if they are used to conventional lecture-based approaches, according to Song et al. (2016) and Kunicina et al. (2024). This problem is intimately connected to the frequent difficulty students experience in applying theoretical knowledge to address engineering problems, which often results in disinterest in traditional classroom environments (Kunicina et al., 2024). Furthermore, elements including scarce resources, time constraints, and inadequate teaching assistance may impact the successful application of Project-Based Learning (Song et al., 2016). Furthermore, because not all project-based learning examples precisely represent real engineering settings (Purba et al., 2025) the distance between academic knowledge and practical application could persist.

Thus, it is vital to know how students turn their theoretical understanding into useful skills. Many earlier studies have concentrated on broad engineering education, while just a limited amount of attention has been directed toward the specific field of electrical engineering (Song et al., 2016; Cobos-Torres et al., 2019). This emphasizes the need of more in-depth qualitative studies on how electrical engineering students develop their knowledge by means of project-based learning. Therefore, this study seeks to investigate the mechanisms that enable the transfer from theoretical understanding to practical application by examining the experiences of students, particularly in a discipline requiring both a strong conceptual understanding and sophisticated technical abilities.

RESEARCH METHODOLOGY

This study used a qualitative approach and a descriptive technique to examine the motivation and demotivation factors for learning English among Politeknik Negeri Sriwijaya students. A qualitative technique was chosen in order to give a comprehensive understanding of research concerns from an academic standpoint. The goal of qualitative research is to comprehend how individuals interpret their experiences and the world. Researchers look at participants' viewpoints, explore their experiences, and then provide in-depth narrative descriptions in this study (Merriam et al., 2025). Politeknik Negeri Sriwijaya was also the site of the study, a public polytechnic found in Palembang, South Sumatra, Indonesia.

Research participants included students in Electrical Engineering Department of Teknik Elektro. Six students in all voluntarily took part in this research, five of whom were men and one women. Most of the participants were Electrical Engineering Department first

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semester through final semester students. In order to preserve their privacy and uphold the research's ethical criteria, the names of the participants in this study were also pseudonyms.

Individual semi-structured interviews were the primary method used in this study to gather data. To collect detailed data and information from the participants, the researchers employed a semi-structured interview adjusted several interview questions drawn from earlier research (Wu et al., 2021; Tiyas et al., 2026) in order to improve relevance and fit for the aims of the study. The interviews were conducted in Indonesian to foster a relaxed and welcoming environment where participants may freely converse, argue, and share their experiences free from linguistic limitations.

Voice-to-note technology, which effectively and accurately translates spoken words into written text, was used to mechanically transcribe the interview sessions for data analysis. After that, the transcripts were carefully examined multiple times in order to code them and categorize them into appropriate themes. Additionally, member verification was carried out to determine the data's reliability. When all transcript data were returned to the participants, member checking took place to ensure that the data accurately reflected what they had said. After reading the transcription, the participants were also given the opportunity to edit their answers.

RESULTS AND DISCUSSION

RESULTS

We interviewed six electrical engineering students, and their answers fell into the themes outlined in Table 2 and Table 3. Three main advantages emerged from the data: academic understanding improved, students gained usable technical skills, and they began thinking critically instead of just memorizing. The disadvantages were equally real: some classmates remained passive, a few were terrified of breaking equipment, and the lab frequently lacked necessary tools.

Tabel 1. Background of the Participants

No.	Pseudonym	Age	Gender
1.	PL1	18	Male
2.	PL2	18	Male
3.	PL3	18	Male
4.	PL4	18	Male
5.	PL5	18	Female
6.	PL6	19	Male

Sumber: Primary data, 2026

Tabel 2. Advantages of Project-Based Learning

No.	Advantages
1.	Helps to enhance academic understanding
2.	Develop technical skills
3.	Critical thinking and problem solving

Sumber: Primary data, 2026

Tabel 3. Disadvantages of Project-Based Learning

No.	Disadvantages
1.	Students who are not very active in class
2.	Fear of making mistakes
3.	Inadequate facilities

Sumber: Primary data, 2026

1) Helps to Enhance Academic Understanding

What surprised us was how many students said the projects finally made the lecture notes click. PL2 told us he stopped treating the course like a memory test once he had to build something real. He stated that he became more confident because he was used to facing real problems, not just theory, and understood concepts better because they were practiced

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directly, not merely memorized (PL2, male, 18). PL3 said basically the same thing, just in different words. He called it a shift from passive listening to actually doing, stating that practice-based learning changed his approach from theoretical to practical, and this method was easier to understand and provided direct experience of various technical aspects required in the field (PL3, male, 18). PL5 spent ages on Proteus simulations, and she said that time actually counted because it was hooked up to real circuits. She explained that it was not just theory, but direct practice with circuits and software like Proteus, and from that, she knew what she could already do and what still needed to be learned, which made her more confident (PL5, female, 18). So the academic gain was not abstract at all; it happened because they could touch the mistake and then fix it. That hands-on feedback loop is something a written exam simply cannot replicate.

2) Develop Technical Skills

The second upside was purely about the hands-on stuff. PL3 said he went from just sitting there to running the whole show. He explained that he was no longer merely a passive listener, but became someone capable of designing, executing, and even evaluating his own work (PL3, male, 18). PL4 said the project made him pick up instruments he had never used before, stating that he was forced to master tools and technical methods independently (PL4, male, 18). PL6 was harder to please overall, yet he still conceded that finishing the technical tasks gave him a concrete sense of progress. He felt more confident because he succeeded in completing technical challenges that previously felt impossible (PL6, male, 19). PL5 kept going back to the same point. She would run the simulation first, then move it to the actual board. The interplay between the device and the display is exactly the kind of experience needed in a real work setting, which cannot be gained through a written test.

3) Critical Thinking and Problem Solving

Then there was the mental side. PL1 said the payoff stretched way past the submission deadline. After completing the project, he became confident not only while working on that project, but could also increase his ability in problem-solving skills for other projects (PL1, male, 18). PL4 described it as learning to enjoy the breakdowns. The biggest improvement was felt when he analyzed or fixed technical errors during the process (PL4, male, 18). He altered how he viewed errors, stating that he started to see mistakes not as failures, but rather as components of the learning process (PL4, male, 18). This method differs entirely from the conventional classroom environment in which the teacher posts the right answer on the board for the pupils to copy. In PBL, the mistake is the teacher.

1) Students Who Are Not Very Active in Class

But not everyone got on the train. PL2 was still hanging back, waiting for someone to tell him what to do next. He admitted that he was still confused in several specific parts, sometimes still needed guidance from the instructor, and was not yet fully confident (PL2, male, 18). PL6 went a step further and said parts of the project felt like dead weight. Not all parts of the project stimulated his curiosity. Some stages felt more like an administrative burden than a meaningful learning process (PL6, male, 19). So while the design of PBL assumes every student becomes an eager contributor, the reality was that some never really stepped into the driver's seat. You cannot just flip a switch and turn passive listeners into active builders.

2) Fear of Making Mistakes

Anxiety was another silent killer. PL6 said the pressure sometimes backfired. There were times when the pressure from the project actually made him feel overwhelmed and not confident, especially when the workload piled up without clear direction from the lecturer (PL6, male, 19). PL2 kept saying he was not yet fully confident, and PL1 admitted confusion still crept in even after finishing. Although sometimes he was still confused about certain parts (PL1, male, 18). That anxiety stopped development rather than just unsettling them. Before engaging with a connection for several minutes, they would concentrate on it, or they

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would repeat the same testing twice because they lacked confidence in the first result. This is not how a working project is meant to run.

3) Inadequate Facilities

PL1 mentioned that during lab sessions, there were a few tools and components the campus had not been able to provide yet. He specifically pointed out Schottky diodes, explaining that there are some tools and components that are less than adequate on this campus, for example Schottky diodes, because they are expensive so the campus has not been able to provide them for us (PL1, male, 18). Another issue came up with the analog multimeters owned by the campus. As the professionals work to guarantee that every course runs without any hiccups, they are being circumspect. The lab is just being cautious with the shared tools many classes rely on, not being obstructive. Still, the result is the same: students cannot practice freely.

DISCUSSION

We started this study with one basic argument: project-based learning should help electrical engineering students stop just memorizing theory and actually start applying it in real projects. After talking to PL1 through PL6, we can say that argument mostly holds up. The students clearly reported better conceptual understanding, stronger technical skills, and more independent problem-solving. But the advantages and disadvantages were not living in separate corners, they were knotted together. Confidence and fear turned out to be two sides of the same coin: PL5 felt more capable after working with Proteus and real circuits, while PL6 admitted the project pressure sometimes made him feel overwhelmed, and PL2 said he was still not fully confident. Likewise, independence only grew when the task was challenging yet supported; when the balance was off, students like PL2 kept waiting for the lecturer to tell them what to do. Then there was the equipment catch-22 that PL1 described: students need hands-on practice to build skills, yet they are denied multimeter access because technicians worry freshmen will break them, and Schottky diodes are missing because they are expensive. That alone is enough to kill the hands-on growth PBL is supposed to deliver.

Our findings line up with several earlier studies, but they also complicate the picture. Faranita et al. (2017) and Song et al. (2016) argued that PBL links practical application to theoretical concepts, and our participants basically repeated that back to us. PL2 and PL3 both said they finally understood the material once they had to build something real. The skill categories from Cobos-Torres et al. (2019) and Viswambaran & Shafeek (2019) also fit neatly: we saw technical skills in PL5's work with Proteus and hardware, plus transferable skills like problem-solving in PL1 and PL4. However, our data push back against the uniformly positive tone from Novalia et al. (2025) and Prestado et al. (2025), who treat curiosity and self-directed learning as automatic byproducts. In our context, those qualities only showed up when conditions were right. The likely reason is that most optimistic studies were probably conducted at better-resourced universities with advanced students, whereas our participants were mostly freshmen at a polytechnic with a tight lab budget. Kunicina et al. (2024) and Song et al. (2016) already pointed out that students struggle to adapt to learner-centered methods, and we saw the same thing. But we would add that the struggle is not purely about the students' mindset. It is also about whether the campus actually provides the equipment and support they need to make that shift.

So what should lecturers actually do? Based on what PL1 and PL2 told us, the answer is not to just set students loose. They specifically asked for guidance at the beginning and more freedom once they got the hang of it. That points to a staged setup: start with clear examples, show them how the tools work, and make sure they know the safety basics. Only after that should the lecturer step back and let them figure things out alone. That would address both the fear of making mistakes and the technician concern about equipment damage. We also think the rigid report formats PL6 complained about deserve a second

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look. If students are spending mental energy formatting documents instead of troubleshooting circuits, the assessment is working against the pedagogy. Engineering notebooks or process portfolios might keep accountability without draining creativity. As for the lab, banning multimeter loans entirely is probably overkill. A simpler fix would be letting students borrow them under supervision, or maybe ask for a small deposit so the technicians feel safer about it. And since Schottky diodes are too expensive to keep in stock, the course planners could just design beginner projects around cheaper, more common parts instead.

Of course, this study has its limits. Six students is a small group, and most were guys. We talked to them once and that was it. Since everything came from what they were ready to tell us, the quieter ones or those who leaned to sit back during lab work most likely downplayed how much difficulty they were really facing. If we could follow these same students all the way to graduation, or even better, check in on them once they get their first engineering job, we would finally know if the confidence and skills they mentioned here really matter in the real world.

CONCLUSIONS AND SUGGESTIONS

At its core, this study set out to see whether project-based learning actually helps electrical engineering students turn classroom theory into workshop practice. After listening to PL1 through PL6, the short answer is yes, but with a catch. The projects clearly pushed these students to understand their coursework more deeply, handle real tools, and think through problems on their own. But the same projects also exposed cracks that are hard to ignore. Not every student became active. Fear of breaking equipment slowed several of them down. And occasionally the lab lacked the required tools.

The pattern becomes rather obvious when we examine the six themes in the findings. Positively, learners from PL2 and PL3 stated that they stopped memorizing by rote and really understood the material after building actual circuits. PL5 and PL4 picked up technical skills by working with software and hardware they had never touched before. PL1 and PL4 also showed they could troubleshoot and carry problem-solving habits into future work. But the disadvantages were equally real and equally tied to the same experiences. PL2 and PL6 revealed that the project format alone does not wake up passive learners. PL6, PL2, and PL1 admitted that fear of mistakes and confusing workloads sometimes froze them rather than motivating them. And PL1's specific accounts about unavailable Schottky diodes and restricted multimeter access showed that when the lab cannot back up the pedagogy, the pedagogy stalls.

For anyone running these courses, the takeaway is practical. Students are not asking for total freedom or total hand-holding. They want both, just at the right moments. Lecturers should front-load guidance and tool training, then gradually step back. The lab needs sensible policies too: supervised access to shared instruments, realistic component budgets, and assessment formats that value the troubleshooting process over rigid report templates. These are small adjustments, but they could close the distance between what PBL promises on paper and what it actually delivers in a polytechnic lab.

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