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Project-Based Learning in Teaching Diode Bias Characteristics to Vocational Students.

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Abstract

Comprehending diode bias characteristics is an essential skill for vocational students in electronics, serving as a foundation for understanding more intricate circuit behaviors. This article outlines the creation and execution of a Project-Based Learning (PBL) model designed to assist students in comprehending the idea of diode bias, encompassing both forward and reverse bias operations. The instructional design was created to promote active learning via project activities, including the assembly of basic diode circuits, observation of their behavior, and presentation of results. The PBL framework was organized into distinct stages: problem identification, planning, prototyping, testing, and reflection. This approach seeks to enhance students' conceptual comprehension and practical application of semiconductor principles through the integration of real-world tasks and collaborative learning. The development process encompasses instructional materials like worksheets, circuit kits, and reflection notebooks. This article enhances vocational learning methodologies by offering a contextual, practical method for teaching abstract electronic topics.

Keywords: diode biass characteristic, project based learning, vocational students

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INTRODUCTION

Diode characteristics in forward-biased and reverse-biased conditions are very important basic materials in electronics learning, especially for Vocational High School students who focus on developing technical skills (Qi et al., 2025). Diodes are two-pole active components that are generally semiconductors, which allow electric current to flow in one direction (forward bias condition) and inhibit current from the opposite direction (reverse bias condition) (Xiao et al., 2024). Therefore, an in-depth understanding of how diodes work in both bias conditions is essential to provide a solid foundation for students in learning more complex electronics topics (Ilić et al., 2024).

Under forward bias conditions, when a positive voltage is applied to the anode and negative to the cathode, the diode will conduct current once a certain threshold voltage is reached, known as the diode threshold voltage (Luo et al., 2024; Manyakhin et al., 2024). Conversely, in reverse bias, the diode will only conduct a very small amount of current (leakage current) or even no current flows at all, except at voltages high enough to damage the diode (Wang et al., 2024). These characteristics illustrate the basic principle of diodes as current flow regulators in electronic circuits and form the basis for understanding various diode applications, such as current rectification in AC to DC electrical circuits (Mamor et al., 2024).

Although these theoretical concepts regarding diode characteristics have been studied in many textbooks and school curricula, it is often difficult for students to connect the theory with practical applications that they can encounter in the real world (Zhang et al., 2024; Sheikh, 2024). Most students may only understand the basic concepts theoretically without actually experiencing them or testing them in hands-on experiments (Weber & Wilhelm, 2024). Therefore, it is important to use an approach that allows students to conduct hands-on experiments and see the results practically.

One effective method to address this issue is by using Project-Based Learning (PjBL). PjBL is a learning approach that focuses on completing real projects (Dowson et al., 2024), which allows students to learn through hands-on experience in designing, testing, and analyzing electronic circuits (Lui et al., 2024). By applying PjBL in learning diode characteristics material, students not only understand the basic theory of diodes, but can also develop technical skills such as designing circuits, measuring current and voltage, and analyzing experimental results.

The PjBL approach in this context allows students to work in teams, identify and solve problems that arise in experiments, and connect theory with practice. This approach is also very relevant to the Merdeka Curriculum, which provides freedom for teachers and students to adapt learning materials to the needs and context of the ever-evolving world of work. Through PjBL, students not only acquire technical knowledge, but also critical and creative thinking skills that are essential in facing challenges in the professional world.

The application of PjBL in learning diode characteristics is expected to enrich students' learning experience, provide deeper insights into the practical application of electronics, and prepare students to enter the industrial world with more applicable and relevant skills.

METHOD

This study uses a descriptive method with a qualitative approach to describe the application of Project Based Learning (PjBL) in learning the characteristics of forward biased and reverse biased diodes in grade 10 of Electronics Engineering Vocational School. This research was conducted in five stages. In the planning stage, teachers and researchers designed project-based learning that aims to understand diode characteristics, improve technical skills, and train students' analytical skills. The teacher determined the main project in the form of an experiment to observe the characteristics of

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diodes under forward bias and reverse bias conditions, and compiled research instruments, such as observation guides, project assessment rubrics, and interviews. The orientation stage begins with an introduction to the basic concepts of diodes that include symbols, structure, and working principles. The teacher poses the main question of the project, namely "*How can diode characteristics be measured and analyzed through experiments?*", to motivate students to think critically and collaboratively.

At the project implementation stage, students are divided into small groups to design, assemble, and test diode circuits on the Multisim application. Each group determines the need for components such as silicon diodes (1N4007), resistors, DC power sources, and multimeters. They assembled a test circuit to measure the current and voltage on the diode under various bias conditions, then drew a graph of the current-voltage relationship and compared it with theory. Afterwards, students present their project results which include Multisim circuit diagrams, measurement results, analysis, and conclusions. The teacher and other students provide feedback to enrich students' understanding.

RESULTS AND DISCUSSION

Figure 1. Learning Media

The development of a Project-Based Learning (PjBL) model for teaching diode bias characteristics provides a promising instructional innovation for vocational education, particularly in electronics engineering (González-Cortés et al., 2024). Although this study did not include field trials, the structured development process and theoretical foundations provide strong indications of the model's instructional relevance, feasibility, and potential impact on student learning. One of the main contributions of this development lies in its alignment with student-centered pedagogy. Traditional approaches to teaching diodes often rely heavily on lectures and textbook explanations, which tend to isolate theory from practice. This results in limited student engagement and a superficial understanding of concepts such as forward and reverse bias. The developed PjBL model, in contrast, encourages students to explore the concept of bias through authentic, hands-on tasks that simulate real-world problem-solving. By designing and simulating circuits, recording voltage and current values, and interpreting data, students are expected to engage in active learning processes that promote deep conceptual understanding.

In terms of instructional design, the learning sequence emphasizes key stages of PjBL: defining a problem, planning, experimenting, analyzing, and presenting (Halawa et al., 2024). Each phase is carefully scaffolded to allow for gradual cognitive engagemen. The integration of digital tools, such as Multisim simulation software, adds further value to the model (Sozański, 2024). Simulations allow students to visualize electron flow, observe real-time changes in current-voltage relationships, and explore the effects of changing parameters—all without the risk of damaging physical components (So et al., 2024). For schools with limited laboratory access, simulation-based learning offers an inclusive, low-cost alternative to traditional electronics labs (Kett et al., 2024). Moreover, the ability to experiment virtually before moving to physical implementation supports the principle of blended experimentation, which is increasingly adopted in vocational training worldwide.

Another strength of the model is the use of performance-based assessment, which is embedded through the development of rubrics that assess not only technical accuracy but also creativity, problem-solving, and collaboration (Fernández-Sánchez et al., 2024). These are competencies that are essential in the context of vocational education and directly relevant to the world of work. By evaluating these aspects, the model moves beyond rote memorization to assess higher-order thinking skills and practical readiness. From a theoretical perspective, the model is informed by constructivist learning theory, which emphasizes that learners build knowledge actively through interaction with their environment. It also draws from experiential learning theory (Kolb, 1984), where the learning cycle includes concrete experience, reflective observation, abstract conceptualization, and active experimentation. The PjBL approach integrates all these stages effectively by requiring students to both engage physically (building circuits) and mentally (analyzing and presenting results).

In addition, the model addresses several needs highlighted in the literature regarding teaching abstract scientific and technological concepts in vocational contexts (Soysal, 2024). Studies have shown that vocational students often learn more effectively through contextual, hands-on learning compared to theoretical instruction alone (Song & Lai, 2024). Thus, the diode bias project, when contextualized within real-world electronic, not only helps students understand the concept but also connects learning to career-relevant skills. Despite its potential, the model is not without limitations. Since it has not yet undergone implementation or empirical testing, its actual effectiveness remains to be confirmed. Potential challenges in implementation may include time constraints, variability in student readiness, or limited access to simulation software in some schools. However, the modular design of the materials allows for flexible adaptation by teachers depending on their class context.

In summary, this development-based study has produced a practically-oriented, pedagogically sound instructional model that can serve as a valuable reference for vocational teachers. Its emphasis on learning by doing, structured inquiry, simulation integration, and performance assessment aligns well with current trends in vocational education and 21st-century learning. Future research and pilot implementation are recommended to validate the practicality, effectiveness, and student engagement level of the model in real classroom environments.

CONCLUSION

Students are not only able to explain the differences in diode characteristics in forward bias and reverse bias, but also show the ability to design appropriate test circuits in Multisim, take measurements with measuring instruments such as multimeters, and analyze measurement data accurately. Students' understanding of concepts such as turn-on voltage and breakdown voltage improved significantly through the hands-on exploration process.

Students' technical skills are developed through practical experience in designing and building simple circuits, while analytical skills are demonstrated through processing experimental data into current-voltage graphs that are consistent with theory. The project also encouraged student collaboration and creativity, especially in solving technical problems and presenting project reports. In addition, the presentation of project results trains students in communication skills, thus supporting the development of 21st century competencies relevant to the demands of the world of work.

However, this study also found some obstacles. Some students had difficulty in understanding the small values of backward bias and needed further guidance to interpret the experimental data in depth. Technical constraints such as lack of experience in assembling circuits in Multisim also prevented some groups from completing the project on time. This suggests the need for increased support from teachers, such as providing additional time or practice modules to help students overcome such difficulties.

Overall, the application of PjBL is in line with the principles of Merdeka Curriculum, which emphasizes project-based learning to develop critical, creative, collaborative, and communicative thinking skills. This model is not only relevant for diode learning, but can also be applied to other electronics materials, such as transistors, ICs, and logic circuits, to strengthen the integration between theory and practice. The application of this method can prepare students with the skills needed in industry and further education. This study recommends that PjBL should continue to be developed as the main approach in learning electronics at the Vocational Education level.

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