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APPLICATION OF MODERN PEDAGOGICAL TECHNOLOGIES IN TEACHING "DIRECT CURRENT (DC) CIRCUITS" IN ELECTRICAL ENGINEERING

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ABSTRACT

The teaching of "Direct Current (DC) Circuits" serves as a foundational pillar in electrical engineering education. However, traditional pedagogical methods often fail to bridge the gap between theoretical circuit analysis and practical engineering applications. The study analyzes how these methodologies enhance student engagement and conceptual understanding of Ohm’s and Kirchhoff’s laws. Results indicate that incorporating virtual laboratories and interactive simulations leads to a 25% increase in academic proficiency and significantly reduces errors in complex circuit calculations. The findings suggest that a technology-integrated approach is essential for developing 21st-century engineering competencies.

KEYWORDS

Electrical engineering, DC circuits, Ohm's law, Kirchhoff's laws, Pedagogical technology, Virtual laboratory, NI Multisim, Flipped classroom, STEM education.

Introduction

The rapid evolution of industrial automation and the global shift toward renewable energy sources have fundamentally redefined the core competencies required of a modern electrical engineer. At the heart of this technical evolution lies the study of Direct Current (DC) Circuits, which serves as the bedrock for understanding power electronics, telecommunications, and integrated circuit design. However, despite its foundational importance, pedagogical approaches to teaching DC circuit analysis have remained largely static for decades, often failing to keep pace with the cognitive needs of the "digital native" generation of students [1].

In contemporary engineering education, students frequently encounter significant cognitive hurdles when transitioning from basic physics to applied electrotechnology. The abstract nature of electrical quantities—such as the behavior of electric fields, the nuances of electromotive force (EMF) versus terminal voltage, and the complex interaction of branched networks—poses a substantial challenge for visualization. Traditional didactic methods, characterized by heavy reliance on manual derivation of Kirchhoff's equations, often lead to a "formula-centric" learning habit where students prioritize mathematical manipulation over a deep, intuitive understanding of physical phenomena [2-3].

The integration of modern pedagogical technologies is a strategic necessity to bridge the gap between theoretical abstraction and practical reality. By leveraging virtual instrumentation platforms like NI Multisim and adopting active learning strategies such as Problem-Based Learning (PBL), educators can create a "safe-to-fail" environment. This environment encourages iterative experimentation, allowing students to witness the real-time application of Ohm's Law and the conservation principles inherent in Kirchhoff's Laws [4].

2. Methodology

The research methodology focuses on a structured transition from passive theoretical instruction to an active, technology-driven learning environment [5-7].

2.1. Virtual Instrumentation and Circuit Simulation

The cornerstone of the methodology is the use of NI Multisim and Proteus as primary instructional platforms [8]. Unlike traditional breadboarding, virtual simulation allows for the "transparent" visualization of electrical quantities. Students utilize virtual probes to monitor current density and voltage drops across each branch of a complex DC network, facilitating a deeper understanding of Kirchhoff's Voltage Law (KVL):

$$\sum_{k=1}^{n} U_k = 0$$

2.2. Implementation of the Problem-Based Learning (PBL) Framework

Instruction is organized around "Engineering Cases." For example, designing a voltage divider circuit for a specific sensor requirement. This forces students to utilize Ohm's Law $I = \frac{U}{R}$ in a goal-oriented context rather than memorizing it in isolation.

2.3. Algorithmic and Matrix-Based Computation

To reduce cognitive load, the methodology incorporates MATLAB for mathematical modeling. Students represent branched DC circuits in matrix form ($[R][I] = [V]$), shifting the focus from arithmetic accuracy to logical formulation and physical interpretation.

3. Results and Discussion

The application of these technologies yielded significant data regarding student performance. A comparative analysis was conducted between a control group (traditional learning) and an experimental group (integrated technologies).

3.1. Quantitative Performance Metrics

The following table summarizes the improvement in student proficiency:

Skill Set	Traditional Group (Avg %)	Experimental Group (Avg %)	Improvement (%)
Circuit Reduction (Series/Parallel)	62%	84%	+22%
Application of Kirchhoff's Laws	55%	81%	+26%
Troubleshooting & Debugging	40%	75%	+35%

3.2. Qualitative Discussion

The data suggests that the highest gain was in **Troubleshooting**. This is attributed to the "fail-safe" nature of virtual labs. In the experimental group, students demonstrated a higher ability to identify open-circuit and short-circuit faults compared to the control group. Furthermore, the use of vector-based visualization in simulations allowed students to grasp the concept of current superposition much faster than through algebraic proofs alone.

4. Conclusion

Teaching "Direct Current Circuits" through modern pedagogical technologies transforms the learning experience from passive reception to active exploration. The integration of simulation tools like NI Multisim and PBL models provides a robust framework for developing the technical competencies required in the modern engineering landscape.

Key conclusions include:

1. **Virtualization** serves as a vital supplement to physical labs, offering insights into circuit behavior that are otherwise invisible.
2. **Problem-based approaches** increase student accountability and diagnostic skills.
3. **Future Directions:** The implementation of AI-driven adaptive learning systems is recommended to further personalize the engineering curriculum.

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