

Harnessing Multiple Intelligences Through Simulation-Based Learning: Enhancing Electric Motor Comprehension in TVET

Raja Nazeli Bin Raja Mamat^{1*}, Rosidah Binti Mohd Saad²,

¹. Department of Electrical Engineering, Politeknik Kota Bharu.

². Department of Civil Engineering, Politeknik Kota Bharu.

*Corresponding author's email: rajanazeli@pkb.edu.my

Abstract: The teaching and learning of electrical machines in Technical and Vocational Education and Training (TVET) face persistent challenges, particularly in helping students grasp complex theoretical concepts and relate them to practical applications. Traditional instructional approaches often fall short in accommodating diverse learning styles, resulting in low engagement and limited conceptual understanding. This study aims to evaluate the effectiveness of a simulation-based learning approach in enhancing students' comprehension of electric motor operations by aligning instructional design with the theory of multiple intelligences. The research employed a mixed-method action research design involving 30 diploma-level electrical engineering students from Polytechnic Kota Bharu, Malaysia. Content analysis was conducted on students' pre- and post-test results, survey responses, and classroom observation data collected over a four-week intervention using MATLAB/Simulink and Ansys Maxwell software. Relevant literature from 2020 to 2023 was reviewed to frame the theoretical and empirical context of the study. The findings reveal a significant improvement in students' understanding of motor performance parameters, including torque and efficiency, as well as an enhancement of their analytical and problem-solving skills. Despite initial challenges in software navigation, students reported increased engagement and preference for simulation-based learning over traditional laboratory sessions. The implications of this study are twofold: for educators, it highlights the need to integrate simulation tools systematically to cater to learners with diverse intelligences; for policymakers and industry stakeholders, the study supports the advancement of digital learning strategies to enhance TVET curriculum effectiveness and graduate readiness in a technology-driven workforce. Future integration of simulation-based modules can foster more inclusive, adaptive, and industry-relevant engineering education.

Keywords: *simulation-based learning, electric motors, multiple intelligences, MATLAB/Simulink, TVET, engineering education*

1.0 INTRODUCTION

The field of Technical and Vocational Education and Training (TVET) plays a vital role in producing a skilled workforce capable of meeting industry demands, particularly in engineering and electrical technology. One of the persistent challenges in electrical engineering education lies in teaching abstract theoretical concepts, such as those related to electric motor operations, which require both conceptual understanding and practical application (Wolff, 2020). The learning requirements of students with different cognitive styles and intelligences are frequently not addressed by traditional educational approaches, which mostly rely on lectures and textbook-based instruction (Chimbunde, Moreeng, & Chawira, 2023).

Gardner's (2011) Theory of Multiple Intelligences highlights the importance of acknowledging individual differences in how learners process and engage with content. For example, students with strong visual-spatial intelligence may benefit more from graphical representations and simulations, while those with logical-mathematical intelligence may excel through data analysis and modelling tasks. These diverse cognitive preferences call for innovative pedagogical strategies that go beyond

conventional instruction.

Simulation-based learning, which incorporates tools like MATLAB/Simulink and Ansys Maxwell, offers a promising solution by enabling learners to visualise and manipulate virtual representations of motor systems. Such interactive environments align with multiple intelligences and support deeper cognitive engagement, critical thinking, and practical reasoning—skills that are essential in the engineering workforce.

This study investigates the effectiveness of simulation-based learning in enhancing students' understanding of electric motors within a Malaysian TVET context. It explores how such approaches support diverse intelligences and contribute to improved learning outcomes. By doing so, the study aims to inform the development of more inclusive and industry-relevant teaching practices in electrical engineering education.

2.0 LITERATURE REVIEW

The increasing complexity of engineering curricula necessitates teaching methods that accommodate students' diverse learning styles and intelligences. Simulation-based learning has been widely recognized as an effective pedagogical approach for visualising abstract concepts and fostering problem-solving skills in technical education (Smith & Johnson, 2021). In particular, simulations in electrical engineering enable students to manipulate parameters such as torque, current, and efficiency in virtual environments, thus bridging the gap between theory and practice.

Kumar, Sharma, and Gupta (2022) found that students who engaged with MATLAB/Simulink simulations demonstrated significantly higher conceptual understanding and analytical capabilities compared to those taught using traditional methods. Simulation environments allow for repeated experimentation in risk-free settings, enabling students to observe system behaviours under various operating conditions. This dynamic feedback loop aligns with constructivist learning theories, which suggest that knowledge is best constructed through active, experiential learning.

However, the implementation of simulation-based learning is not without challenges. Tan (2020) highlighted that students often struggle with complex interfaces and interpreting simulation outputs without adequate guidance. This reinforces the need for structured instructional design and scaffolding during simulation activities.

Despite its proven benefits, few studies have explicitly examined how simulation-based learning intersects with the Theory of Multiple Intelligences in TVET settings. Gardner (2011) posited that instructional strategies should address a range of intelligences—visual-spatial, logical-mathematical, bodily-kinesthetic—to support inclusive learning. This study addresses that gap by investigating how simulations can be pedagogically aligned with diverse intelligences to improve students' comprehension and engagement in the electrical engineering domain.

Problem Statement

In the context of Technical and Vocational Education and Training (TVET), teaching complex engineering subjects such as electric motor operation remains a persistent challenge by Trunova et al. (2023). Many students struggle to understand abstract theoretical concepts when instruction relies solely on traditional teaching methods, such as lectures or textbook-based problem-solving. This often results in low engagement, superficial comprehension, and limited ability to apply theoretical knowledge to real-world scenarios (Maroungkas et al. (2023).

Moreover, conventional approaches do not adequately address the diversity of learners' cognitive styles, particularly in polytechnic settings where students exhibit varied intelligences, learning preferences, and levels of academic preparedness. According to Gardner's (2011) Theory of Multiple Intelligences, instructional methods should be designed to cater to different intelligences—including visual-spatial, logical-mathematical, and bodily-kinesthetic—to ensure inclusive and effective learning. However, most electrical engineering curricula are not yet adapted to support this diversity.

Simulation-based learning offers an alternative instructional approach by enabling learners to visualise dynamic motor behaviours, interact with system parameters, and experiment in a low-risk environment. Despite their potential, there is no empirical data on how these tools affect students' comprehension in the Malaysian TVET context or whether they are useful for students with varying intelligences by Amdan et al. (2024).

Therefore, this study aims to address this gap by evaluating the effectiveness of simulation-based learning in enhancing students' understanding of electric motors and identifying the challenges encountered in its implementation among polytechnic students.

Research Objective

This study was conducted with the following objectives:

- i. To evaluate the effectiveness of simulation-based learning in enhancing students' understanding of electric motor operations within a TVET context.
- ii. To identify the challenges encountered by students in using simulation software tools such as MATLAB/Simulink and Ansys Maxwell.

3.0 METHODOLOGY

This study employed an action research design combining both quantitative and qualitative approaches to examine the impact of simulation-based learning on students' understanding of electric motors. The study was conducted over four weeks at Politeknik Kota Bharu, Malaysia, involving 30 diploma-level Electrical Engineering students selected through purposive sampling. This cohort had previously completed fundamental modules on electrical principles and was suitable for advanced topics related to

motor operation and performance.

The intervention utilised simulation software tools, including MATLAB/Simulink and Ansys Maxwell, integrated into a structured learning module. Students engaged with simulations that illustrated real-time motor behaviours under various load conditions, such as changes in torque, current flow, and efficiency levels.

Three instruments were used for data collection:

- i. Pre- and post-tests to measure students' conceptual understanding before and after the simulation-based learning intervention.
- ii. Student feedback surveys to capture perceptions, preferences, and encountered challenges.
- iii. Classroom observations to assess engagement levels and student interaction with the simulations.

Quantitative data from test scores and surveys were analysed using descriptive statistics to determine performance improvements and trend patterns. Qualitative data from open-ended survey responses and observational notes were analysed thematically to identify recurring issues, behavioural changes, and pedagogical implications.

This mixed-method strategy enabled a comprehensive understanding of both the effectiveness and limitations of simulation-based learning, while also providing insights into its alignment with diverse learning styles within the TVET framework.

4.0 FINDINGS

4.1 Pre- and post-test results

The analysis of test scores before and after the simulation-based intervention indicates a notable improvement in students' understanding of electric motor operations. The average pre-test score was 55% (SD = 8.5), while the average post-test score increased to 78% (SD = 6.0), suggesting a 23-percentage-point gain in conceptual understanding. This improvement reflects the effectiveness of using simulation tools to visualise and interact with abstract motor concepts, such as torque, electromagnetic force, and current flow.

4.2 Student Feedback Survey

The student feedback survey revealed the following insights:

- i. 85% of participants agreed that the simulation-based activities improved their conceptual understanding.
- ii. 80% expressed a preference for simulation activities over conventional laboratory methods

due to their interactive and visual nature.

- iii. 40% of students reported initial difficulties in using simulation tools, citing software complexity and unfamiliarity as main barriers.
- iv. Several students highlighted that repeated exposure and instructor support helped them overcome these challenges by the end of the module.

4.3 Classroom Observations

Observation data supported the survey findings. Students demonstrated increased engagement, often working collaboratively to interpret simulation outcomes and solve technical problems. Instructors were frequently required to intervene, especially during the early stages of software use, indicating a learning curve associated with simulation tools. However, by the third and fourth weeks, students showed more independence and confidence in navigating the platforms. Overall, the data show that simulation-based learning contributed positively to both cognitive and affective dimensions of student learning, despite some initial obstacles related to technical proficiency.

5.0 DISCUSSION AND CONCLUSION

The findings of this study affirm that simulation-based learning significantly enhances students' understanding of electric motor operations in a TVET setting. The substantial improvement in post-test scores suggests that students benefited from the visualisation and interactivity provided by tools such as MATLAB/Simulink and Ansys Maxwell. These platforms allowed learners to experiment with motor behaviour in real time, thus making abstract concepts more tangible—a result consistent with the observations of Smith and Johnson (2021), who highlighted the pedagogical value of visual simulations in technical education.

The high level of student agreement in the feedback survey reinforces the argument that simulation supports deeper cognitive processing and engagement. According to Gardner's (2011) Theory of Multiple Intelligences, learners possess different cognitive strengths, and instruction must be varied to reach them effectively. In this study, simulation activities particularly benefited students with visual-spatial and logical-mathematical intelligences, allowing them to engage through animated models and data-driven problem-solving.

Despite the benefits, initial difficulties in using simulation tools were evident. Similar to findings by Tan (2020), some students required extra time and support to become proficient in navigating complex simulation environments. This highlights the importance of integrating structured training and scaffolding mechanisms in any simulation-based module.

The observed shift in learner behaviour—from dependence to autonomy—demonstrates the potential

of simulation-based learning to foster not only content mastery but also independent learning skills. According to Vimbelo & Bayaga (2024), training students for real-world problem-solving is crucial in the context of TVET, and this result is quite pertinent.

In summary, the integration of simulation-based learning in the electrical engineering curriculum offers a promising avenue for enhancing educational quality, accommodating learner diversity, and aligning with the demands of industry and 21st-century skills.

This study has demonstrated that simulation-based learning is an effective pedagogical approach for enhancing students' understanding of electric motor operations within a TVET framework. By integrating software tools such as MATLAB/Simulink and Ansys Maxwell into the teaching process, students were able to visualise complex theoretical concepts, engage with dynamic simulations, and apply knowledge in a practical, problem-solving context. Morris, Perry, and Wardle (2021) found that the approach's instructional effectiveness is strongly supported by the notable improvements in post-test performance and the favourable feedback from students.

Moreover, the alignment of simulation-based learning with the Theory of Multiple Intelligences further underscores its potential to support diverse learning needs. Students with visual-spatial and logical-mathematical strengths benefited from the interactive and data-driven nature of the simulations. Adeleke, Balogun, and Ayanwale (2025) emphasise the significance of creating inclusive teaching methods that are adapted to various cognitive profiles, particularly in technical education, where conceptual mastery is essential.

Although initial challenges in software usage were noted, these barriers were gradually overcome through guided instruction and repeated practice, leading to increased learner autonomy and confidence. Accordingly, the study concludes that simulation-based learning fosters autonomous learning skills that are necessary for success in the rapidly changing technological landscape, in addition to improving conceptual comprehension by Elendu et al. (2024).

In advancing the TVET agenda, integrating simulation tools into core engineering curricula represents a strategic step towards producing industry-ready graduates equipped with 21st-century skills, digital fluency, and adaptive learning capabilities.

Recommendations

Based on the findings and conclusions of this study, the following recommendations are proposed to enhance the integration and effectiveness of simulation-based learning in TVET, particularly within electrical engineering education:

Curriculum Integration:

Simulation-based modules should be routinely incorporated into electrical engineering curricula by

educational institutions (Azid et al. 2023). These modules should not be treated as supplementary but rather as core instructional tools aligned with learning outcomes and assessment strategies.

Instructor Training and Support:

Continuous professional development should be provided to instructors to ensure they are proficient in simulation software tools such as MATLAB/Simulink and Ansys Maxwell. Effective facilitation requires both technical expertise and pedagogical strategies tailored to multiple intelligences by Rakhman (2023).

Scaffolded Learning Materials:

Structured guides, tutorials, and instructional videos should accompany simulation activities to assist students in navigating complex interfaces and interpreting simulation outputs, particularly during early exposure stages (Chernikova et al. 2020).

Adaptive Learning Approaches:

Instructional design should account for diverse learning profiles by incorporating simulation activities that cater to different intelligences—e.g., interactive visualisation for visual learners, data manipulation for logical learners, and guided exploration for kinesthetic learners (Mersha, 2024).

Policy-Level Endorsement:

Educational policymakers should recognise simulation-based learning as a core component of future-ready TVET programs. Funding and resource allocation should support the acquisition of simulation software, training infrastructure, and research on digital learning efficacy (Elendu et al. 2024).

By implementing these recommendations, TVET institutions can create a more inclusive, engaging, and technologically relevant learning environment that prepares students for the demands of modern industry and supports long-term educational transformation.

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