Vol. 9, No. 2, November 2025, pages 181 - 192

JEE

Jurnal Edukasi Elektro

https://doi.org/10.21831/jee.v9i2.89226

Development of Virtual Reality-Based Electric Motor Control Simulation for Improving Electric Motor Installation Competency in Vocational High Schools

Rizal Muhammad Ramdhan[1], Ima Ismara[1], Agus Ramelan[2]

[1]Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

[2]Universiti Malaya, Kuala Lumpur, Malaysia

Abstract— Many vocational schools in Indonesia face limitations in laboratory facilities and practical equipment, which hinders students' ability to master electric motor installation competencies. Virtual Reality (VR) offers a potential solution by providing safe, interactive, and cost-efficient learning environments that simulate real laboratory conditions. This study aims to develop and assess the feasibility of a VR-based electric motor control simulation as instructional media for vocational high schools. The novelty of this research lies in integrating pedagogical, ergonomic, and occupational safety aspects into VR learning, which are rarely addressed in previous studies. A Research and Development (R&D) approach was employed using a modified Waterfall model. Three-dimensional assets were created in Blender and implemented in Unreal Engine 5 to build immersive virtual environments. Validation was conducted by two media experts, two material experts, and 73 vocational students using questionnaires, observations, and pre/post-tests. The results showed feasibility scores of 68.53% from media experts and 79.58% from material experts, both categorized as feasible. Reliability analysis confirmed Cronbach's Alpha values above 0.75, while student trials indicated significant learning improvement. These findings demonstrate that the developed VR simulation is feasible and effective as a pre-practical learning tool. In conclusion, this study contributes theoretically by extending VR pedagogy to safety-oriented vocational training and provides practical implications as an innovative solution for schools with limited resources.

Keywords: competency improvement, electrical installation, virtual reality, simulation learning, vocational education.

Article submitted 2025-08-16.
Resubmitted 2025-10-07.
Final acceptance 2025-10-08.
Final version published as submitted by the authors.

Corresponding Author:
Rizal Muhammad Ramdhan,
Universitas Negeri Yogyakarta,
Yogyakarta, Indonesia.
Email: rizalmuhammad.2022@student.uny.ac.id

Citation Document:
Ramdhan, R. M., Ismara, K. I., & Ramelan, A. (2025). Development of Virtual Reality-Based Electric Motor Control Simulation for Improving Electric Motor Installation Competency in Vocational High Schools. *Jurnal Edukasi Elektro*, *9*(2), 181–193. https://doi.org/10.21831/jee.v9i2.89226

1 Introduction

The rapid integration of digital technology in education has transformed traditional learning methods and introduced new opportunities for skill-based training. In vocational education, especially in electrical engineering programs, mastering practical competencies requires continuous hands-on experience supported by adequate laboratory facilities. However, many vocational high schools in Indonesia still face limited access to physical laboratories and modern training equipment, leading to gaps between theoretical understanding and practical proficiency [1], [2]. These constraints hinder students' readiness for industrial work environments that increasingly rely on automation and control systems.

Virtual Reality (VR) has emerged as an innovative pedagogical medium that can simulate real laboratory conditions through immersive three-dimensional environments [3]. VR allows learners to engage with complex technical systems without physical risk or material limitations, offering a safe and cost-efficient approach to learning [4], [5]. Previous studies have demonstrated VR's potential in improving motivation, conceptual understanding, and psychomotor performance across engineering disciplines [6]-[8]. However, despite its growing adoption, most VR-based learning research focuses mainly on cognitive outcomes, neglecting essential aspects such as ergonomics, safety awareness, and human machine interaction elements that are critical in vocational and technical education [9].

In this context, the present study develops and evaluates a Virtual Reality-based electric motor control simulation tailored to the learning needs of vocational high school students. The simulation aims to enhance electric motor installation competencies while simultaneously introducing ergonomic and safety principles aligned with industrial standards [10]. The novelty of this research lies in combining pedagogical, ergonomic, and occupational safety perspectives into a single VR-based training environment. By integrating these dimensions, the developed media not only serves as a learning tool but also as a pre-practical safety training system that prepares students before entering real workshop conditions [11]-[13].

2 Literature Review

2.1 Learning Media and Vocational Pedagogy

Learning media is crucial in shaping the quality of instruction and supporting students' comprehension of technical concepts. Effective media must integrate visual, auditory, and kinesthetic elements that align with pedagogical objectives [14]. In vocational education, learning media also play a pivotal role in bridging the gap between theoretical instruction and hands-on experience [15]. According to Akrim [16], multimedia-based instruction can enhance students' motivation and reduce cognitive overload by providing contextual visualization. Similarly, Djouab and Bari [17] emphasized that the quality of educational media depends on usability, reliability, and efficiency, as defined by ISO 9126 standards.

2.2 Virtual Reality in Education

Virtual Reality is a three-dimensional computer-generated environment that enables users to interact with digital objects as if in the real world [18]. Recent studies have highlighted VR's transformative potential in education by enabling experiential and immersive learning [19], [20]. Montebello and Camilleri [21] found that VR facilitates engagement and understanding in higher education, while Curcio et al. [22] emphasized that immersive experiences foster deeper conceptualization. In addition, the integration of VR into engineering education has been shown to enhance spatial reasoning and procedural memory retention [23].

However, research also indicates that the effectiveness of VR depends on instructional design, interactivity, and the degree of cognitive engagement provided [24]. Fernandez [25] argued that immersive media must be pedagogically grounded to avoid passive observation and promote active learning. Hence, the instructional design of VR environments should align with constructivist and experiential learning theories.

2.3 VR for Vocational and Safety Training

The adoption of VR in vocational education has expanded rapidly due to its ability to simulate hazardous environments safely. Wu et al. [26] conducted a systematic review showing that VR-assisted vocational training can significantly improve procedural knowledge and reduce the risk of accidents. More recently, Li and Wang [27] designed an ergonomics-based VR environment that enhanced learners' awareness of safety procedures in industrial workshops. Similarly, Zhao et al. [28] demonstrated that immersive VR training improves not only technical accuracy but also safety compliance among electrical engineering students.

Studies such as Ouyang and Chang [29] and Chen and Huang [30] confirmed that game-based VR simulations can strengthen engagement, retention, and collaboration in technical learning contexts. Despite these advances, few studies have explicitly incorporated ergonomic design principles and occupational safety elements within VR-based vocational learning systems. This research addresses that gap by developing a VR media that integrates ergonomic postures, proper tool handling, and safe electrical procedures thereby extending the pedagogical scope of VR from mere knowledge transfer to safety-oriented skills formation.

3 Method

This research employed a Research and Development (R&D) approach using a modified Waterfall model, consisting of four main stages: requirement analysis, design and modeling, construction and testing, and deployment and evaluation. Figure 1 shows the waterfall development model.

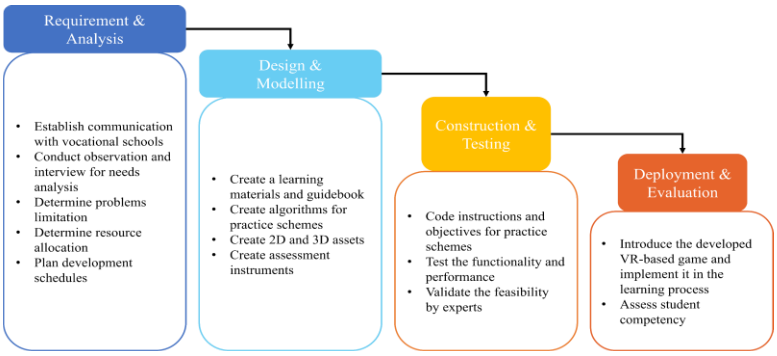

Figure 1. Waterfall stage

3.1 The Research Design

The development began with requirement analysis, including observations and interviews with teachers and students to identify problems in existing electric motor installation practices. The design and modeling stage involved creating detailed 3D assets of laboratory environments, equipment, and personal protective equipment (PPE) using Blender. These assets were then integrated into Unreal Engine 5 to build an interactive VR simulation.

3.2 Respondents

Students were divided into control and experimental groups to measure the effectiveness of the VR simulation compared with traditional learning. The subjects of this study consisted of:

- Two media experts (for media feasibility validation),
- Two material experts (for content validation),
- 73 vocational students in grade XI of Electrical Installation Engineering from SMKN 1 Cihampelas and SMK Cendekia Batujajar (for user testing).

3.3 Instruments

Data were collected through:

- Observation and interviews → to identify user needs and contextual problems.
- Expert validation questionnaires → to assess media and content feasibility (4-point Likert scale).
- Student questionnaires → to measure user responses and usability.
- Pre-test and post-test → to evaluate competency improvement in electric motor installation.
- Black-box testing → to assess functionality and performance of the VR application.

3.4 Data Analysis

Data analysis used a mixed-method approach. Qualitative data from observation and interviews were analyzed following Miles & Huberman's steps (data reduction, display, and conclusion). Quantitative data from expert validation, questionnaires, and pre/post-tests were analyzed using descriptive statistics, Cronbach's Alpha for reliability, and N-gain to measure learning effectiveness. Additional statistical tests (normality and paired t-test) were conducted to examine significance of learning improvement.

The media feasibility data analysis is obtained from questionnaires given to media experts, content experts, and users (students) with the determination of feasibility levels as shown in Table 1. In addition to the functionality data analysis, quantitative data analysis is obtained from the effectiveness level analysis of the electric motor control simulation learning media, which involves a series of tests including calculating the N-gain value, normality, and t-test (hypothesis testing).

Table 1. Feasibility category intervals

Intervals	Feasibility Category
$Mi+1,5\ SDi<x\leq Mi+3\ SDi$	Very Feasible
$Mi<x\leq Mi+1,5\ SDi$	Feasible
$Mi-1,5\ SDi<x\leq Mi$	Less Feasible
$Mi-3\ SDi<x\leq Mi-1,5\ SDi$	Not Feasible

4 Results and Discussion

4.1 Requirement & Analysis Stage

In the required stage, the research involved qualitative analysis through observation and interviews in the electric motor installation laboratories at two schools, namely SMKN 1 Cihampelas and SMK Cendekia Batujajar. The observation results indicate that the laboratory conditions do not meet the standards for laboratory practice rooms and occupational health and safety (OSH) standards. Shortages of practical equipment and materials also pose challenges. Interviews with teachers and the head of the Electrical Installation Engineering Program revealed that the electric motor installation learning has not been optimal due to limitations in equipment and materials, as well as insufficient practice space.

Furthermore, in the analysis stage, several steps were identified. Scope definition involved teachers in planning the introduction of tools and materials as well as installation procedures in VR simulation. User needs analysis was conducted through interviews with teachers and students to understand expectations and challenges in electric motor control. Resource allocation included development team, hardware, and VR software. Project scheduling encompassed planning, modeling, construction, and implementation stages with realistic deadlines set. Planning validation was conducted through discussions with the development team, teachers, and industry experts to ensure agreement from all parties involved.

4.2 Design & Modelling Stage

In the design and modelling stage, the results include creating asset objects for the virtual reality-based electric motor installation laboratory learning media. This entire process illustrates efforts to identify, plan, and model electric motor control simulations as an alternative for more effective and comprehensive learning.

Table 2. List of asset requirements for the introduction area of electric motor installation components

Model Group	Model Name
Introduction to Electric Motor Components	Electric motor
	1-Phase Miniature Circuit Breaker
	3-Phase Miniature Circuit Breaker
	Contactor
	Thermal Overload Relay
	Storage table for materials
PPE	Practice Uniform
	Safety helmet
	Pair of safety shoes
	Pair of gloves
	Wardrobe for PPE
	Storage table for PPE
Practicum Area of Electric Motor Installation	Set of workspaces
	Set of Electrical panels
	Terminal
	1-Phase Miniature Circuit Breaker
	3-Phase Miniature Circuit Breaker
	Contactor
	Thermal Overload Relay
	Pilot lamp
	Emergency stop
	Push button
	Electric motor
	Vise
	Vise storage table
	Chair
	Set of computers (CPU, monitor, keyboard, mouse)
	Computer table
Other Indoor Assets	OSH poster
	First aid kit
	Fire extinguisher
	Window
	Exhaust fan
	Globe
Outdoor Assets	Garden lamp
	Pool
	Gazebo
	Bench
	River
	Other buildings
	Plants

Table 2 present the detailed asset requirements for developing the Virtual Reality-based Electric Motor Installation Laboratory used in this research. These assets serve as the foundational elements for creating an immersive and realistic simulation environment, ensuring that the virtual laboratory accurately replicates real-world conditions.

The researcher utilized Blender application for designing models, as Blender offers several advantages compared to other applications, such as; comprehensive features tailored for students, extensive format support in modeling, user-friendly interface, and the largest user community among 3D modeling application developers. The 3D models created were then integrated into a game engine called Unreal Engine 5 for programming and customization according to user needs in VR. After designing the media, the researcher created a user guide as a supporting product for the research. The workflow of using the electric motor control simulation media (virtual electric motor installation laboratory) is explained in Figure 2.

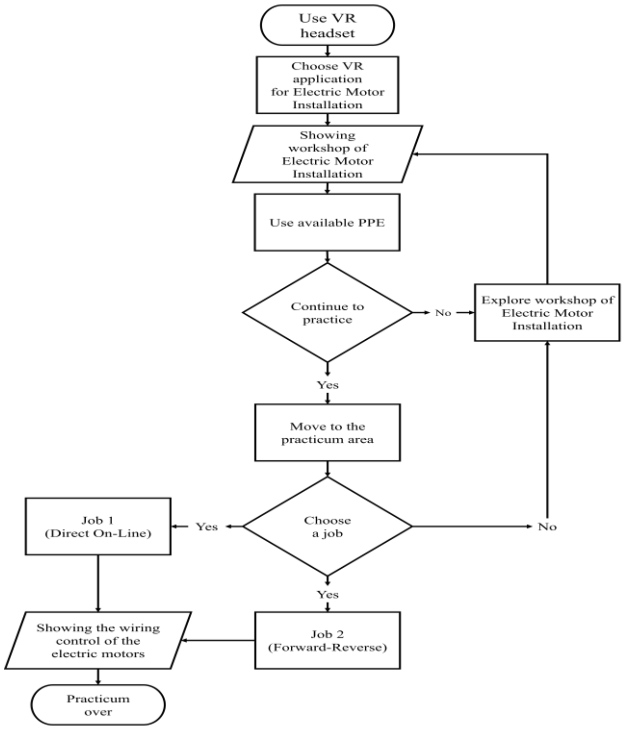

Figure 2. Flowchart of electric motor installation laboratory usage

Figure 2 illustrates the workflow for using the VR-based Electric Motor Installation Laboratory. The process begins with the user wearing a VR headset and selecting the VR application for Electric Motor Installation. Upon entering the simulation, the system displays the virtual workshop environment. The user is then prompted to equip the available Personal Protective Equipment (PPE) to comply with safety standards.

At this stage, the user decides whether to proceed with practical activities or explore the workshop environment. If the user chooses exploration, they can freely navigate and observe the virtual laboratory before returning to the main flow. If the user chooses to practice, they are directed to the practicum area. In the practicum area, the user is presented with a choice of specific jobs. Two job options are available: Job 1 – Direct On-Line (DOL) and Job 2 – Forward-Reverse motor control. Once a job is selected, the system guides the user through the steps of performing the task, including showing the wiring control of the electric motors.

The workflow concludes when the assigned practicum is completed, marking the end of the VR-based training session. This structured flow ensures that students can engage in both exploratory learning and guided practical exercises within a safe, immersive virtual environment, reinforcing both technical skills and adherence to occupational safety protocols.

Table 3. Measured scores of the assessment instrument reliability

Instrument Name	Total	Cronbach's Alpha
Media expert validation questionnaire	56 items	0,944
Material expert validation questionnaire	30 items	0,760
Test questions	36 items	0,793

Table 3 presents the measured reliability scores for the assessment instruments used in this study. Three types of instruments were evaluated: the media expert validation questionnaire, the material expert validation questionnaire, and the test questions for measuring student learning outcomes. The media expert validation questionnaire consisted of 56 items and achieved a Cronbach's Alpha value of 0.944, indicating excellent internal consistency and high reliability. The material expert validation questionnaire, containing 30 items, obtained a Cronbach's Alpha of 0.760, which is considered acceptable for research purposes. The test questions used to assess student competencies in Electric Motor Installation comprised 36 items and achieved a Cronbach's Alpha value of 0.793, also reflecting good reliability.

These results confirm that all the instruments used for validation and testing in the research are consistent and dependable. This ensures that the data collected through these instruments whether for expert validation or student competency assessment can be considered trustworthy and suitable for further statistical analysis.

Table 4. Rating Scale Used for Expert Validation

Score	Statement
1	Strongly disagree
2	Disagree
3	Agree
4	Strongly agree

Table 4 outlines the rating scale used for expert validation. The scale is based on a four-point Likert format: 1 – Strongly Disagree, 2 – Disagree, 3 – Agree, and 4 – Strongly Agree. This format was chosen to avoid neutral responses, ensuring that experts provide clear positive or negative feedback.

4.3 Construction & Testing Stage

The creation and development of virtual reality-based electric motor control simulation media begin with designing 3D models using Blender software according to the media requirements and integrating them into the game engine as a developer for interactions in the game. The researcher uses the Unreal Engine 5 application for developing interactions with the game, as can be seen in Figure 3. When compared to Unity software, Unreal Engine has several advantages, such as; the application can be downloaded for free through Epic Games, and it offers comprehensive features. Another advantage of this application is that users do not need to be proficient in programming languages like C or C# because the language used to integrate the game is through blueprints, making the application easier to learn.

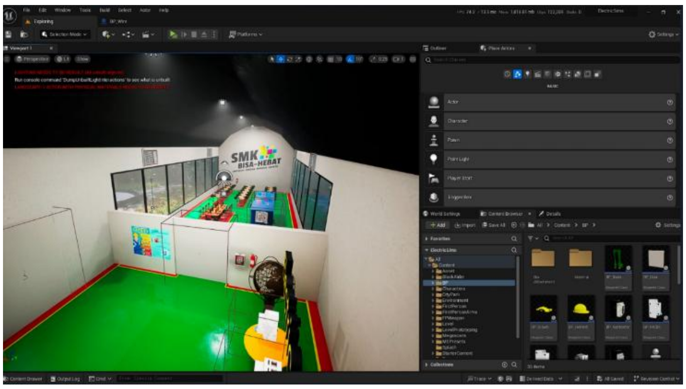

Figure 3. Design stage using unreal engine 5 software

Figure 3 illustrates the design stage in Unreal Engine 5 (UE5) after the 3D models have been created in Blender. At this stage, assets such as electric motor installation laboratory components, practice rooms, and environmental elements are imported into UE5 and arranged as a VR "level." The design process includes adjusting materials/textures, setting up lighting, defining collision boundaries for VR interaction, and configuring navigation/view controls to ensure a smooth immersive experience using the Meta Quest 2 headset. The ultimate goal of this stage is to prepare the scene/environment so that it is ready to be integrated with interactive logic for the electric motor control simulation.

After all designs are created, the researcher exports them into PC and VR game formats stored on a computer/laptop for direct testing by the researcher through black-box testing. The purpose of this testing is to assess the functionality of the system, ensuring that all functions operate as expected. Figure 5 describe teachers are trying out the functionality of the tools and game applications created by researchers to provide input if there are any shortcomings.

Figure 4. Blackbox testing process

At this stage, revisions were conducted as part of the refinement process for the concept previously developed, in the formative revisions to identify shortcomings or errors in the final product, which is the workshop introduction media accompanied by a user guide. This revision received input from media experts and subject matter experts who are lecturers in the Department of Electrical Engineering Education. The simulation media received improvement suggestions in its development by adding a feature for adjusting the height of the worktable to meet the ergonomic standards of the electric motor installation laboratory.

4.4 Deployment & Evaluation Stage

A total of two media experts and two material experts have given validations of the developed VR-based game to measure the feasibility scores can be seen in Table 5 and Table 6, respectively. Figure 5 shows the distribution of the scores. These results become a reference for improvements before deploying the product which will finally be implemented in the learning process.

Table 5. Media experts' validation scores

Sub-aspect	Min. Score	Max. Score	Validation Score		Mean	Percentage (%)
			Expert 1	Expert 2		
Effectiveness of the learning media	5	20	15	5	10	**50.00**
Technology compatibility	5	20	16	12	14	**70.00**
Quality of learning content	6	24	18	17	17.50	**72.92**
Hardware & software of VR	6	24	18	16	17	**70.83**
Elements of VR	6	24	18	14	16	**66.67**
Effectiveness of VR	6	24	17	13	15	**62.50**
Workshop	4	16	18	20	19	**79.17**
Norms and standards	6	24	11	10	10.50	**65.63**
Ergonomic	6	24	18	18	18	**75.00**
Competency in Electric Motor Installation	6	24	18	15	16.50	**68.75**
Total	56	224	167	140	153.50	
Percentage (%)			**74.46**	**61.68**	**68.53**	

Table 6. Material Expert Validation Scores

Sub-aspect	Min. Score	Max. Score	Validation Score		Mean	Percentage (%)
			Expert 1	Expert 2		
Relevance of learning content	6	24	21	22	21.50	**89.58**
Quality of learning content	8	32	24	26	25	**78.13**
Usefulness of the guidebook	6	24	19	17	18	**75**
Accuracy of learning materials	10	40	28	34	31	**77.50**
Total	30	120	92	99	95.50	
Percentage (%)			**76.67**	**82.50**	**79.58**	

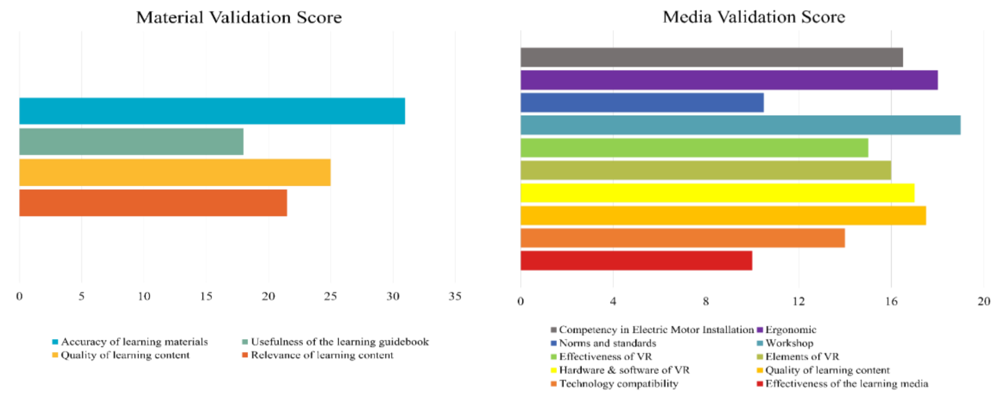

Figure 5. Distribution of the calculated feasibility scores.

4.5 Final Review of the Research Product

Expert validation showed that the VR-based electric motor control simulation was categorized as feasible. Media experts provided an average score of 68.53%, while material experts gave 79.58%, both falling into the feasible category. Reliability testing confirmed Cronbach's Alpha values above 0.75 for all instruments, indicating high consistency.

The product was tested on 73 vocational students divided into control and experimental groups. Pre-test and post-test results demonstrated significant improvement in the experimental group using the VR simulation. The calculated N-gain values exceeded 0.3 (medium category), confirming its effectiveness in improving student competencies in electric motor installation. Student response questionnaires also showed positive perceptions regarding interactivity, ease of use, and alignment with safety standards.

The findings demonstrate that the VR-based electric motor control simulation is both feasible and effective for vocational education. The medium successfully bridges theoretical understanding with hands-on skills, supporting previous studies that highlight VR's capacity to improve learning motivation and procedural performance [6], [7].

When compared with the findings of Wu et al. [26], who reported that VR-assisted training enhances psychomotor skills in mechanical education, the present study further integrates safety behavior training—an aspect rarely addressed in earlier works. Similarly, Li and Wang [27] emphasized the importance of ergonomic considerations in VR design, showing that learners trained with ergonomically optimized VR systems demonstrate higher safety compliance and lower fatigue levels. The integration of ergonomic and safety elements in this study aligns with such recommendations, ensuring that students not only learn technical accuracy but also adopt safe postures and handling practices.

Zhao et al. [28] and Chen and Huang [30] both demonstrated that immersive and game-based VR environments promote sustained engagement. This research extends those insights by embedding contextual safety warnings and procedural feedback within the simulation, creating a form of experiential learning loop that reinforces both skill mastery and risk awareness. In contrast with Ouyang and Chang [29], whose VR system emphasized collaboration and teamwork, this study focuses more on individual procedural competence and safety adherence, addressing the specific needs of electrical installation training.

In addition, the positive student responses corroborate earlier findings by Montebello and Camilleri [21] and Curcio et al. [22], who confirmed that realistic immersion and interactivity are key factors driving learner satisfaction. The VR environment designed in this study uses spatial audio and tactile feedback to enhance realism, contributing to higher engagement and lower cognitive overload during simulation-based learning [19].

From a pedagogical perspective, the study supports the principles of constructivist learning theory, in which learners actively construct understanding through direct interaction with virtual objects [24]. It also aligns with experiential learning theory, emphasizing iterative learning through doing, reflecting, and applying [12]. Therefore, the contribution of this research is twofold:
(1) it provides a theoretical model for integrating ergonomics and safety into VR-based vocational education; and
(2) it delivers a practical solution that enables schools with limited facilities to implement advanced, safe, and scalable digital training environments.

These outcomes reinforce the growing consensus in recent VR pedagogy research (e.g., [1], [2], [9], [20]) that immersive technology, when well-designed, can effectively enhance both cognitive and behavioral learning outcomes. This supports the vision of transforming vocational education through Industry 4.0-based digital learning ecosystems.

5 Conclusion

This study developed and evaluated a Virtual Reality (VR)-based electric motor control simulation to support vocational high school learning. The developed VR simulation achieved feasibility scores of 68.53% (media experts) and 79.58% (material experts), categorized as feasible, with reliability coefficients above 0.75. This indicates that the media is valid and reliable as instructional support. Student trials showed significant improvement between pre-test and post-test results, with N-gain values in the medium category, confirming that the VR simulation effectively enhances competency in electric motor installation. Unlike previous VR studies that focus mainly on cognitive outcomes, this research integrates pedagogical, ergonomic, and occupational safety aspects, providing a comprehensive model for vocational training. The study extends VR pedagogy by demonstrating that immersive simulations can be designed not only for conceptual learning but also for skill-based and safety-oriented vocational education. The VR simulation offers a cost-efficient and scalable solution for vocational schools facing limitations in laboratory facilities and equipment, enabling students to practice safely and effectively before entering real workshops. In conclusion, the VR-based simulation can serve as both a pre-practical training tool and an innovative pedagogical model for vocational education. Future research is recommended to expand the simulation with more complex motor control systems (e.g., star-delta, PLC-based control) and to evaluate long-term skill retention through extended trials resources.

6 Acknowledgment

The authors would like to express their sincere appreciation to the reviewers of Jurnal Edukasi Elektro for their insightful comments and constructive suggestions, which have significantly improved the quality of this article. Gratitude is also extended to the Department of Electrical Engineering Education, Universitas Negeri Yogyakarta, for providing institutional and technical support throughout the research process. The authors also thank the participating vocational high schools (SMKN 1 Cihampelas and SMK Cendekia Batujajar) for their collaboration and enthusiasm in implementing the VR-based learning trials.

7 References

[1] Li, X., & Zhou, Y. (2021). Integrating VR and AR technologies for vocational skills assessment. Journal of Vocational Education and Training, 73(6), 963–981. https://doi.org/10.1080/13636820.2020.1825607
[2] Monteiro, P., & Rodrigues, J. (2020). Integrating VR in technical education: Pedagogical challenges and benefits. Education and Information Technologies, 25(5), 4273–4292. https://doi.org/10.1007/s10639-020-10183-2
[3] Burdea, G. C. (2003). Virtual reality technology (2nd ed.). John Wiley & Sons.
[4] Curcio, I. D. D., Dipace, A., & Norlund, A. (2016). Virtual realities and education. Research on Education and Media, 8(2), 60–68. https://doi.org/10.1515/rem-2016-0019
[5] Fernandez, M. (2017). Augmented virtual reality: How to improve education systems. Higher Learning Research Communications, 7(1), 1–15. https://eric.ed.gov/?id=EJ1150087
[6] Wu, C., Chen, S., & Lin, M. (2020). Virtual reality-assisted vocational training: A systematic review. Educational Technology Research and Development, 68(6), 3355–3378. https://doi.org/10.1007/s11423-020-09824-2
[7] Zhao, Y., Tan, J., & Zhang, L. (2024). Immersive VR for technical skills training in vocational education. Computers & Education, 207, 104870. https://doi.org/10.1016/j.compedu.2024.104870
[8] Chen, X., & Huang, Y. (2021). Game-based virtual simulation for electrical engineering education. International Journal of Engineering Education, 37(5), 1253–1262.
[9] Li, H., & Wang, J. (2023). Ergonomic-based VR learning design for industrial safety training. Education and Information Technologies, 28(4), 5121–5142. https://doi.org/10.1007/s10639-023-11847-8
[10] Prastawa, H., Mahachandra, M., & Waly, G. Z. (2023). Occupational safety and health risk assessment in an electronic manufacturing company in Indonesia. E3S Web of Conferences, 448, 01014. https://doi.org/10.1051/e3sconf/202344801014
[11] Lin, J., & Cheng, Y. (2023). Enhancing cognitive engagement in VR-based vocational training. British Journal of Educational Technology, 54(2), 480–497. https://doi.org/10.1111/bjet.13272
[12] Kolb, D. A. (2015). Experiential learning: Experience as the source of learning and development (2nd ed.). Pearson Education.
[13] Ismara, K. I., & Prianto, E. (2017). How to create safe, healthy, and comfortable vocational laboratories. UNY Press.
[14] Aleksandrov, E. P. (2014). Use of audiovisual texts in the university education process. Universal Journal of Educational Research, 2(3), 252–255. https://doi.org/10.13189/ujer.2014.020308
[15] Montebello, M., & Camilleri, V. (2018). Employing virtual reality in academia. International Journal of Information and Education Technology, 8(10), 736–741. https://doi.org/10.18178/ijiet.2018.8.10.1131
[16] Akrim, M. (2018). Media learning in digital era. Proceedings of AMCA 2018, 458–460. https://doi.org/10.2991/amca-18.2018.127
[17] Djouab, R., & Bari, M. (2016). An ISO 9126 based quality model for the e-learning systems. International Journal of Information and Education Technology, 6(5), 370–375. https://doi.org/10.7763/ijiet.2016.v6.716
[18] Burdea, G. C., & Coiffet, P. (2003). Virtual reality technology (2nd ed.). John Wiley & Sons.
[19] Sun, H. (2023). Enhancing higher education English learning through VR and game-based approaches using the fuzzy deep model. Computer-Aided Design and Applications, 20(S14), 231–248. https://doi.org/10.14733/cadaps.2023.S14.231-248
[20] Nasrullah, M., & Rahim, F. (2024). Development of VR-based learning for automotive training. Journal of Technical Education and Training, 16(2), 150–166. https://doi.org/10.30880/jtet.2024.16.02.010

[21] Montebello, M., & Camilleri, V. (2018). Employing virtual reality in academia. International Journal of Information and Education Technology, 8(10), 736–741. https://doi.org/10.18178/ijiet.2018.8.10.1131
[22] Curcio, I. D. D., Dipace, A., & Norlund, A. (2016). Virtual realities and education. Research on Education and Media, 8(2), 60–68. https://doi.org/10.1515/rem-2016-0019
[23] Li, M., & Zhang, J. (2025). Simulation-based learning effectiveness in electrical engineering education: A meta-analysis. IEEE Transactions on Education, 68(2), 155–166. https://doi.org/10.1109/TE.2025.3354781
[24] Ouyang, F., & Chang, Y. (2022). Pedagogical design in immersive VR for engineering education. Interactive Learning Environments, 30(6), 1101–1118. https://doi.org/10.1080/10494820.2020.1821718
[25] Fernandez, M. (2017). Augmented virtual reality: How to improve education systems. Higher Learning Research Communications, 7(1), 1–15. https://eric.ed.gov/?id=EJ1150087
[26] Wu, C., Chen, S., & Lin, M. (2020). Virtual reality-assisted vocational training: A systematic review. Educational Technology Research and Development, 68(6), 3355–3378. https://doi.org/10.1007/s11423-020-09824-2
[27] Li, H., & Wang, J. (2023). Ergonomic-based VR learning design for industrial safety training. Education and Information Technologies, 28(4), 5121–5142. https://doi.org/10.1007/s10639-023-11847-8
[28] Zhao, Y., Tan, J., & Zhang, L. (2024). Immersive VR for technical skills training in vocational education. Computers & Education, 207, 104870. https://doi.org/10.1016/j.compedu.2024.104870
[29] Ouyang, F., & Chang, Y. (2022). Pedagogical design in immersive VR for engineering education. Interactive Learning Environments, 30(6), 1101–1118. https://doi.org/10.1080/10494820.2020.1821718
[30] Chen, X., & Huang, Y. (2021). Game-based virtual simulation for electrical engineering education. International Journal of Engineering Education, 37(5), 1253–1262

8 Authors Biography

Rizal Muhammad Ramdhan is a Master Student of Electrical Engineering Education Department, Faculty of Engineering, Universitas Negeri Yogyakarta (email: rizalmuhammad.2022@student.uny.ac.id).

Ketut Ima Ismara is a Lecturer Student of Electrical Engineering Education Department, Faculty of Engineering, Universitas Negeri Yogyakarta (email: imaismara@uny.ac.id).

Agus Ramelan is a Doctoral Student of Department of Electrical Engineering, Universiti Malaya, Kuala Lumpur, Malaysia (email: 23107537@siswa.um.edu.my).