International Journal of Engineering Innovation and Dissemination
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Journal Homepage: http://ijeid.virtualrealia.org/

Integrating Simulation-Based Instruction in Industrial Motor Control: Development and Evaluation of a CADe-SIMU-Enhanced Laboratory Manual

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ARTICLE INFO

Article history:

Received 26 July 2025
Revised 13 Aug 2025
Accepted 21 Sept 2025
Available online 02 Oct 2025

Keywords:

CADe-SIMU;
Industrial Motor Control;
Simulation-Based Learning;
Electrical Technology Education;
Experiential Learning;
ADDIE Model;
Hybrid Training

ABSTRACT

This developmental research designed, developed, and pilot-tested an instructional laboratory manual for Industrial Motor Control that integrates CADe-SIMU simulation software. Grounded in Kolb's experiential learning cycle, Kühn's simulation model, and structured through the ADDIE framework, the manual was organized into 23 sequenced skill-based activities, progressing from basic circuit design to advanced motor control applications. Each activity combined theoretical foundations, safety guidelines, simulation walkthroughs, and performance rubrics to support blended and face-to-face instruction. The manual was evaluated by 30 purposively selected respondents—students, technical faculty, and curriculum specialists—using an adapted WVSU-ODI-SOI evaluation tool. Results showed high acceptability across six dimensions: material content (M = 3.68), instructional quality (M = 3.72), technical quality (M = 3.74), presentation and organization (M = 3.79), accuracy and up-to-datedness (M = 3.73), and assessment alignment (M = 3.81). Feedback emphasized the manual's effectiveness in bridging gaps between theory and practice, while recommending improvements in rubric refinement, enhanced visual presentation, and compatibility with additional simulation platforms. Overall, the study affirms the manual's pedagogical soundness, technical validity, and contextual relevance, offering a scalable and outcomes-based solution to address laboratory constraints in industrial motor control education.

1 INTRODUCTION

The rapid advancement of industrial automation has intensified the demand for professionals skilled in the installation, design, and maintenance of complex control systems. Industrial motor control has become a core competency in electrical and industrial engineering education (Bauer, Heitzmann, & Fischer, 2022). Traditional methods of teaching motor control, however, continue to rely heavily on physical equipment and direct laboratory practice. While these methods are valuable, they present several challenges, including high equipment costs, limited availability, risk of equipment damage, and inadequate laboratory resources, all of which restrict opportunities for students to acquire practical experience (Feng & Rong, 2005; Rahman, 2014).

In response to these limitations, simulation-based learning has emerged as an effective alternative. Software such as CADe-SIMU provides a virtual environment where students can repeatedly practice motor control operations in a safe, low-cost, and accessible manner. Simulation enhances both conceptual understanding and technical competence while minimizing

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https://doi.org/10.69481/POXM9005

risk, and it is particularly effective when paired with structured instructional design and activity-based learning strategies (Camperos, Jaramillo, & Castrillón, 2023; Herrera Roldan & Cruz, 2020).

In the Philippine context, engineering institutions continue to struggle with insufficient laboratory facilities and financial support for technical education. A focus group conducted among fourth-year electrical technology students at West Visayas State University–Pototan Campus revealed that while 80% could perform motor control operations with a diagram, only 8% could perform them independently, and 70% lacked confidence in applying these skills. These findings illustrate a persistent gap between theoretical knowledge and practical competence, highlighting the urgent need for more accessible, structured, and pedagogically sound learning resources (Robles et al., 2021).

To address this gap, the present study developed a novel instructional manual that integrates CADe-SIMU simulation software with Kolb's Experiential Learning Cycle and Kühn's Simulation Cycle. Designed through the ADDIE instructional design framework, the manual consists of 23 sequenced activities that progress from simple circuit tasks to advanced motor control applications. Each activity blends theoretical grounding, safety protocols, simulation exercises, and performance assessments, providing both simulated and hands-on learning opportunities (Čubela et al, 2023).

This study contributes to engineering education by offering a low-cost, scalable, and outcomes-based instructional resource that strengthens student engagement, supports active learning, and bridges the divide between classroom instruction and laboratory practice. It also responds to calls for integrating experiential learning and simulation into technical curricula to promote deeper understanding, learner confidence, and industry-relevant skills (Salunke & Vijayalakshmi, 2016; Müller, Menn, & Seliger, 2017).

While existing studies highlight the benefits of simulation-based instruction (Rahman, 2014; Salunke & Vijayalakshmi, 2016; Bauer, Heitzmann, & Fischer, 2022; Camperos, Jaramillo, & Castrillón, 2023; Herrera Roldan & Cruz, 2020; Müller, Menn, & Seliger, 2017), most focus on either the software itself or the underlying pedagogical models. There remains limited empirical evidence on the integration of simulation software, experiential learning cycles, and systematic instructional design into a single, outcomes-based manual for industrial motor control—particularly in resource-constrained settings such as Philippine higher education institutions. Therefore, this study aims to design, develop, and evaluate the acceptability of a hybrid instructional laboratory manual for Industrial Motor Control by integrating CADe-SIMU simulation software. The manual is intended to enhance the practical competencies of electrical and industrial engineering students through a structured blend of simulation-based and hands-on activities.

2 Methodology

This study employed a developmental research design, which emphasizes the systematic creation, validation, and evaluation of instructional products aligned with curriculum objectives and learner needs (Richey & Klein, 2007). The ADDIE instructional design framework, consisting of Analysis, Design, Development, Implementation, and Evaluation, was adopted as the overarching process for developing and testing the CADe-SIMU–enhanced instructional manual in Industrial Motor Control.

2.1 Analysis Phase

The analysis phase focused on identifying the competency gaps of electrical technology students at West Visayas State University–Pototan Campus. Data were gathered through focus group discussions and classroom observations, which revealed that students demonstrated limited confidence and practical proficiency in motor control. This was attributed to the lack of laboratory equipment and insufficient technical resources. Findings from this stage guided the formulation of instructional goals, learning outcomes, and competency benchmarks, particularly emphasizing mastery of circuit logic and troubleshooting protocols that are essential for industry certifications.

2.2 Design Phase

In the design phase, specific learning outcomes were mapped against Bloom's taxonomy and distributed across 23 skill-based activities. These activities followed a progressive structure, beginning with fundamental tasks such as direct-on-line starters and advancing to more complex applications, including reversing motor controls and sequential motor operations. To ensure pedagogical soundness, each activity was aligned with Kolb's experiential learning cycle and Kühn's simulation cycle, thereby guiding learners through concrete experiences, reflective observation, abstract conceptualization, and active experimentation. Assessment tools, including performance rubrics and checklists, were also designed at this stage to measure procedural accuracy, logical reasoning, and alignment with learning outcomes.

2.3 Development Phase

The development phase involved producing the instructional materials. Each activity was supplemented with CADe-SIMU tutorial walkthroughs, safety guidelines and warnings, theoretical references, circuit diagrams exported from CADe-SIMU, step-by-step instructions, and performance rubrics. To validate content accuracy, technical rigor, and alignment with curriculum standards, the draft manual was reviewed by two subject matter experts: a registered electrical engineer and a senior faculty member specializing in technical education. Their inputs were integrated into the final version to strengthen both technical validity and instructional quality.

2.4 Implementation Phase

The implementation phase consisted of pilot testing the manual with a purposive sample of 30 participants, including 22 electrical technology students, 5 technical staff members, and 3 curriculum experts. Pilot sessions were conducted in classroom and laboratory settings, combining simulation-based practice on computers with parallel hands-on tasks using available motor control trainers. To ensure accessibility, the manual was distributed in both print and electronic formats, making it adaptable to varying instructional modalities.

2.5 Evaluation Phase

The evaluation phase utilized an adapted version of the WVSU-ODI-SOI evaluation instrument. This tool measured six key dimensions: material content, instructional quality, technical quality, presentation and organization, accuracy and up-to-datedness, and assessment alignment. Respondents rated each dimension on a four-point Likert scale, ranging from 1 (Barely Acceptable) to 4 (Very Acceptable). Quantitative data were analyzed through descriptive statistics, with mean scores computed for each dimension. In addition, qualitative feedback provided by respondents was thematically analyzed to identify strengths and areas for improvement. Finally, to ensure academic integrity, the manual was subjected to Turnitin checks, confirming acceptable similarity indices and verifying 0% AI-generated content.

3 Results and Discussion

Table 1 shows the results of the evaluation of the instructional manual against Material Content. The results indicate a general high level of acceptability in all the tested measures, with a computed area mean of 3.68, which is marked as "Very Acceptable." This indicates that the manual content is appropriate for the target learners, aligns with the specified course learning outcomes, and supports higher-order cognitive skills development, such as problem-solving and critical thinking. In addition, it has been demonstrated to be free from cultural, gender, or ideological bias and supports development of desirable values. The manual also includes sufficient safety guidelines and covers key concepts and principles related to industrial motor control. The findings suggest that the material content aligns with the course learning objectives and aligns with educational standards.

Table 1. Acceptability of the Instructional Manual in Terms of Material Content

Criteria	Mean Score	Interpretation
Appropriateness to student level	3.60	Very Acceptable
Alignment with course learning objectives	3.40	Very Acceptable
Development of higher-order cognitive skills	3.40	Very Acceptable
Freedom from bias (ideological, cultural, etc.)	3.40	Very Acceptable
Promotion of desirable values and traits	3.60	Very Acceptable
Student engagement through task design	3.60	Very Acceptable
Safety warnings and health advisories	3.40	Very Acceptable
Coverage of essential principles and concepts	3.60	Very Acceptable
Area Mean	**3.68**	**Very Acceptable**

Table 2 summarizes the outcome of the evaluation of the instructional quality of the laboratory manual prepared. The mean average score of 3.72 as "Very Acceptable" indicates that the instructional strategies incorporated in the manual are pedagogically sound and facilitative for learners. Evaluators agreed that the use of graphics and color was acceptable and instructional and not cosmetic. Further, the manual proved to be effective in promoting student creativity through activity-based activities. Feedback mechanisms were properly integrated, enabling learners to reflect and correct their understanding. Lastly, the content was presented at an appropriate pace and sequence, which ensured smooth flow throughout learning activities. The results confirm that the instructional design promotes active learning and overall teaching-learning process.

Table 2. Acceptability in Terms of Instructional Quality

Criteria	Mean Score	Interpretation
Use of graphics and color for instructional purposes	3.60	Very Acceptable
Stimulation of learner creativity	4.00	Very Acceptable
Provision of learner feedback	3.60	Very Acceptable
Appropriate pacing and sequencing	3.60	Very Acceptable
Area Mean	**3.72**	**Very Acceptable**

Table 3 portrays the technical quality assessment of instruction in the form of Technical Quality of the instruction manual with an area mean rating of 3.74, or "Very Acceptable." This implies that the manual was presented well in both visual and text presentation. Specifically, the font size, type, and line spacing were found to be readable and suitable for the intended learners. The images used across the manual were of high resolution, not pixelated, and unambiguously aligned with instruction content. Additionally, the visuals were relevant, kept learners engaged, and did not detract from learning objectives. These results affirm that the technical features of the manual greatly contributed to clarity, usability, and learner focus—key features of effective instructional materials in engineering education.

Table 3. Acceptability in Terms of Technical Quality

Criteria	Mean Score	Interpretation
Readability of text (font, size, spacing)	3.80	Very Acceptable
Quality of visuals and resolution	4.00	Very Acceptable
Clarity of images supporting content	3.60	Very Acceptable
Visuals sustain interest without distraction	3.40	Very Acceptable
Area Mean	**3.74**	**Very Acceptable**

Table 4 summarizes the findings on Presentation and Organization of the instructional manual. The 3.79 average score, rated as "Very Acceptable," signifies that the manual is properly organized and pedagogically clear. The activities, according to the participants, not only captivated them but also were clearly and understandably presented. The content also possessed a rational flow of ideas, hence making learners follow tasks with little confusion. The use of vocabulary was also appropriate to the learners' academic level, while the sentence length and structure were appropriate to their understanding capacity. The variation in sentence and paragraph structure helped to sustain interest and improve the clarity of content. From the findings, the manual is well-organized to facilitate both learning progression and cognitive engagement.

Table 4. Acceptability in Terms of Presentation and Organization

Criteria	Mean Score	Interpretation
Engaging, interesting, and understandable activities	4.00	Very Acceptable
Logical and smooth flow of ideas	3.80	Very Acceptable
Appropriate vocabulary for learners' level	3.60	Very Acceptable
Sentence length appropriate for comprehension	3.80	Very Acceptable
Variety in sentence and paragraph structure	3.80	Very Acceptable
Area Mean	**3.79**	**Very Acceptable**

Table 5 gives a grading of the instructional manual for the accuracy and currency of the information, with a mean score of 3.73, which is described as "Very Acceptable." The score indicates that the information, concepts, and technical data presented in the manual are generally accurate and current, complying with established standards and industry practices. The grading of maps, graphs, and illustrations suggested that they were generally correct and usable, although some minor improvement was suggested. The manual was also generally free of grammatical, computational, and typographical errors, although some reviewers suggested that better proofreading was necessary. The results confirm the credibility of the instructional content but indicate the necessity for continuous revision and meticulous editing to guarantee its academic and professional quality.

Table 5. Acceptability in Terms of Accuracy and Up-To-Datedness

Criteria	Mean Score	Interpretation
Accuracy and currency of facts	3.60	Very Acceptable
Accuracy of maps, graphs, and images	3.40	Very Acceptable
Freedom from grammatical/computational errors	3.40	Very Acceptable
Absence of typographical or labeling errors	3.40	Very Acceptable
Area Mean	**3.73**	**Very Acceptable**

Table 6 presents the rating results in relation to the Assessment component of the instructional manual. The 3.81 area mean score is the highest for the areas assessed and is interpreted as "Very Acceptable." This score measure reveals that the manual has well-designed assessment instruments that are appropriate, valid, and clearly aligned to the instructional objectives. The assessments comprise a broad range of strategies, including skills rubrics, simulations, and practical applications, that facilitate differentiated measure of student performance. Furthermore, the manual has been seen to cite credible sources, thereby enhancing the academic validity of the activities. These findings illustrate that the manual effectively integrates assessment practices that measure both theoretical knowledge and applied skills, and as such, the manual is an effective tool for outcome-based education.

Table 6. Acceptability in Terms of Assessment Alignment

Criteria	Mean Score	Interpretation
Provision of appropriate assessment tools	4.00	Very Acceptable
Alignment of assessments with instructional objectives	3.80	Very Acceptable
Variety in assessment strategies	3.60	Very Acceptable
Use of appropriate and valid references	3.80	Very Acceptable
Area Mean	**3.81**	**Very Acceptable**

Across all six evaluation domains, the manual was rated uniformly 'Very Acceptable,' a testament to its excellent quality of instruction, alignment with course goals, and appropriateness for instruction by simulation.

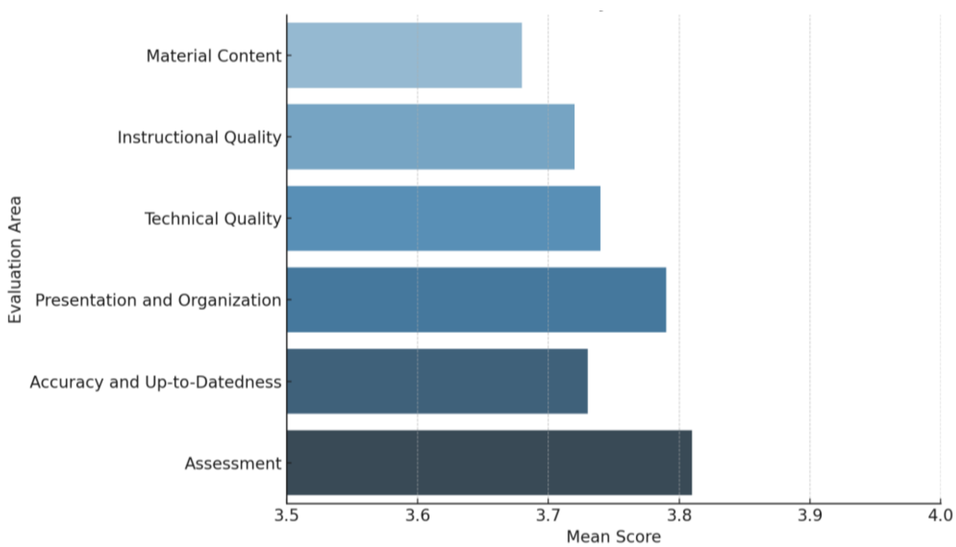

Figure 1. Mean Scores by Evaluation Area

Figure 1 presents a graphic representation of average scores on six dimensions of evaluation obtained from respondents' feedback. It is evident that all the criteria are within the range of "Very Acceptable" since the average scores are more than 3.65 on a scale of 4. The highest rating was under the Assessment category (M = 3.81), showing a good alignment of learning outcomes and performance tasks. This was closely followed by Presentation and Organization (M = 3.79) and Technical Quality (M = 3.75), reflecting well-organized material and the good visual coordination of diagrams produced by CADe-SIMU.

Simultaneously, the dimensions of Accuracy and Up-to-Datedness (M = 3.72) and Instructional Quality (M = 3.74) were also positively assessed, indicating that the content is both contemporary and pedagogically effective. Material Content, despite being the lowest rated among the six criteria (M = 3.68), remained comfortably within the “Very Acceptable” category, reflecting the manual’s thoroughness and applicability. Collectively, the data presented in the chart highlights the uniformity of the manual's instructional value across all assessed areas. The manual shown in table 7 was rated Very Acceptable across all six domains, with assessment alignment receiving the highest score (M = 3.81). This indicates strong validity of the assessment tools and their consistency with instructional objectives. Material content scored the lowest (M = 3.68), suggesting a need for continuous enrichment of instructional content and diagrams.

Table 7. Acceptability of the Instructional Manual (n = 30)

Evaluation Dimension	Mean Score	Interpretation
Material Content	3.68	Very Acceptable
Instructional Quality	3.72	Very Acceptable
Technical Quality	3.74	Very Acceptable
Presentation & Organization	3.79	Very Acceptable
Accuracy & Up-to-Datedness	3.73	Very Acceptable
Assessment Alignment	3.81	Very Acceptable
Overall Mean	**3.75**	**Very Acceptable**

Conclusions

This developmental research successfully designed, developed, and evaluated a CADe-SIMU–enhanced instructional manual for Industrial Motor Control. In response to RQ1, the manual was developed through the ADDIE framework and grounded in Kolb’s experiential learning cycle and Kühn’s simulation model. It contained 23 sequenced activities that combined theoretical grounding, simulation walkthroughs, safety guidelines, and performance rubrics, offering both simulation-based and hands-on learning pathways.

In addressing RQ2, CADe-SIMU was effectively integrated into laboratory activities by providing safe, repeatable, and interactive environments for learning motor control circuits. Students were able to simulate operations before actual implementation, thereby reducing risks of equipment damage and building confidence in real-world applications.

Findings for RQ3 revealed that the manual achieved a high level of acceptability across all six dimensions of evaluation. With mean scores ranging from 3.68 to 3.81, it was rated Very Acceptable by students, faculty, and curriculum experts. The highest score in assessment alignment confirmed the manual’s strength in ensuring outcomes-based evaluation, while material content, though still very acceptable, highlighted the need for further enrichment and continuous updating.

Overall, the study demonstrated that the developed manual is pedagogically sound, technically valid, and contextually relevant. It bridges the gap between theory and practice in industrial motor control education and offers a scalable solution to address laboratory constraints in Philippine higher education.

A note on study limitations, such as sample size, short-term evaluation, and a single-software focus, has been added to provide a more complete perspective on the research.

Recommendations

Based on the results of this study, the following recommendations are proposed:

- Rubric Refinement – Revise performance rubrics to ensure clearer descriptors, alignment with Bloom’s taxonomy, and consistency in competency-based grading, which strengthens the assessment rubric refinement recommendation.

- Visual Enhancement – Improve diagrams with labeling and color coding to support visual learners and minimize confusion in circuit interpretation.
- Software Compatibility – Expand the manual's adaptability by integrating additional simulation platforms such as PCSIMU, Siemens Logo, and TIA Portal for broader industry alignment, addressing the suggestion for multi-software compatibility.
- Institutional Adoption – Encourage higher education institutions to formally adopt the manual into their electrical technology curricula, accompanied by faculty orientation and training for consistent implementation.
- Continuous Updating – Establish mechanisms for regular feedback from teachers and students to update content, correct errors, and integrate emerging industry practices.
- Further Research – Conduct longitudinal studies to measure the manual's long-term impact on student learning outcomes, employability, and workplace readiness in industrial motor control fields, addressing the recommendation for long-term effectiveness studies.

Funding

Unavailable.

Credit Authorship Contribution Statement

Ramos, J.R.: Ramos was responsible for the design and creation of the simulation-based instruction module using the CADe-SIMU software. He developed the practical exercises and integrated them into the laboratory manual, ensuring the technical accuracy and functionality of the simulation component. He also played a key role in data collection related to the technical performance of the simulations.

Gabawa, L.M.: Gabawa was responsible for the collection and organization of the data from the study's evaluation. She performed the analysis to assess the effectiveness of the CADe-SIMU-enhanced laboratory manual. She also took the lead in writing the manuscript, including the literature review, methodology, results, and discussion sections.

Ethical Statement

The authors confirm that this research was conducted in full compliance with the ethical standards set by the International Journal of Engineering Innovation and Dissemination (IJEID). All participants provided informed consent prior to their involvement, and approval was obtained from the relevant educational authorities. The study adhered to principles of transparency, confidentiality, and academic integrity, with all data reported honestly and all sources properly cited.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

The authors declare that the data supporting the findings of this study will be made available upon reasonable request.

AI Usage Disclosure

This manuscript utilized Grammarly and Gemini AI for language refinement and editorial suggestions. Grammarly was used to enhance grammar, clarity, and readability, while Gemini AI provided support in rephrasing and improving sentence structure. These tools were not used for generating original content, conducting data analysis, or interpreting research findings. The authors retain full responsibility for the scholarly integrity, originality, and intellectual contribution of this work.

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