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Design and Implementation of a Digital Project-Based Learning Framework for Electrical Circuit Laboratory Instruction

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Abstract

Electrical circuit instruction in aviation vocational education faces persistent challenges, including limited laboratory infrastructure, conventional teaching methods, and low student engagement. This study developed an instructional module based on Project-Based Learning (PjBL), integrated with a Learning Management System (LMS) and mockup trainers, using the ADDIE model through its Analysis, Design, and Development phases. The module comprises a semester learning plan (RPS), LMS-based digital content, practical mockups, and rubric-based project assessments. Expert validation confirmed the module's technical feasibility, media quality, and pedagogical relevance, with scores of 83% from the electrical engineering expert, 80% from the media expert, and 85% from the instructional technology expert. These results affirm the module's readiness for implementation in vocational education. The study underscores the value of contextual digital instructional design in bridging theory and practice, enhancing student motivation, and fostering industry-relevant competencies.

Keywords: Project-Based Learning, LMS, Mockup Trainer, Electrical Circuits, Vocational Education

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INTRODUCTION

Electrical circuit instruction serves as the fundamental cornerstone of vocational training within the Diploma 3 Air Navigation Engineering program. This curriculum is meticulously designed to equip students with the essential theoretical and technical knowledge required to navigate the complexities of aviation-related electrical systems. In the high-stakes environment of air navigation, a profound understanding of circuitry is not merely an academic requirement but a critical safety imperative. Students are expected to master intricate concepts ranging from basic Ohm's law applications to complex signal processing circuits and demonstrate the ability to apply this knowledge in real-world maintenance and diagnostic scenarios[1].

The current pedagogical landscape faces significant hurdles that impede effective knowledge transfer. Delivery is often constrained by a persistent reliance on lecture-heavy, teacher-centered methods that fail to stimulate cognitive curiosity. This issue is exacerbated by limited laboratory infrastructure, where a lack of modern equipment prevents students from engaging in meaningful hands-on experimentation. As noted by Coetzee et al. (2022), understanding basic electrical circuit concepts remains a formidable challenge for engineering students, particularly in introductory phases[2]. These systemic limitations contribute to a widening gap between theoretical comprehension and the practical competence required in the field.

Recent educational scholarship strongly advocates for the transition toward active learning models to bridge this competency gap. Project-Based Learning (PjBL) has emerged as a particularly transformative framework, demonstrating a unique effectiveness in enhancing student engagement and fostering critical thinking. By immersing students in experiential learning, PjBL encourages the development of vital 21st-century skills such as complex problem-solving and self-directed inquiry[3]. This approach moves beyond rote memorization, challenging students to synthesize their knowledge to create tangible solutions, thereby aligning academic outcomes with the rigorous demands of technical professions.

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[1] Dr. Shiv Dayal Dewra, 'Innovative Approaches in Modern Education: Bridging Theory and Practice', *INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT*, 09.05 (2025), doi:10.55041/ijsrem46731.

[2] Weihan Sun and others, 'An Analytical Review of Construction and Demolition Waste Management and Quantification Methods Using a Science Mapping Approach', in *Recycling*, no. 3, preprint, 2025, X, doi:10.3390/recycling10030115.

[3] Josué Guevara-Reyes and others, 'Implementation of Personalized Frameworks in Computational Thinking Development: Implications for Teaching in Software Engineering', in *Frontiers in Education*, preprint, 2025, X, doi:10.3389/feduc.2025.1584040; Wahyu Kholis Prihantoro, 'Implementasi Deep Learning Untuk Meningkatkan Karakter Religius Dalam Pembelajaran Pendidikan Agama Islam', *La-Tahzan*, 17.2 (2025); Noora Bosch, Tellervo Härkki, and Pirita Seitamaa-Hakkarainen, 'Teachers as Reflective Learning Experience Designers: Bringing Design Thinking into School-Based Design and Maker Education', *International Journal of Child-Computer Interaction*, 43 (2025), doi:10.1016/j.ijcci.2024.100695.

Beyond individual cognitive gains, the implementation of PjBL strengthens the "soft skills" that are indispensable in the modern aviation industry. Research indicates that project-oriented curricula significantly improve collaboration, communication, and creative innovation among students[4]. In a field where teamwork and precise communication are essential for operational safety, these competencies are as valuable as technical mastery. Despite these clear pedagogical advantages, the adoption of PjBL in vocational higher education specifically within air navigation programs remains disappointingly sparse, leaving a void in the modernization of technical training.

The slow adoption of PjBL is largely attributed to a lack of structured, industry-relevant instructional resources. Many programs currently operate without project-based syllabi, interactive digital modules, or physical mockup trainers that accurately reflect the scenarios engineers face on the job. Without these tools, instructors find it difficult to transition from traditional lecturing to a facilitative role. This resource scarcity creates a stagnant learning environment where the materials remain largely static and print-based, failing to utilize the potential of digital integration[5].

This disconnect is further intensified by the evolving characteristics of Generation Z learners, who now dominate the vocational education demographic. These "digital natives" exhibit a distinct preference for interactive, flexible, and tech-driven environments accessible through Learning Management Systems (LMS)[6]. They thrive on multi-modal content and immediate feedback, which traditional textbooks cannot provide. When instructional delivery ignores these digital preferences, student motivation wanes, and the effectiveness of the foundational electrical courses is compromised, leading to suboptimal learning outcomes and a lack of preparation for a digital-first industry.

[4] Uun Lionar and others, 'Investigating Local Historical Figures: The Implementation of the PjBL Model to Increase Historical Literacy', *Paramita*, 35.1 (2025), doi:10.15294/paramita.v35i1.23411; Zhomart Naushabekov and others, 'Effect of Project-Based Learning on Middle School Students' Conceptual Understanding of Mechanics: A Quasi-Experimental Study', *European Journal of Science and Mathematics Education*, 13.3 (2025), doi:10.30935/scimath/16826; Siti Heni Farisah and Siti Wafiqah, 'Model Pembelajaran PJBL Untuk Meningkatkan Keterampilan Belajar Siswa', *Jurnal Ilmu Pendidikan*, 1.1 (2025).

[5] Fika Rahayu Astuti, Indah Rama Sahara, and Gusmaneli Gusmaneli, 'Pelaksanaan Pembelajaran Berbasis Proyek (PjBL) Dalam Pembelajaran Pendidikan Agama Islam', *Jurnal Bintang Pendidikan Indonesia*, 3.1 (2025); Raras Setyo Retno and others, 'Conceptual Framework Design for STEM-Integrated Project-Based Learning (PjBL-STEM) for Elementary Schools', *Asian Education and Development Studies*, 14.3 (2025), doi:10.1108/AEDS-08-2024-0188.

[6] Uthman Alturki and Ahmed Aldraiweesh, 'Application of Learning Management System (Lms) during the Covid-19 Pandemic: A Sustainable Acceptance Model of the Expansion Technology Approach', *Sustainability (Switzerland)*, 13.19 (2021), doi:10.3390/su131910991; Vaughn Malcolm Bradley, 'Learning Management System (LMS) Use with Online Instruction', *International Journal of Technology in Education*, 4.1 (2020), doi:10.46328/ijte.36; Sibongile Simelane-Mnisi, 'Effectiveness of LMS Digital Tools Used by the Academics to Foster Students' Engagement', *Education Sciences*, 13.10 (2023), doi:10.3390/educsci13100980.

To address these multifaceted pedagogical and technological gaps, this study introduces a comprehensive PjBL module that integrates LMS delivery with physical mockup trainers. This holistic intervention includes a project-oriented Semester Learning Plan (RPS), high-quality digital content, and rubric-based assessments designed to evaluate both process and product. By contextualizing the design to overcome laboratory constraints and aligning it with the digital habits of Generation Z, the module fosters an applied and industry-relevant learning experience. Ultimately, this research seeks to bridge the chasm between theory and practice, offering a scalable model for digital transformation that ensures aviation graduates are both technically proficient and professionally adaptable.

RESEARCH METHODS

This study employed a Research and Development (R&D) approach to produce a contextualized instructional module for electrical circuit learning in vocational education. The development process was guided by the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation[7]. However, the scope of this research was deliberately limited to the first three stages Analysis, Design, and Development without proceeding to Implementation and Evaluation. This limitation was set to focus on producing a prototype that is pedagogically valid and ready for future classroom application.

The instructional module developed in this study was designed to address specific learning challenges faced by students in the Diploma 3 Air Navigation Engineering program. These challenges include limited access to laboratory facilities, low student engagement, and the lack of digital learning resources. By concentrating on the development phase, the study aimed to produce a structured and feasible learning package that integrates Project-Based Learning (PjBL) principles with digital delivery through a Learning Management System (LMS) and hands-on mockup trainers.

Expert validation was conducted to assess the quality of the instructional components, including the project-oriented Rencana Pembelajaran Semester (RPS), LMS-based digital modules, mockup trainers, and rubric-based assessment instruments. The PjBL model is designed to promote active learning through engagement in real-world projects[8]. The validation process involved subject matter experts in electrical engineering, instructional media specialists, and instructional design professionals. Their feedback was

[7] Amalia Siti and others, 'RnD & ADDIE IN DESIGNING AND DEVELOP A MOBILE-BASED FOOD ORDERING AND PAYMENT INFORMATION SYSTEM Article Info Abstract', in *Asia Information System Journal*, no. 1 (2024), III; Alturki and Aldraiweesh, 'Application of Learning Management System (Lms) during the Covid-19 Pandemic: A Sustainable Acceptance Model of the Expansion Technology Approach'.

[8] Ilma Almaida Fasa and Kristi Liani Purwanti, 'Pengembangan Media Pembelajaran Berbasis Website Mata Pelajaran Matematika Untuk Siswa Madrasah Ibtidaiyah', *Sekolah Dasar: Kajian Teori Dan Praktik Pendidikan*, 32.1 (2023), doi:10.17977/um009v32i12023p15-24.

used to refine the module and ensure its alignment with vocational learning needs and industry relevance.

Data collection was conducted through multiple techniques to ensure comprehensive input. Observations were carried out to examine the existing instructional conditions and student engagement levels. Interviews with course instructors provided insights into pedagogical constraints and expectations for instructional improvement. Additionally, validation questionnaires were distributed to expert reviewers to evaluate the module's content accuracy, structural coherence, and visual presentation and validation score catagories shown as Figure 1.

Table1. Validation Score Categories

Score Range (%)	Category	Interpretation
85–100	Very Valid	The product is highly appropriate and requires no revision
70–84	Valid	The product is appropriate with minor revisions needed
55–69	Moderately Valid	The product is usable but requires several improvements
40–54	Less Valid	The product is less appropriate and needs major revision
Below 40	Not Valid	The product is not suitable for use

Validation scores were interpreted using a standardized percentage-based classification system to determine the product's level of appropriateness. Scores ranging from 85–100% were categorized as "Very Valid," indicating that the product is highly suitable and requires no revision. A score between 70–84% was deemed "Valid," suggesting minor improvements may be needed. Scores within 55–69% were classified as "Moderately Valid," implying that the product is usable but requires several refinements. A range of 40–54% was considered "Less Valid," indicating substantial revisions are necessary, while scores below 40% were categorized as "Not Valid," signifying that the product is unsuitable for implementation.

The research instruments included observation sheets, interview guides, and a validation questionnaire using a 5-point Likert scale. Validators were also invited to provide qualitative feedback in the form of comments and suggestions for improvement. Data analysis was performed using both quantitative and qualitative methods. Quantitative data were derived from the average scores of each validation aspect, which were then converted into feasibility categories as shown in the table below. Meanwhile, qualitative data from expert feedback were used to revise and refine the instructional module to better align with student needs and instructional goals.

RESULT AND DISCUSSION

The development process resulted in a structured Rencana Pembelajaran Semester (RPS) for the Electrical Circuit course, designed in accordance with the Indonesian

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National Standards for Higher Education (SN-Dikti) and the latest guidelines for curriculum development. The RPS outlines the Graduate Learning Outcomes (CPL), Course Learning Outcomes (CPMK), and sub-CPMKs derived from core topics. These include fundamental concepts such as electrical units and scales, Ohm's Law, Kirchhoff's Laws (KCL and KVL), equivalent circuit methods (Thevenin and Norton), the superposition principle, voltage and current dividers, as well as the application of filters and oscillators. This structure ensures that the course content is both comprehensive and aligned with the technical competencies required in the field of air navigation engineering.

The RPS was designed using a Project-Based Learning (PjBL) approach, integrated with the support of a Learning Management System (LMS). This integration allows the course to move beyond traditional lecture-based delivery by providing students with opportunities to engage in real-world projects that reflect the demands of the aviation industry. Through this approach, students are encouraged to apply theoretical knowledge in practical contexts, fostering deeper understanding and skill development (Palmer & Hall, 2011). The LMS serves as a platform for accessing digital modules, submitting project tasks, and receiving feedback, thereby enhancing flexibility and interactivity in the learning process.

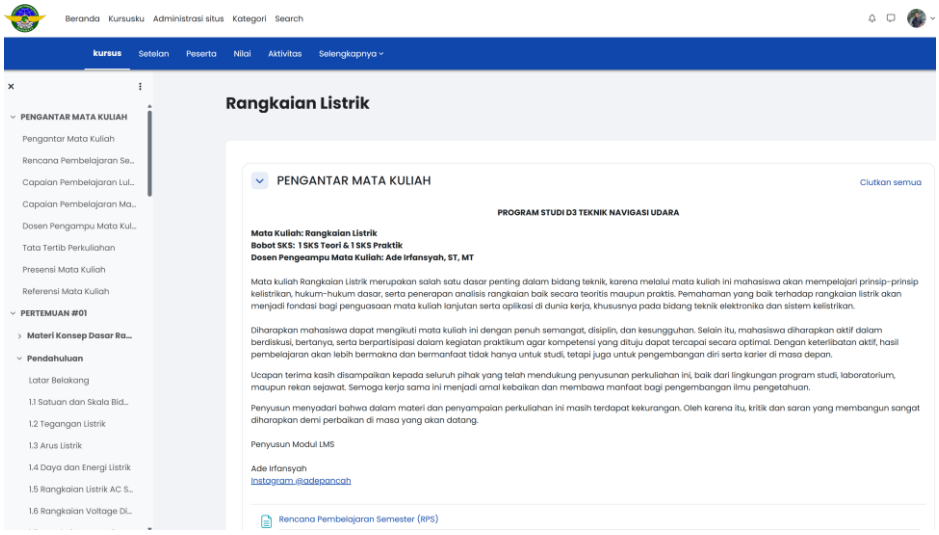


Figure 1. Course Homepage: Electrical Circuits

The LMS interface for the Electrical Circuits course in the Diploma 3 Air Navigation Engineering program presents a structured and pedagogically coherent layout that supports project-based learning. Figure 1 displays the structured layout of the Electrical Circuits course page within the Learning Management System, illustrating the integration of theoretical modules, learning outcomes, and weekly project-based topics tailored for vocational engineering education. The sidebar navigation includes sequential learning components, ranging from course introduction and learning outcomes to weekly topics such as Ohm's Law, Kirchhoff's Laws, and three-phase circuits, reflecting a progressive scaffolding of electrical theory and application. The introductory section outlines course credits, instructor identity, and learning objectives, emphasizing the integration of

theoretical analysis and practical design, which aligns with vocational education standards and digital learning environments.

This strategy is consistent with findings from previous studies, which emphasize the effectiveness of PjBL in improving critical thinking, teamwork, and problem-solving skills among engineering students. PjBL has proven to be more effective in fostering collaboration and problem-solving skills than conventional methods[9]. Both highlight that PjBL not only enhances academic performance but also prepares students for collaborative and creative work environments[10]. By aligning the instructional design with these pedagogical insights, the developed RPS offers a relevant and adaptive framework for vocational education, particularly in preparing students for the complex challenges of the aviation sector.

In addition to the Rencana Pembelajaran Semester (RPS), a comprehensive learning module was developed to serve as the primary guide for students in mastering both theoretical and practical aspects of electrical circuit concepts. Each chapter in the module follows a structured format that includes learning objectives, contextual background, core theoretical content, formative evaluation through true–false quizzes, and structured assignments. To enhance clarity and relevance, the module is enriched with circuit illustrations, aviation-related application examples, and mini-projects at the end of each chapter. This design ensures that students not only acquire conceptual understanding but also engage in meaningful practice aligned with vocational demands.

A key strength of the module lies in its integration into a Learning Management System (LMS), which offers flexible access to instructional content in various formats. These include digital text, presentation slides, tutorial videos, discussion forums, and interactive quizzes. Such multimodal delivery supports diverse learning styles and enables students to engage with the material both independently and collaboratively. The LMS also facilitates asynchronous learning, allowing students to revisit content and complete tasks at their own pace, which is particularly beneficial in vocational settings with varied schedules and practical workloads.

From a content perspective, the module was deemed consistent with the expected learning outcomes, including Graduate Learning Outcomes (CPL), Course Learning Outcomes (CPMK), and sub-CPMKs. The alignment with vocational curriculum standards was considered appropriate and relevant. The organization and presentation of material were assessed as coherent and well-integrated, although minor revisions were suggested to improve the consistency of chapter sequencing. Language use and

[9] Jenny Koce Matitaputty and others, 'PjBL-Based Digital History Model to Improve Historical Concept Skills and Historical Consciousness', *Journal of Education and Learning*, 18.2 (2024), doi:10.11591/edulearn.v18i2.21152.

[10] Nabilah Mustika Putri, Lukman El Hakim, and Rizhal Hendi Ristanto, 'Studi Literatur Penerapan Project-Based Learning (PjBL) Pada Pembelajaran Kimia', *Ideguru: Jurnal Karya Ilmiah Guru*, 10.1 (2024), doi:10.51169/ideguru.v10i1.1251; Huixin Gao, Harwati Hashim, and Melor Md Yunus, 'The Effect of Project-Based Learning (PjBL) Class Model on Chinese Undergraduates' Argumentative Writing Performance', *Cogent Education*, 11.1 (2024), doi:10.1080/2331186X.2024.2396715.

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readability were rated as communicative and accessible, particularly for vocational students, ensuring clarity in both theoretical explanations and practical instructions.

The LMS-based delivery was positively evaluated for its support of interactive features, accessibility, and integration with project-based activities. Experts noted that the digital platform enhanced student autonomy and engagement, especially in asynchronous learning contexts. Practical instructions and evaluation instruments were considered sufficiently clear, with recommendations to expand the diversity of assessment items to better capture student performance across different cognitive levels.

These findings are consistent with prior research by Purwaningsih et.al. (2020)[11], which emphasize the effectiveness of practical and digital-based instructional tools in improving conceptual understanding and technical skills among engineering students. The validation outcomes affirm that the developed module possesses high pedagogical validity and is suitable for implementation in the Electrical Circuit course within the Diploma 3 Air Navigation Engineering program. Its contextual design and digital integration offer a promising model for enhancing vocational education in technical disciplines.

To address the limitations of laboratory infrastructure commonly encountered in vocational education settings, this study developed a series of practical mockup trainers designed to simulate real-world electrical circuit applications. The mockups produced include: (1) a basic home electrical installation board, (2) a voltage divider circuit, (3) a power bank simulation using battery configurations, and (4) an IoT-based system for monitoring household electrical load usage. The use of IoT mockups in learning responds to future technological challenges in sustainability and smart systems. Each mockup was constructed to reflect authentic project scenarios that students are likely to encounter in the field of air navigation and aviation technology.

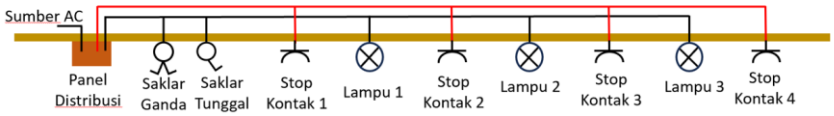


Figure 2. Lay Out Diagram Single Line

The Single Line Layout Diagram in Figure 1 shows a simplified configuration of household AC power distribution, tracing current flow from the source to switches, sockets, and lamps. It uses clear conductor lines to highlight circuit structure, with components like double and single switches controlling multiple lamps and outlets. This format supports vocational learning by illustrating safe, functional, and organized electrical installations.

These mockups serve as tangible representations of the projects students are expected to complete, thereby reinforcing the principles of hands-on learning that are central to

[11] E. Purwaningsih and others, 'The Effect of Stem-Pjbl and Discovery Learning on Improving Students' Problem-Solving Skills of the Impulse and Momentum Topic', *Jurnal Pendidikan IPA Indonesia*, 9.4 (2020), doi:10.15294/jpii.v9i4.26432.

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vocational pedagogy. By engaging directly with physical models, students are able to apply theoretical concepts in a controlled yet realistic environment, which enhances their understanding and retention of technical knowledge. The use of mockups also facilitates experiential learning, allowing students to experiment, troubleshoot, and reflect on the outcomes of their work[12].

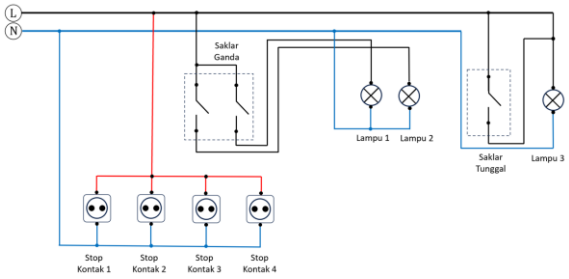


Figure 3. Schematic Wiring Diagram of a Basic Residential Electrical Installation

The wiring diagram in Figure 3 illustrates the actual flow of current in a household system, showing how switches, lamps, and outlets are interconnected. It begins with a power source labeled "L" and "N," distributing electricity to four outlets and three lamps, with switches controlling each lamp independently. This schematic supports vocational training by helping students understand circuit logic, switching mechanisms, and safe installation practices.

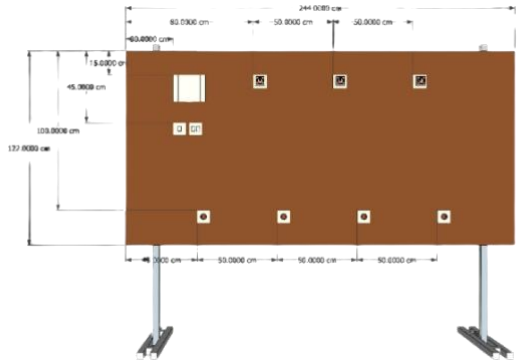


Figure 4. Basic Residential Electrical Installation Board with Component Layout and Precision Measurements

Figure 4 shows a basic residential electrical installation board mounted on vertical stands. The components, including switches, sockets, and lamps, are arranged with precise spacing based on measured intervals. This layout supports structured learning and safe practice in vocational electrical training.

[12] Anselmus Y. Mones, Aristiawan, and Deasy Irawati, '"Project Based Learning (PjBL) Perspektif Progresivisme Dan Konstruktivisme"', *Prosiding Seminar Nasional*, 2023.

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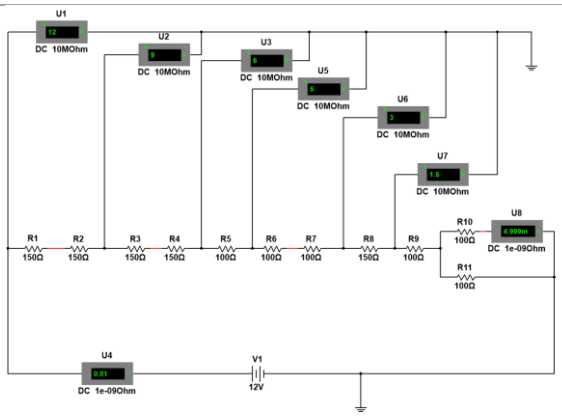


Figure 5. Voltage divider circuit mockup

Figure 5 presents a wiring diagram for a mockup voltage divider circuit powered by a 12V DC source. It consists of multiple resistors arranged in series-parallel configurations, with voltage measurements taken at key nodes to demonstrate potential differences across components. This setup is ideal for vocational training, enabling learners to observe voltage distribution and apply basic circuit analysis principles.



Figure 6. Paralel arrangement of battery

Figure 6 displays a project-based learning mockup featuring a parallel arrangement of 10 lithium-ion battery cells. This configuration increases the overall capacity (Ah) of the battery pack without changing its voltage, allowing for longer operational time in powering devices. The setup also integrates a charging module with multiple output ports and voltage regulation, enabling safe and efficient energy distribution for various loads during practical learning activities.

Figure 6 presents the wiring diagram for the SIMONDE project (Sistem Informasi Monitoring Daya dan Energi Listrik), which integrates a NodeMCU microcontroller with a PZEM-004T power monitoring module, an LCD display via I2C interface, and a current transformer. This setup enables real-time measurement and display of electrical parameters such as voltage, current, power, and energy consumption from an AC source to a connected load. Designed for educational and prototype purposes, SIMONDE supports data-driven learning and promotes awareness of energy usage in vocational contexts.

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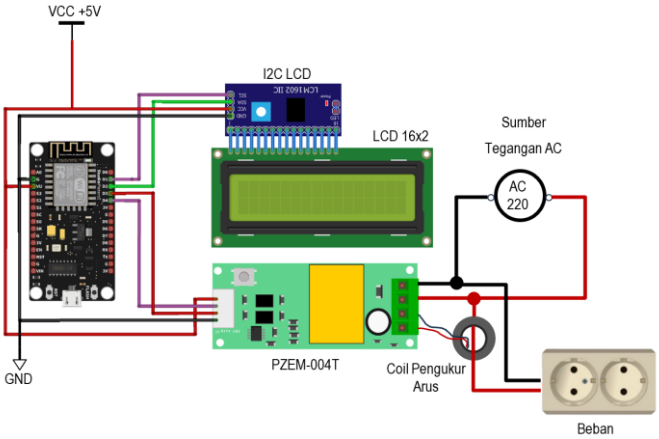


Figure 7. Wiring diagram for the SIMONDE project

Moreover, the presence of these mockup trainers has been shown to increase student motivation and engagement. When learners can observe the direct connection between abstract theory and practical implementation, their sense of relevance and purpose in the learning process is strengthened. This alignment between instructional design and vocational authenticity supports the development of both cognitive and psychomotor skills, preparing students for the demands of the aviation industry and other technical fields.

To ensure fair and comprehensive evaluation of student performance, the assessment instrument was designed in the form of a rubric that covers both process and product dimensions. The process assessment focuses on key indicators such as project planning, teamwork, and student engagement throughout the learning activities. These elements reflect the extent to which students participate actively, collaborate effectively, and demonstrate initiative in managing their project tasks.

Table 2. Rubric-Based Assessment Instrument

Assessment Criteria	Excellent (4)	Good (3)	Fair (2)	Needs Improvement (1)
1. Technical Accuracy	All components are correctly installed and function as intended. Wiring is neat and safe.	Most components work correctly; minor errors in wiring or layout.	Some components function; noticeable errors in wiring or connections.	Many components fail; major errors in installation or safety risks.
2. System Integration	Modules (e.g., NodeMCU, PZEM, LCD) are fully integrated and	Modules are mostly integrated; minor issues in data display or flow.	Partial integration; data not consistently displayed or processed.	Modules not integrated; system fails to monitor or display data.

	data flows correctly.			
3. Innovation & Functionality	Project shows creative application and solves a real-world problem effectively.	Project is functional with some innovative features.	Project is basic; limited innovation or practical relevance.	Project lacks clear function or relevance to real-world application.
4. Documentation & Explanation	Clear schematic, layout, and explanation of system operation and purpose.	Adequate documentation; explanation covers most aspects.	Limited documentation; explanation lacks depth or clarity.	No documentation or explanation provided.
5. Teamwork & Collaboration	Excellent collaboration; roles are clear and work is well-coordinated.	Good teamwork; some coordination issues.	Uneven contribution; limited collaboration.	Poor teamwork; individual work dominates or conflicts occur.
6. Presentation & Communication	Project is presented clearly, confidently, and responds well to questions.	Presentation is clear but lacks confidence or depth.	Presentation is unclear or incomplete.	No presentation or unable to explain the project.

The rubric-based assessment instrument employs a total score range of 6 to 24 to evaluate student performance in project-based learning activities. A score between 21 and 24 indicates an Outstanding Project, demonstrating excellent quality and readiness for exhibition or competition. Scores ranging from 16 to 20 reflect a Good Project, which meets the learning objectives with only minor revisions required. A score of 11 to 15 denotes a Satisfactory Project, suggesting that several aspects need improvement to reach the expected standard. Finally, scores between 6 and 10 are categorized as Incomplete, indicating that the project does not meet minimum criteria and requires substantial revision or rework.

Meanwhile, the product assessment evaluates the final outcomes of student projects based on several criteria: design accuracy, functional performance, creativity, quality of written reports, and clarity of presentation. Each criterion is aligned with the expected competencies in vocational engineering education, particularly in the context of applied electrical circuit design. By incorporating both formative and summative aspects, the rubric provides a balanced view of student achievement.

The rubric was developed to promote objective and transparent assessment practices, in line with the principles of Project-Based Learning (PjBL). It enables instructors to evaluate student work consistently while offering clear performance expectations. Moreover, the rubric serves as a feedback tool that guides students in improving their

technical and collaborative skills, reinforcing the pedagogical goals of vocational education.

The instructional module developed in this study was validated by three experts representing distinct domains: a subject matter expert in electrical engineering, a media design specialist, and a pedagogical expert in instructional design. Their evaluations were conducted using a structured Likert-scale instrument, complemented by qualitative feedback. The results indicated that the module achieved average scores within the "good" to "very good" categories, confirming its overall validity and feasibility for instructional use.

This instrument is designed to assess the feasibility, quality, and pedagogical relevance of the developed product based on expert judgment from three domains: electrical engineering, educational media, and educational technology. To ensure the quality, feasibility, and pedagogical relevance of the developed product, a structured validation process was conducted involving three domain experts: an electrical engineering specialist, a media design expert, and a technology education expert. Each expert was provided with a tailored evaluation instrument designed to assess specific aspects of the product aligned with their field of expertise.

The validation instrument consisted of a set of aspects and indicators, systematically constructed to reflect the critical dimensions of product quality. Each aspect represents a broader evaluative domain (e.g., technical conformity, visual design, instructional usability), while the indicators operationalize these domains into measurable criteria.

Experts were instructed to evaluate each indicator using a five-point Likert scale to ensure consistency and clarity in judgment. The scale ranged from 1 to 5, with each point representing a specific level of quality: 1 indicated "Strongly Inadequate," 2 denoted "Inadequate," 3 represented "Adequate," 4 signified "Good," and 5 reflected "Excellent." This standardized rating system enabled the quantification of expert opinions and facilitated the aggregation and interpretation of validation results across different domains.

In addition to numerical ratings, each item included an open comment field to capture qualitative feedback and recommendations. This dual-format approach allowed for both quantitative scoring and qualitative insights, enriching the validation process and supporting triangulation of findings.

The expert validation instruments used in this study are presented in the following tables, each corresponding to a specific domain of expertise. Table 1 outlines the instrument designed for the electrical engineering expert, focusing on technical aspects such as component conformity, circuit quality, and safety features. Table 2 presents the instrument for the educational media expert, which evaluates visual design, graphic consistency, interactivity, and accessibility. Table 3 details the instrument for the educational technology expert, emphasizing curriculum alignment, usability, active learning potential, and feedback mechanisms. These instruments were tailored to capture domain-specific judgments and ensure comprehensive validation of the developed product. Each table outlines the evaluated aspects, corresponding indicators, rating scale,

and comment section. These instruments served as the basis for analyzing expert judgments and refining the product prior to implementation.

Tabel 3. Instrument for Electrical Engineering Expert

Aspect	Indicator
Component conformity	Components comply with electrical standards and are safe for use
Circuit quality	Circuit is stable, durable, and efficient
Safety and protection	Adequate protection against overcurrent and short circuits
Technical documentation	Technical manual is clear and comprehensible for users

Tabel 4. Instrument for Educational Media Expert

Aspect	Indicator
Visual design	Layout is attractive, proportional, and appropriate for target users
Graphic consistency	Use of colors, fonts, and icons is consistent throughout
Media interactivity	Product supports active user interaction
Accessibility	Media is accessible to users with diverse needs (e.g., visual impairments)

Tabel 5. Instrument for Educational Technology Expert

Aspect	Indicator
Curriculum alignment	Product supports learning objectives aligned with vocational curriculum
Usability	Instructions are clear and easy to follow for vocational students
Active learning potential	Product encourages student engagement and active learning
Feedback and evaluation	Product enables formative assessment and feedback mechanisms

The expert validation results indicate that the developed product meets the criteria of technical feasibility, media quality, and pedagogical relevance, with validation scores of 83% from the electrical engineering expert, 80% from the media expert, and 85% from the instructional technology expert. These findings affirm the product's overall readiness for implementation in vocational education settings.

Expert validation is a critical phase in educational product development, serving as a quality assurance mechanism to ensure that the product aligns with both technical standards and instructional goals. According to recent studies, such as those by Trianda and Suhery (2021)[13], expert judgment contributes significantly to establishing the content validity and practicality of learning media, particularly when the product integrates interdisciplinary components like technology, media, and pedagogy .

[13] Diar Arum Trianda and Tatang Suhery, 'Pengembangan Instrumen Validasi Untuk EXPERT Tentang Media Berbasis STEM', *Jurnal Penelitian Pendidikan Kimia: Kajian Hasil Penelitian Pendidikan Kimia*, 8.1 (2021).

The electrical engineering expert's score of 83% reflects that the product is technically sound, with appropriate component selection, circuit stability, and safety mechanisms. This aligns with the findings of Matitaputty et al. (2024), who emphasized that technical validation ensures the operational reliability of educational tools, especially in vocational contexts where real-world application is essential[14].

The media expert's score of 80% suggests that the product demonstrates strong visual and interactive qualities, though minor improvements in graphic consistency and accessibility are recommended. This is consistent with the work of Gao et.al. (2024), who argue that media aesthetics and usability significantly influence learner engagement and comprehension, particularly in digital learning environments [15].

The highest score, 85%, was given by the instructional technology expert, highlighting the product's alignment with curriculum objectives, support for active learning, and capacity to facilitate formative assessment. The triangulated validation results reinforce the product's quality across domains. The integration of expert feedback not only strengthens the product's credibility but also aligns with the formative evaluation model proposed, which emphasizes iterative refinement based on expert input. These findings suggest that the developed product is both valid and practical, and ready for pilot testing in real classroom settings.

CONCLUSION

This study successfully developed an instructional package for the Electrical Circuit course, grounded in the principles of Project-Based Learning (PjBL) and tailored to the specific context of vocational education in the Diploma 3 Air Navigation Engineering program. The package comprises four integrated components: a project-oriented Semester Learning Plan (SLP), a digital learning module embedded within a Learning Management System (LMS), a set of practical mockup trainers, and a rubric-based assessment instrument. The design was informed by a comprehensive analysis of student learning needs, curriculum standards, and the pedagogical characteristics of vocational education.

Expert validation confirmed that the instructional package meets the criteria for content validity, structural coherence, and visual clarity. The materials were found to be well-aligned with Graduate Learning Outcomes (CPL), Course Learning Outcomes (CPMK), and sub-CPMKs, and were deemed relevant to project-based vocational instruction. The LMS platform was praised for its interactivity and accessibility, while the practical instructions and assessment rubrics were considered effective in supporting the implementation of PjBL strategies.

[14] Matitaputty and others, 'PjBL-Based Digital History Model to Improve Historical Concept Skills and Historical Consciousness'.

[15] Gao, Hashim, and Md Yunus, 'The Effect of Project-Based Learning (PjBL) Class Model on Chinese Undergraduates' Argumentative Writing Performance'.

RESEARCH CONTRIBUTION AND IMPLICATIONS

The findings of this study offer a significant contribution to the development of instructional resources in vocational education, particularly within the context of the Electrical Circuit course. By integrating the Project-Based Learning (PjBL) model with a Learning Management System (LMS), the instructional package responds directly to the learning preferences of Generation Z students, who are highly familiar with digital technologies and expect flexible, interactive learning environments. This integration not only enhances student engagement but also serves as a strategic solution to overcome infrastructural limitations, especially the lack of access to fully equipped laboratories.

A key innovation of this study lies in the development of practical mockup trainers, which effectively bridge the gap between theoretical instruction and hands-on experience. These mockups enable students to engage in contextual learning activities that simulate real-world applications, even in settings with limited physical resources. As a result, students gain meaningful exposure to applied technical skills while reinforcing their conceptual understanding through project-based tasks.

RECOMMENDATIONS

Based on the findings of this study, several recommendations are proposed to support the effective implementation and further development of the instructional package.

For lecturers, it is recommended to consistently utilize the PjBL-based instructional tools throughout the course delivery. This includes integrating theoretical content, practical exercises, and project-based tasks within the Learning Management System (LMS). Lecturers are also encouraged to continuously adapt and refine the instructional materials in response to technological advancements and evolving demands in the aviation industry. Such alignment will ensure that the learning experience remains relevant, engaging, and industry-oriented. Consistent implementation of PjBL can significantly enhance students' learning motivation (Hapsari & Airlanda, 2018).

For students, active participation in using the digital modules and mockup trainers is essential. Students should take advantage of the discussion forums and interactive assessments available within the LMS to deepen their conceptual understanding and technical proficiency. Group collaboration should also be optimized to ensure that project-based learning activities are carried out effectively, fostering teamwork and problem-solving skills.

For the institution, Politeknik Penerbangan Surabaya is advised to support the implementation of this innovative instructional package by enhancing infrastructure and learning facilities. This includes providing more adequate laboratory resources and ensuring stable internet connectivity to facilitate LMS access. Institutional policy support will be critical in driving the transformation toward a more modern and application-oriented vocational education system.

For future researchers, this study was limited to the development and validation stages of the instructional package. Therefore, subsequent research is recommended to evaluate the effectiveness and practicality of the module on a broader scale. Future studies should involve a larger sample of students and assess the impact of the instructional

package on learning outcomes and 21st-century skills, including critical thinking, creativity, collaboration, and communication. Further research may examine the effectiveness of the module in online or hybrid learning environments (Najeeb & Memon, 2022).

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