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Development of a website-based "CircuitPintar" to improve the Competencies of the Electrical Installation Engineering Students

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ABSTRACT

Purpose – This study aimed to develop and evaluate CircuitPintar, a website-based learning medium designed to improve the competencies of vocational high school students in the Basic Electrical Theory element of the Electrical Installation Engineering program.

Methodology – The research employed a Research and Development approach using the ADDIE model: analysis, design, development, implementation, and evaluation. The implementation trial involved 35 Grade X TITL students at SMKN 3 Surabaya. Data were collected through media and material validation sheets, teacher and student response questionnaires, a 25-item cognitive test, and psychomotor and affective observation rubrics. Data were analyzed using percentage-based validity and practicality criteria, Shapiro-Wilk normality tests, paired-sample t-tests, and normalized gain (N-gain).

Findings – CircuitPintar was categorized as highly valid in media validation (91%) and material validation (94%). Practicality was also high, with teacher responses of 91% and student responses of 86%. Students' mean scores increased from 72.74 to 88.17 in the cognitive domain, from 71.77 to 88.74 in the psychomotor domain, and from 73.40 to 88.00 in the affective domain. All improvements were statistically significant ($p < 0.001$), and N-gain values for all domains were in the moderate category.

Significance – This study presents an empirically tested model of website-based vocational learning media that combines concept mastery and virtual practice on a single platform, offering a practical reference for developing similar digital media for other technical and vocational subjects.

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INTRODUCTION

Vocational education is expected to prepare learners not only to recall subject matter but also to perform technical procedures and demonstrate productive work attitudes. In the Electrical Installation Engineering (TITL) program, the Basic Electrical Theory element serves as a foundational subject that introduces key quantities such as voltage, current, resistance, and power, as well as circuit relationships that are essential for installation, control, and maintenance tasks. Weak mastery of these foundational competencies often leads to difficulties in subsequent practice-based courses, as students lack stable conceptual models for interpreting diagrams, selecting components, and predicting measurement outcomes.

This study focuses on the development of a website-based learning medium, CircuitPintar, and its effect on students' competencies in the TITL program at SMKN 3 Surabaya. The independent variable is the use of CircuitPintar, while the dependent variable is students' competencies measured across cognitive, psychomotor, and affective domains.

Empirical conditions in SMKN 3 Surabaya demonstrate a clear instructional problem. Based on needs analysis, Grade X TITL students experienced difficulties in basic circuit calculations, component identification, and circuit interpretation. Teachers also reported constraints related to limited laboratory equipment, particularly measuring instruments, and restricted instructional time. Existing digital learning materials were predominantly static, insufficient to support sequence-based procedural skills such as circuit assembly, probe placement, and measurement verification. These conditions highlight the urgency of developing a learning medium that is accessible, structured, and capable of supporting repeated practice without full dependence on physical laboratory resources.

Previous studies have shown that digital learning environments, particularly website-based media, can improve accessibility, flexibility, and learning effectiveness in vocational education (Meduri et al., 2022; Pandie, I. J. J., & Basuki, 2021). In addition, web-based learning has been associated with enhanced student engagement, improved access to learning resources, and stronger competence development in technical subjects (Anggara, A. D., & Sujatmiko, 2024; Annatasya, N., & Prismana, 2023; Permatasari & Ekohariadi, 2023; Syah & Hidayatullah, 2024). Interactive and multimedia-based learning has also been reported to improve conceptual understanding, psychomotor skills, and student motivation (Faradayanti, K. A., Endryansyah, Joko, & Agung, 2020; Jaiz, M., Vebrianto, R., Zulhidah, Z., & Berlian, 2022; Musthofa, 2020; Saviraningsih & Aribowo, 2022). These findings indicate that digital media have strong potential to support vocational learning, particularly in addressing abstract concepts and enhancing learning engagement.

However, despite these advantages, existing studies predominantly focus on content delivery, visualization, or general e-learning access. In contrast, only a limited number of studies have developed integrated learning environments that systematically combine conceptual explanation, guided simulation, and procedural practice within a continuous learning sequence. Some studies emphasize theoretical understanding without simulation (Muntu, 2017), while others focus on usability without adequately supporting psychomotor skill development (Faradayanti, K. A., Endryansyah, Joko, & Agung, 2020). In addition, media developed using platforms such as Adobe Flash tend to have limitations in flexibility and accessibility (Sriadhi & Yuwanda, 2020). As a result, the integration of knowledge, skills, and work attitudes, core components of vocational competence, remains insufficiently addressed. This condition highlights a clear research gap and reinforces the urgency of developing an integrated learning medium that aligns conceptual learning with action-oriented practice.

To address this gap and urgency, this study developed CircuitPintar, a website-based learning medium designed as an integrated instructional ecosystem. CircuitPintar combines conceptual learning (materials, videos, and quizzes) with virtual laboratory simulation through two main features: CircuMa (conceptual learning) and CircuLabs (virtual practice). This design enables students to transition directly from conceptual understanding to guided procedural practice within a single platform, while teachers can monitor learning progress through integrated dashboard features.

The novelty of this study lies in integrating conceptual learning, interactive simulation, and procedural practice within a single web-based environment specifically designed for vocational electrical education. In addition, this study evaluates its effectiveness across three domains of competence: cognitive, psychomotor, and affective, which are rarely examined simultaneously in previous research. This integrated approach is supported by previous studies indicating that continuity between explanation, practice, and feedback can improve learning independence, reduce fragmentation between theory and application, and create more meaningful learning experiences (Haryudo et al., 2025; Ikhsan, J., Akhyar, M., & Naıs, 2024; Kiptiyah, M., Munoto, M., Basuki, I., & Ismayati, 2022; S Sriadhi, R Restu, 2019; Sriadhi & Yuwanda, 2020).

Therefore, this study aims to: (1) develop a valid website-based learning medium, CircuitPintar; (2) evaluate its practicality in classroom implementation; and (3) examine its effectiveness in improving students' competencies in the Electrical Installation Engineering program. This research contributes an integrated learning model and empirical evidence to support vocational education, particularly in bridging the gap between theoretical understanding and practical application.

METHODOLOGY

Research Design

This study employed a Research and Development (R&D) approach using the ADDIE model, comprising analysis, design, development, implementation, and evaluation stages. The ADDIE model was selected because it provides a systematic framework that guides the process from identifying field problems to designing, developing, validating, and implementing an instructional product. The model has been widely applied in recent studies to develop technology-based learning environments due to its structured, iterative nature (Li & Cheong, 2023; Shakeel et al., 2023; Singh & Ahmad, 2024).

The stages of the ADDIE model in this study were carried out as follows: (1) Analysis, identifying learning needs, student characteristics, and obstacles in learning Basic Electrical Theory; (2) Design, developing the structure of CircuitPintar, including interface layout, material organization, interactive features, and supporting media; (3) Development, producing the CircuitPintar learning media and conducting validation by media and subject-matter experts; (4) Implementation, applying CircuitPintar in classroom learning and testing its effectiveness with a group of student's; and (5) Evaluation, assessing each stage based on validation results, student and teacher responses, and improvements in student's' understanding of basic electrical concepts. These stages align with recent studies that emphasize the importance of systematic instructional design models for developing effective digital learning media (Li & Cheong, 2023; Shakeel et al., 2023).

In this study, the independent variable was the use of the website-based learning medium, CircuitPintar. In contrast, the dependent variable was students' competencies in the Electrical Installation Engineering (TITL) program, which were measured across three domains: cognitive, psychomotor, and affective. The effectiveness of the developed product was evaluated using a one-group pre-test–post-test design, as the primary objective at this stage was to examine the feasibility and initial effectiveness of CircuitPintar in improving students' competencies in a real classroom setting prior to wider implementation. This approach aligns with recent development studies that prioritize initial validation and feasibility testing before broader experimental application (Li & Cheong, 2023; Shakeel et al., 2023).

Participant

The participants in this study were 35 students from the Electrical Installation Engineering (TITL) program at SMKN 3 Surabaya. The sample was selected using a purposive sampling technique, in which the class was chosen based on its relevance to the research objectives. The selected participants represented the intended target users of the developed product, as they were studying basic electrical theory and required support in both conceptual understanding and practical skills. In addition, the selected class was implementable and reflected typical learning conditions in vocational electrical education. Therefore, it was considered appropriate for evaluating the feasibility and initial effectiveness of the CircuitPintar learning medium in a real classroom context.

Data Collection

Data collection covered product quality, user response, and student competence. Product quality data were obtained through expert validation sheets. Three validators, comprising one university lecturer and two vocational teachers, reviewed the media, materials, assessment instruments, response questionnaires, and job sheets. Practicality data were collected after implementation through teacher and student questionnaires. Effectiveness data were collected through a 25-item cognitive achievement test and observation sheets for psychomotor and affective performance during learning activities.

The product and instruments that entered the validation process were comprehensive. Media validation focused on interface, navigation, usability, and suitability of learning features. Material validation assessed content accuracy, relevance to the curriculum, sequence of explanation, and the suitability of examples and tasks. Instrument validation covered the cognitive test, the psychomotor observation sheet, the affective observation sheet, the student response questionnaire, and the jobsheet. The original pool of cognitive test items was refined during validation so that the final test remained representative of the indicators while still feasible to administer in classroom conditions.

Instrument

The cognitive instrument was administered as a pre-test and a post-test. The psychomotor observation rubric used a five-point Likert scale and assessed four performance clusters: initial operation and navigation, circuit assembly, measurement procedures, and evaluation or reporting of results. The affective observation rubric also used a five-point Likert scale and focused on activeness, learning motivation, responsibility, and cooperation. In addition, the response questionnaires asked users about ease of use, clarity of presentation, relevance to learning needs, attractiveness, and the usefulness of the product for understanding electrical concepts and completing tasks.

CircuitPintar itself was organized into teacher and student workflows. The student side provided a structured sequence of pre-test, learning materials, quizzes, simulation activities, and post-test, along with progress information that helped learners see which steps had been completed. The teacher's side provided access to student data, quiz results, and job sheet-related monitoring. These features were important in the practicality analysis because they were expected to reduce the operational burden of using the medium during class while still supporting individual learning progress.

Data Analysis

Validation and practicality scores were converted to percentages and interpreted according to predetermined criteria adopted in this study. A product was considered acceptable when the average score met or exceeded the valid or practical threshold. In addition, descriptive statistics, including minimum, maximum, mean, and standard deviation, were used to summarize the learning outcomes before and after CircuitPintar implementation. Because the sample size was 35, the Shapiro–Wilk test was used to assess normality. When the assumption of normality was met, a paired-samples t-test with $\alpha = 0.05$ was used to determine whether there was a statistically significant difference between pre-test and post-test scores. The magnitude of improvement was further analyzed using normalized gain (N-gain), which provides an interpretation of learning progress beyond statistical significance.

In this study design, effectiveness is interpreted as evidence of meaningful improvement after the product is implemented in the trial class, rather than as causal superiority over other instructional models. This interpretation is important because the study was conducted in a limited trial setting to determine feasibility, practicality, and initial effectiveness before broader implementation.

The collected data were then analyzed using a percentage formula adapted from Arkadiantika (2020), as shown in Equation (1), where Va represents the validity value, TSe represents the obtained score, and TSh represents the maximum expected score (Arkadiantika et al., 2020). The validity data analysis is calculated using the following Equation:

$$V_a = \frac{TS_e}{TS_h} \times 100\% \qquad (1)$$

The following table shows the validity categories of learning tools based on the final score obtained on a scale (0-100).

Table 1. Categories of learning media validity

Interval	Category
85% - 100%	Highly valid
69% - 84%	Valid
53% - 68%	Quite valid
37% - 52%	Less valid
≤ 36%	Cancel

The calculation of student response data analysis to interactive e-modules uses the following equations:

$$V_a = \frac{TS_e}{TS_h} \times 100\% \qquad (2)$$

The respondents' responses can be categorized as shown in Table 2.

Table 2. Response questionnaire criteria

Interval	Category
85% - 100%	Very Practical
69% - 84%	Practical
53% - 68%	Quite Practical
37% - 52%	Less Practical
≤ 36%	Not Practical

The N-Gain formula is used as follows:

$$N - Gain = \frac{X\ post - X\ pre}{X\ max - X\ pre} \quad (3)$$

With the following acquisition categorizations:

Table 3. N-Gain score category

Range	Category
N-Gain ≤ 0,3	Low
0,7 ≥ N-Gain > 0,3	Medium
N-Gain > 0,7	High

FINDINGS

CircuitPintar was developed as a website-based vocational learning platform that integrates conceptual study and virtual practice in a single environment. The product includes a landing page, role-based login, teacher and student dashboards, structured content pages, quizzes, a progress-based learning sequence, and the CircuLabs workspace. In CircuMa, students learn through text explanations, illustrations, videos, and topic-specific quizzes. In CircuLabs, they assemble circuits using drag-and-drop components, perform virtual multimeter measurements, complete resistor identification tasks, and follow job sheets that guide the practice. The product operationalizes the design intention established in the ADDIE stages: a single digital ecosystem that supports understanding, action, and reflection.

The teacher dashboard enhances the instructional value of the product by allowing monitoring of pre-test scores, quiz results, post-test scores, and job sheet-related activity. The student dashboard supports self-regulation by showing identity information, learning progress, the order of tasks, and whether specific activities have been completed. In practical terms, these features help teachers coordinate class time while helping students follow a structured pathway rather than moving randomly through content. This is important in vocational learning, where the sequence and completion of tasks often influence whether students attain the intended competence. The developed product is presented in Figure 1, while Table 4 summarises the role of each major component in supporting orientation, monitoring, conceptual study, and virtual practice within CircuitPintar.

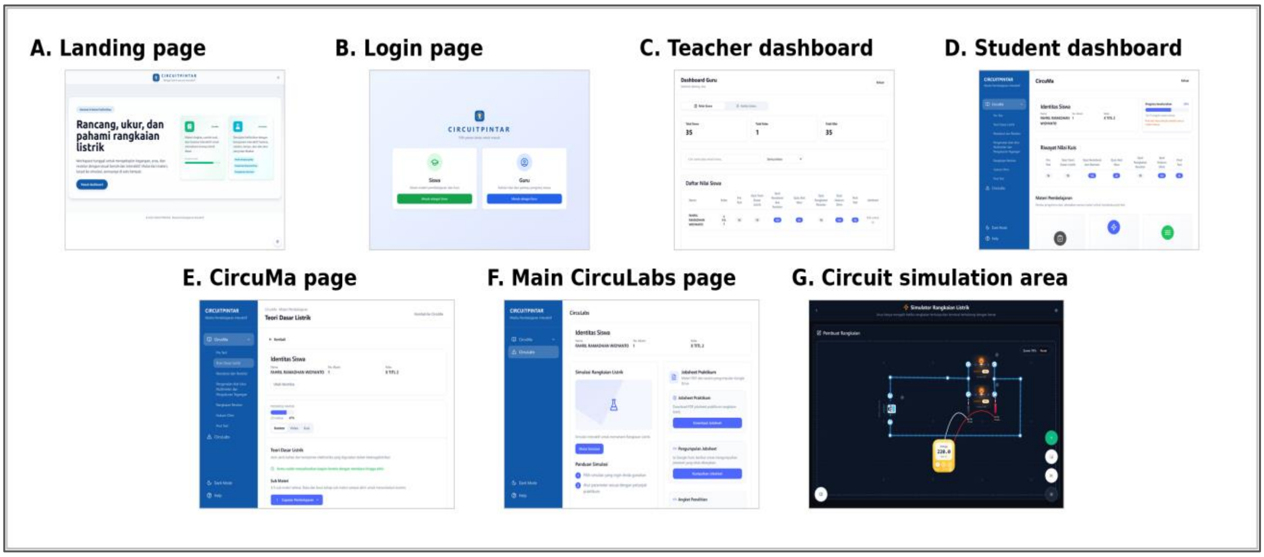

Figure 1. Sequential interfaces of CircuitPintar: (A) landing page, (B) login page, (C) teacher dashboard, (D) student dashboard, (E) CircuMa learning page, (F) CircuLabs workspace, and (G) circuit simulation area

Figure 1 presents the sequential user flow of CircuitPintar, beginning with the access pages and dashboards and continuing to the CircuMa and CircuLabs environments. This arrangement highlights the integration of access, monitoring, conceptual learning, and guided virtual practice within a single web-based platform. The visual realization of the product is pedagogically important. The landing page introduces the two learning environments and directs users into the system; the teacher dashboard supports score and progress monitoring; CircuMa structures content, videos, and quizzes into a guided sequence; and CircuLabs provides a workspace for drag-and-drop circuit construction, measurement practice, and jobsheet-based tasks.

Table 4. Product architecture and main features of CircuitPintar

Component	Main function	Contribution to learning
Landing page and login flow	Introduces the platform, highlights CircuMa and CircuLabs, and directs students and teachers to the appropriate workspace.	Helps users understand the learning sequence and supports role-based access from the outset.
Teacher dashboard	Displays student lists, pre-test/post-test scores, quiz history, and jobsheet-related records.	Helps teachers monitor progress and follow up on both conceptual and practical performance.
Student dashboard	Shows student identity, completion progress, available topics, and quiz-score history.	Encourages self-regulated learning because students can track what has been completed and what has not.
CircuMa	Provides structured theory content, embedded learning videos, and topic-based quizzes.	Strengthens conceptual understanding and supports cognitive achievement through sequenced study and feedback.
CircuLabs	Offers a virtual laboratory with drag-and-drop components, measurement activities, interactive resistors, and links to submit job sheets.	Supports psychomotor practice and active engagement by allowing repeated procedural exercises in a safe digital environment.

Note. Product descriptions are adapted from the developed media and the final thesis documentation.

Table 4 indicates that the developed medium addressed three complementary instructional needs at once: orientation and learning control, conceptual study, and virtual practice. This matters in vocational learning because students need not only conceptual understanding, but also repeated opportunities to apply procedures and receive feedback beyond limited laboratory sessions.

Validity of CircuitPintar

The validity of CircuitPintar was evaluated by three validators, consisting of one lecturer and two vocational teachers. The validation covered six aspects: media, material, test instruments (pre-test and post-test), psychomotor assessment, affective assessment, student response questionnaire, and jobsheet.

Table 5. Summary of validity results

Aspect	Percentage	Category
Media validity	91%	Highly valid
Material validity	94%	Highly valid
Pre-test–post-test instrument	95%	Highly valid
Psychomotor observation sheet	96%	Highly valid
Affective observation sheet	96%	Highly valid
Student response instrument	96%	Highly valid
Jobsheet validity	92%	Highly valid

Note. The product met the eligibility criteria in all assessed aspects.

The expert validation results in Table 5 show that CircuitPintar reached high standards across the product and its supporting instruments. Media validity reached 91% and material validity reached 94%, both of which were categorized as highly valid. Supporting instruments also received very high scores: 95% for the pretest-posttest instrument, 96% for the psychomotor observation sheet, 96% for the affective observation sheet, 96% for the student response instrument, and 92% for the jobsheet. These results indicate that the product was not only attractive at the interface level but also aligned with curriculum content, assessment needs, and the intended learning activities' logic.

Practicality of CircuitPintar

The practicality of CircuitPintar was evaluated through teacher and student responses after implementation.

Table 6. Summary of practicality results

Aspect	**Percentage**	**Category**
Teacher response	91%	Very practical
Student response	86%	Very practical

Note. The product met the practicality criteria in all assessed aspects.

Practicality results were also strong. Teacher responses reached 91% and student responses 86%, both in the very practical category. These scores suggest that CircuitPintar was manageable in real classroom use, easy to access through available devices, and understandable in terms of navigation and task flow. The practicality data are especially meaningful because they reflect two complementary viewpoints: teachers judged whether the medium could be integrated into instruction, while students judged whether it was clear, usable, and supportive of learning. The positive results from both groups imply that the product functioned well not only as a development artifact but also as an instructional tool.

Improved Learning Outcomes

The effectiveness of CircuitPintar was evaluated across three learning domains: cognitive, psychomotor, and affective. The descriptive statistics of pre-test and post-test results are shown in Table 7.

Table 7. Descriptive statistics of pre-test and post-test scores

Domain	Factor Loading					
	Measure	N	Min	Max	Mean	Std. Deviation
Cognitive	Pre-test	35	42	96	72.74	14.176
Cognitive	Post-test	35	68	100	88.17	7.752
Psychomotor	Pre-test	35	59	81	71.77	4.628
Psychomotor	Post-test	35	78	95	88.74	3.776
Affective	Pre-test	35	50	87	73.40	8.500
Affective	Post-test	35	68	96	88.00	5.724

Note. The table summarises pre-test and post-test performance for the cognitive, psychomotor, and affective domains.

Table 7 shows that all three competency domains improved after the implementation of CircuitPintar. In the cognitive domain, the mean score increased from 72.74 to 88.17, with the minimum score rising from 42 to 68 and the maximum from 96 to 100. The standard deviation decreased from 14.176 to 7.752, indicating that post-test scores became more homogeneous. In the psychomotor domain, the mean increased from 71.77 to 88.74, with minimum and maximum values changing from 59–81 to 78–95, and the standard deviation decreased from 4.628 to 3.776. In the affective domain, the mean increased from 73.40 to 88.00, while the minimum increased from 50 to 68, the maximum from 87 to 96, and the standard deviation decreased from 8.500 to 5.724. These descriptive data show that improvement was not limited to a few high performers; the overall distribution of scores shifted upward across the class.

Table 8. Shapiro-Wilk normality test results

Domain	Factor Loading				
	Measure	Statistic	df	Sig.	Interpretation
Cognitive	Pre-test	0.966	35	0.347	Normal
Cognitive	Post-test	0.949	35	0.109	Normal
Psychomotor	Pre-test	0.946	35	0.086	Normal
Psychomotor	Post-test	0.939	35	0.051	Normal
Affective	Pre-test	0.974	35	0.559	Normal
Affective	Post-test	0.976	35	0.622	Normal

Note: SAE = Student Academic Engagement; SEA = Student Engagement with Academic Staff; SEP = Student Engagement with Peers; and SEC = Student Engagement in Communities.

Table 8 presents the Shapiro-Wilk normality test results. All significance values were above 0.05, which indicates that the pre-test and post-test datasets in the cognitive, psychomotor, and affective domains were normally distributed. Because the normality assumption was met, paired-sample t-tests were used for the effectiveness analysis.

Table 9. Paired sample t-test and N-gain results

Domain	Factor Loading					
	Mean Difference	t	df	Sig.	N-Gain	Category
Cognitive	-15.429	-8.838	34	< .001	0.5	Moderate
Psychomotor	-16.971	-22.689	34	< .001	0.6	Moderate
Affective	-14.600	-12.272	34	< .001	0.5	Moderate

Note. Sig. A p-value of 0.05 indicates that the dataset is normally distributed.

Table 9 presents the paired-sample t-test and N-gain results. The paired comparisons were significant in every domain: cognitive t = -8.838, p < .001; psychomotor t = -22.689, p < .001; affective t = -12.272, p < .001. Mean gains were 15.43 points in the cognitive domain, 16.97 points in the psychomotor domain, and 14.60 points in the affective domain. The negative mean differences reflect the pretest-minus-posttest calculation used by SPSS and therefore indicate that post-test scores were higher than pre-test scores. N-gain analysis further showed moderate improvement in all domains, with values of 0.5 for cognitive, 0.6 for psychomotor, and 0.5 for affective. Taken together, the validation, practicality, descriptive, and inferential findings indicate that CircuitPintar was feasible for classroom use and produced promising learning improvements in a vocational electrical context.

DISCUSSION

The findings of this study demonstrate that implementing CircuitPintar, a website-based learning medium, effectively improves students' competencies across the cognitive, psychomotor, and affective domains. These results reflect not only the feasibility of the product but also the effectiveness of an instructional design that systematically integrates conceptual understanding, simulation, and procedural practice within a unified learning environment.

The strong validity results confirm that CircuitPintar functions as a coherent instructional system. This coherence is achieved through the alignment between learning objectives, instructional materials, simulation activities, and assessment instruments. CircuitPintar structures learning into a continuous sequence consisting of conceptual explanation, guided exploration, and procedural application. This structured design ensures that each instructional component reinforces the others, resulting in a consistent and goal-oriented learning process. As a result, the product demonstrates both technical appropriateness and instructional relevance.

The high practicality ratings indicate that CircuitPintar is fully compatible with classroom implementation in vocational education settings. Practicality in this context is determined by ease of access, clarity of use, and suitability for classroom conditions. CircuitPintar meets these requirements through role-based dashboards, integrated navigation, and clearly organized learning stages. These features reduce unnecessary cognitive load and allow students to focus directly on learning tasks. This finding is consistent with previous studies showing that well-designed website-based learning environments enhance usability and engagement when aligned with authentic learning activities (Annatasya, N., & Prismana, 2023; Meduri et al., 2022; Permatasari & Ekohariadi, 2023; Syah & Hidayatullah, 2024). In addition, this study establishes that usability is directly linked to instructional structure rather than merely to interface design.

The responses from users further confirm the practicality findings and directly address the second research problem related to usability. Students provided an average response of 86% (very practical), while teachers gave an average of 91% (very practical). These results indicate that CircuitPintar is easy to use in classroom settings, in terms of access, navigation, and feature functionality. This aligns with previous research by Andira & Puspasari (2023), which found that web-based learning media with interactive evaluation features received very positive user responses, emphasizing that accessibility and interactivity are key determinants of acceptance in web-based learning environments (Andira & Puspasari, 2023). Thus, usability in this study is not only a technical aspect but also reflects instructional clarity and learning design quality.

The improvement in cognitive competence results from the integrated and multimodal learning approach implemented in CircuitPintar. Students engage with the same concepts through textual explanations, instructional videos, quizzes, and practical applications. This repeated exposure across multiple representations strengthens conceptual understanding by reinforcing connections between abstract concepts and their applications. In Basic Electrical Theory, where learning requires integrating symbolic, numerical, and conceptual knowledge, this approach ensures the formation of stable, transferable mental models. These findings are consistent with previous studies demonstrating the effectiveness of web-based learning environments in improving conceptual understanding through flexible access and repeated engagement (Anggara, A. D., & Sujatmiko, 2024; Gunawan et al., 2019; Pandie, I. J. J., & Basuki, 2021; Sari & Surwi, 2019). This study further establishes that structured integration between explanation and application is a determining factor in cognitive development.

The most substantial improvement occurs in the psychomotor domain, confirming the critical role of simulation-based practice in vocational learning. Psychomotor competence requires the accurate execution of procedures, the appropriate use of components, and the correct interpretation of measurement results. CircuitPintar, through its CircuLabs feature, provides a virtual environment that supports continuous and guided practice. The drag-and-drop circuit assembly, virtual measurement tools, and job-sheet-based activities ensure that students perform tasks in a structured, sequential manner. This repeated practice results in procedural mastery and reduces execution errors. These findings are consistent with prior research emphasizing the effectiveness of interactive digital media in developing psychomotor skills through simulation and feedback (Faradayanti, K. A., Endryansyah, Joko, & Agung, 2020; Kiptiyah, M., Munoto, M., Basuki, I., & Ismayati, 2022; Simanullang & Jongga Manullang, 2022; Zuwe & Elfizon, 2021). Furthermore, this study demonstrates that integrating simulation with conceptual learning produces stronger psychomotor outcomes than isolated practice environments.

The improvement in the affective domain indicates that CircuitPintar also enhances students' engagement, responsibility, and learning attitudes. The structured learning flow, combined with progress tracking, task completion indicators, and interactive activities, creates a learning environment that encourages active participation and accountability. Students clearly understand the learning objectives and monitor their progress, which strengthens their motivation and sense of responsibility in completing tasks. The direct connection between theory and practice reinforces the relevance of the learning material, which is essential in vocational education. These findings align with previous studies reporting that interactive and multimedia-based learning environments improve student engagement and learning behavior (Jaiz, M., Vebrianto, R., Zulhidah, Z., & Berlian, 2022; Saviraningsih & Aribowo, 2022; Simanullang & Jongga Manullang, 2022). This study confirms that affective development emerges as an integral outcome of well-structured instructional design.

The effectiveness of CircuitPintar is also supported by quantitative evidence from pre-test–post-test analysis and N-gain results. The results confirm that the improvement is consistent across all domains, with the most dominant gain occurring in the psychomotor aspect, which aligns with the simulation-based learning design. The effectiveness of CircuitPintar is determined by its integrated instructional architecture rather than by its digital format alone. While previous studies have highlighted the benefits of web-based learning and interactive media in vocational education (Anggara, A. D., & Sujatmiko, 2024; Haryudo et al., 2025; Permatasari & Ekohariadi, 2023; Syah & Hidayatullah, 2024), most focus on isolated aspects such as content delivery or user engagement. This study provides a more comprehensive contribution by demonstrating that a fully integrated system combining conceptual learning, simulation, and evaluation simultaneously enhances cognitive, psychomotor, and affective competencies. This finding confirms that effective vocational learning requires aligning knowledge, skills, and attitudes within a unified instructional process.

These findings also translate directly into instructional strategies that can be implemented in vocational classrooms. CircuitPintar functions as an effective pre-laboratory learning tool, where students complete conceptual modules and simulation-based tasks before engaging in physical practice. This approach ensures that students enter laboratory sessions with procedural readiness, thereby increasing the efficiency of limited practice time. In addition, the platform supports a structured learning sequence in which students progress systematically from conceptual understanding (CircuMa) to guided simulation and procedural execution (CircuLabs). This sequence eliminates the gap between theory and practice that commonly occurs in conventional instruction. CircuitPintar also enables differentiated, independent learning, allowing students to repeat simulations and review materials at their own pace. Teachers can assign remedial or enrichment activities without requiring additional physical resources. Furthermore, the integrated quizzes, job sheets, and activity tracking features support continuous formative assessment, enabling teachers to monitor student progress, identify learning difficulties, and provide targeted feedback. Through these strategies, CircuitPintar not only improves learning outcomes but also restructures the instructional process in vocational education.

Despite these strengths, several limitations must be acknowledged. The use of a one-group pre-test–post-test design limits the ability to make causal comparisons with other instructional methods. The findings demonstrate significant improvement following the intervention, but do not provide comparative evidence against alternative approaches. In addition, the study was conducted in a single class within a single school, limiting the generalizability of the results. Baseline measurements for the psychomotor and affective domains were obtained during the implementation period, which may influence the interpretation of initial competency levels. Future research should involve larger, more diverse samples, include control groups, and examine the implementation of CircuitPintar across more complex topics or in combination with physical laboratory activities.

Overall, the findings provide strong empirical evidence that CircuitPintar functions as an effective, practical, and pedagogically sound learning medium for vocational education. More importantly, the results demonstrate that integrating conceptual understanding, simulation, and structured practice within a single platform enhances student competencies across cognitive, psychomotor, and affective domains. This reinforces the importance of designing digital learning environments that support the complete learning process, particularly in practice-oriented fields such as electrical engineering education (Meduri et al., 2022; Pandie, I. J. J., & Basuki, 2021; Permatasari & Ekohariadi, 2023).

CONCLUSION

This study concludes that CircuitPintar, a website-based learning medium, effectively improves students' cognitive, psychomotor, and affective competencies in Basic Electrical Engineering. The most significant improvement occurs in the psychomotor domain, supported by statistical analysis and N-gain results, indicating consistent learning gains across all domains.

The main contribution of this research is the development of an integrated instructional system that combines conceptual learning, simulation-based practice, and assessment within a single platform. This study extends previous research by demonstrating that learning outcomes improve more optimally when cognitive, skill, and affective processes are systematically integrated.

The novelty lies in integrating CircuMa and CircuLabs features into a structured learning sequence that bridges theory and practice in vocational education. This study is limited to a single class and uses a one-group pre-test–post-test design, which limits generalizability and causal inference. Future research should involve larger samples and control-group designs to strengthen external validity.

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