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Improving Critical Thinking Skills in Digital Electronics Education Through Simulation-Based Learning Media, Taking into Account the Basic ICT Skills of Vocational High School Students

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Abstract
This study aims to analyze the effect of using simulation-based learning media on students' critical thinking skills in digital electronics learning, with basic information and communication technology (ICT) skills as a moderator variable. This study employs a quantitative approach using a quasi-experimental nonequivalent control group design. The research subjects were 11th-grade students in the Industrial Electronics Vocational Program at SMK Negeri 2 Kupang, comprising an experimental group and a control group. Data analysis was conducted using a Two-Way Analysis of Variance (ANOVA). The results indicated a significant difference in critical thinking skills between students who participated in simulation-based learning and those who participated in conventional learning ($p < 0.05$). However, basic ICT proficiency did not show a significant effect on students' critical thinking skills. Furthermore, no interaction was found between learning strategies and basic ICT proficiency regarding critical thinking skills. These findings indicate that the use of simulation-based learning media can be an effective strategy for enhancing students' critical thinking skills in digital electronics courses at vocational high schools, regardless of their basic ICT proficiency.

Keywords: simulation-based learning, critical thinking, digital electronics, ICT literacy, vocational education

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INTRODUCTION

The government must develop better vocational education and training strategies focused on priority sectors to meet human resource needs in the Industry 4.0 era. Vocational High Schools (SMK), polytechnics, and vocational training centers (BLK), or training institutions, are part of these three vocational education institutions. Vocational high schools (SMK) serve dual roles: as a source of labor and as a talent development hub—roles that naturally involve innovations aligned with government programs to revitalize vocational institutions and education in producing competent workers. Everyone knows that new skills such as those required for bloggers, web developers, big data analysts, and others demand that students possess the ability to think critically, logically, systematically, analytically, and algorithmically, as well as coding and programming skills. This certainly presents its own set of challenges (Ananiadou and Claro, 2009) .

One of the challenges in developing vocational high school students' skills is preparing them to enter the workforce and the industrial sector (DU/DI), which demands not only physical skills but also other skills relevant to the needs of the Fourth Industrial Revolution. Critical thinking skills are essential 21st-century skills that vocational students must possess to be able to solve contextual and workplace problems (Pamungkas et al., 2020). This ability involves analyzing information, evaluating evidence, and making rational decisions in problem-solving (Kurniawan, 2021). Critical thinking consists of students' ability to think critically and openly, use abstract concepts, pose important questions and problems, and gather and assess relevant information (Lestari et al., 2020).

Students' critical thinking skills in Indonesia remain very low (Harjo et al., 2019). This is evidenced by several indicators, such as: (1) inaccurate problem analysis; (2) difficulty solving higher-order problems (C4–C6) (Ariyanto et al., 2020; Lestari et al., 2020); (3) passive participation in group work; (4) difficulty connecting concepts and problems; and (5) an inability to express their opinions during discussions—even though, according to Nailufar et al. (2020), problem-solving and critical thinking skills are key components of learning that must be taught and developed in every classroom to help students adapt to both industry and academia. In the vocational education learning process, according to Dewanto et al. (2018), there is a need to enhance critical and creative thinking skills to adapt to ever-evolving technology. Through learning activities, vocational high school students are expected to acquire critical thinking skills, which are essential for them to continue their education and enter the workforce. Career success and life in the 21st-century workplace depend heavily on students' ability to think critically and solve problems.

Erozkan (2013) adds that if the skills taught to graduates do not align with industry needs, their chances of being hired will be significantly reduced, which could ultimately contribute to rising unemployment rates among graduates. Therefore, these skills require continuous practice. According to Maknun (2019), these skills are not simply innate but must be developed through continuous practice to help students improve their critical thinking skills. He argues that innovative learning models are essential for fostering critical thinking skills, creativity, and problem-solving abilities. Relying solely on standard operating procedures (SOPs) is not sufficiently effective in promoting the development of these abilities in students (Samani et al., 2019). Critical thinking skills play a crucial role in determining an individual's success in the 21st-century workforce.

Many studies highlight other skills that can support critical thinking. Problem-based learning (PBL) is effective in enhancing students' critical thinking skills, particularly in the context of vocational education. This is supported by findings that problem-based learning not only enhances critical thinking skills but also improves students' collaboration skills and learning motivation (Nurtanto et al., 2018; Sholihah et al., 2020). Wahyuni et al. (2018) further note that communication skills are closely linked to critical thinking skills, as communication allows individuals to articulate, test, and reflect on ideas logically. Amiruddin et al. (2015) highlight that students' communication skills today still need to be improved to complement their critical thinking skills, which are considered lacking, even after they have entered the workforce. Furthermore, the modern workplace prioritizes communication as one of the key criteria for hiring employees, as it enables individuals to share, clarify, develop, and evaluate ideas systematically (Novianti, 2017; Robles, 2012). In this context, communication serves not only as a tool for conveying information but also as a means to build and strengthen the critical thinking process. Additionally, individuals' perceptions of communication and problem-solving skills influence how they analyze and resolve problems (Erozkan, 2013).

Critical thinking is an essential competency that develops optimally through the integration of various supporting skills, such as communication, collaboration, motivation to learn, and problem-solving. Critical thinking is a key competency that must be developed in the learning process to support students' readiness to face the challenges of modern industry (Sholihah & Lastariwati, 2020; Nurlaela et al., 2020).

In the context of vocational education, in addition to problem-based learning, simulation-based learning serves as a strategic alternative because it can recreate situations that resemble the real-world workplace, thereby encouraging students to analyze, make decisions, and reflect on solutions directly. Through simulations, students are not only trained to think critically in solving contextual problems but also hone their communication skills in presenting, testing, and evaluating ideas logically (Wahyuni et al., 2018). Simulation-based learning can be facilitated through interaction and collaboration among students. Simulation-based learning media allow students to visualize abstract concepts more concretely and conduct virtual experiments. Simulations play a crucial role because they bridge the gap between theory and practice. Students can conduct virtual experiments, try various scenarios, and observe the consequences of each decision without the risk of real-world errors. This makes simulations an effective tool for enhancing conceptual understanding and critical thinking skills.

Research shows that digital simulation-based learning can significantly improve students' critical thinking skills. The integration of web-based simulations into the guided discovery learning model has been shown to enhance digital literacy and critical thinking skills through active exploration and experience-based problem-solving (Sinaga & Rusilowati, 2026). According to(2019); Samani et al.,(2019) ; Sukmawati et al., (2025), various studies indicate that the use of simulation technology in engineering education can improve students' conceptual understanding and problem-solving skills. Furthermore, the use of simulation methods has also been proven effective in improving critical thinking skills compared to conventional learning (Chafshah et al., 2024). Wrahatnolo and Munoto,(2018) add that simulation media provide students with the opportunity to explore various system conditions interactively, thereby making the learning process more meaningful.

It is time to incorporate the use of software and applications into learning, including in the field of engineering. Information and Communication Technology (ICT) can be used by teachers to meet the learning needs of schools. Teachers need to develop learning strategies that enable students to build basic critical thinking skills first, so that they can subsequently focus on improving higher-order thinking skills (Dunn et al., 2008). The Electrical Engineering program at vocational high schools (SMK), for example, can use Simulink as a simulation tool to teach digital electronics or circuit simulation. The use of software such as MATLAB, Python, and others—which include Simulink—is an innovative alternative in electrical engineering education at SMKs to enhance students' practical and applied competencies.

Mastering the skills required for the Fourth Industrial Revolution demands that teachers be well-prepared. Vocational high schools (SMK) are at the forefront of producing a high-quality workforce; therefore, SMK teachers must adopt new teaching approaches. Since vocational education today is required to develop 21st-century skills—including critical thinking, creativity, communication, and collaboration (Facione, 2015) —teachers' readiness to develop innovative, technology-based learning models is key to improving the quality of vocational high school graduates so they can compete in the era of the Fourth Industrial Revolution.

In technical education, mastery of concepts is achieved not only through theoretical learning but also through practical experience and the exploration of digital learning technologies (Wrahatnolo and Munoto, 2018) . The integration of technology into technical education enables students to visualize complex concepts and develop higher-order thinking skills through exploratory activities and problem-solving (Maknun, 2019) . Research specifically examining the impact of simulation media on critical thinking skills in digital electronics instruction at vocational high schools remains relatively limited. Few studies have considered the role of basic information and communication technology (ICT) skills as a factor that can moderate the effectiveness of technology use in learning (Verhoeven et al., 2016) . The United Nations Educational, Scientific and Cultural Organization (UNESCO) emphasizes that ICT competencies encompass three main dimensions: technology literacy, knowledge deepening, and knowledge creation. These three dimensions illustrate that the use of ICT is not limited to operational skills but also includes the ability to develop knowledge and create innovations through technology (UNESCO, 2018).

In educational practice, basic ICT competencies include skills such as using office software, searching for information online, managing digital data, and online communication. Mastering these skills is crucial for supporting technology-based learning processes, including online learning, digital simulations, and project-based learning. Research shows that strong ICT skills can enhance the effectiveness of learning, expand access to information, and foster students' independent learning (Voogt et al., 2015). Furthermore, although basic ICT skills are essential competencies for 21st-century learning, their presence does not automatically contribute significantly to the development of critical thinking skills. ICT proficiency that focuses solely on operational aspects—such as software use or information access—does not necessarily encourage students to engage in in-depth analysis, evaluation, or critical reflection. This suggests that the use of technology in learning tends to be tool-oriented rather than a cognitive strategy that directly develops higher-order thinking skills. This finding aligns with a report by the Organization for Economic Co-operation and Development (OECD) indicating that increased computer use in schools does not always correlate with improvements in students' cognitive abilities, including critical thinking (OECD, 2015). Furthermore, research by Van Deursen and Van Dijk also confirms that technical digital skills do not necessarily lead to higher-order thinking skills without more strategic and reflective use (Van Deursen & Van Dijk, 2014).

Based on this discussion, it is clear that mastery of basic ICT skills alone is insufficient to foster the development of students' critical thinking skills without the support of an appropriate learning approach. Therefore, a learning model is needed that not only utilizes technology as a tool but also integrates it into higher-order cognitive processes. One promising approach is simulation-based learning, which allows students to actively engage in analyzing, evaluating, and solving problems in contexts that resemble the real world.

Consequently, this study aims to examine how the use of simulation-based learning media in digital electronics instruction can enhance students' critical thinking skills, while considering basic ICT proficiency as a moderating variable.

Research Hypotheses:

H1: Simulation-based learning has a significant effect on students' critical thinking skills
H2: Basic ICT skills have a significant effect on students' critical thinking skills.
H3: There is an interactive effect between learning strategies and basic ICT skills on students' critical thinking skills.

METHODS

Research Method

This study is a quantitative experiment. It employs a quasi-experimental design known as the Nonequivalent Control Group Design, which consists of treatments, outcome measures, and experimental units, but the participants are not randomly assigned. The experimental group receives the treatment, and the control group serves as a comparison. This study uses a 2x2 factorial design, which means it consists of two factors: a digital electronics learning model based on circuit simulation media, each with two levels of ICT proficiency low and high. The effect of each independent variable on its dependent variable and the relationship between these variables can be observed separately and simultaneously through treatment or manipulation using this factorial design. To analyze the data, a two-way analysis of variance (ANOVA) was used in conjunction with the IBM SPSS statistical software.

Research Subjects

This study was conducted at SMK Negeri 2 Kupang, Indonesia, in the 11th-grade Industrial Electronics (ELIN) program. In this study, two parallel classes were selected, with 11th-grade ELIN Class 1 serving as the experimental group and 11th-grade ELIN Class 2 serving as the control group. All students enrolled in the Electronic Control Systems course served as research subjects. Prior to the study, the research subjects were given a pretest to assess the initial proficiency of both classes in the subject. The pretest results were statistically analyzed using the t-test, and the research subjects were selected based on the criterion of homogeneous initial proficiency.

Research Variables

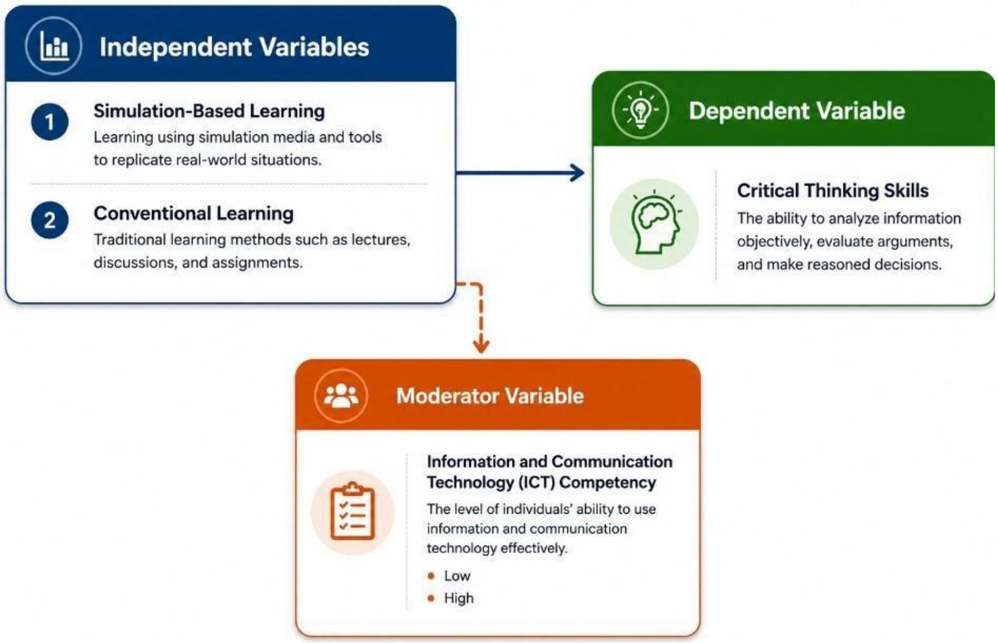

Figure 1. Relationship Between Research Variables

Figure 1 illustrates the relationship between the dependent variable—also known as the response variable or criterion—which is influenced by other variables. In this study, the dependent variable is critical thinking skills, while the independent variables are simulation-based learning and conventional learning; the moderator variable is basic ICT proficiency.

SIMULATION-BASED LEARNING

Circuit Simulation and Coding Media

The implementation of simulation-based learning in the digital electronics course is specifically designed to develop students' critical thinking skills through the integration of circuit simulation media and coding activities. In the initial stage, the activity involves presenting students with contextual problems that require analysis, such as designing or repairing simple digital circuits. Students then use circuit simulation tools to identify components, test interconnections, and systematically analyze the circuit's function and performance. Through this process, students are encouraged to formulate hypotheses, evaluate simulation results, and make improvements based on the evidence obtained.

Next, coding activities are used to deepen critical thinking by translating circuit concepts into algorithmic logic. In this stage, students not only write code but also analyze logical flow, identify errors (debugging), and evaluate the effectiveness of the resulting solutions. This process trains students in logical reasoning, decision-making, and reflection on their work. Teachers act as facilitators who guide discussions, provide guiding questions (scaffolding), and encourage students to explain the reasoning behind each decision they make.

Thus, simulation-based learning serves not only as a means of visualizing concepts but also as a medium that actively stimulates critical thinking skills through analysis, evaluation, and reflection. The integration of circuit simulation and coding enables students to build a deeper understanding and develop the ability to solve problems logically and in a structured manner, in line with the demands of 21st-century learning.

Basic ICT Skill

Xiong & Ning (2015) state that ICT skills are fundamental and vital for students in responding to advancements and the needs of the information technology industry after they graduate. These skills include logical analysis, which helps students analyze and solve problems. In vocational high schools (SMK), there is a basic programming course designed to train students to systematically describe and design problem-solving approaches; students will struggle to solve a problem if they do not fully understand each statement in the computer language (Nurhidayati et al., 2018) . This skill plays a crucial role in preparing students to contribute in the future by introducing them to fundamental concepts involving algorithmic thinking—specifically, defining problems, breaking them down into smaller parts, and identifying the steps to solve them (Denner et al., 2012) .

An understanding of programming is inseparable from an understanding of computers, software, or ICT. Mastering ICT can help students develop their skills. Lee et al. (2007) found an improvement in students' practical skills as a result of learning using computer software and short-term modules in web-based PBL and SRL. Soraya et al. (2019) state that students need to adapt to advances in web technology and be trained to learn independently so that they will ultimately be able to adapt to the world of work, which demands new competencies to keep pace with the latest technologies. Verhoeven et al. (2016) add that mastery of ICT can be achieved through training in high school as an investment in students' future, because without adequate knowledge of basic ICT skills, students will face difficulties in their professional lives. This also applies to college students. In addition to students, teachers today must also master ICT, especially in classroom instruction. This presents both an opportunity and a challenge for teachers in creating meaningful and enjoyable learning experiences if they are able to utilize information and communication technology in the learning process (Patmanthara & Hidayat, 2018);. found that, demographically, younger teachers possess better digital skills than their senior counterparts, whereas Nurhabibah et al. (2018) highlighted gender differences, noting that male teachers use ICT literacy presentations in teaching more frequently than female teachers. These foundational concepts served as a reference in designing the basic ICT competency instrument.

Basic ICT skills in this study were positioned as a moderator variable measured using a Likert-scale questionnaire. This measurement refers to the concept of digital literacy, which encompasses basic skills in operating technology, utilizing software, accessing and managing information, and communicating digitally. Indicators of basic ICT skills include: (1) computer operation and file management skills, (2) the use of learning support software, (3) the ability to search for and evaluate information via the internet, (4) digital communication and collaboration, and (5) simple technology-based problem-solving. Each indicator is broken down into several items organized on a five-point Likert scale, ranging from "strongly disagree" to "strongly agree." This instrument is used to identify students' levels of basic ICT proficiency, which are then analyzed as a moderating variable in the relationship between the use of simulation-based learning media and critical thinking skills. Before use, the instrument was tested for validity and reliability to ensure the accuracy and consistency of the measurement.

RESULTS & DISCUSSION

Describes the outcome can be an increase in knowledge, skill or product. The results also reveal the level of achievement of the target activity. If in the form of objects there needs to be an explanation of product specification, its advantages and disadvantages. Output writing should include photos, charts, graphs, charts, drawings and more. The discussion is sequential in the order in which the objectives are, and it has been described first. The discussion is accompanied by a logical argument by linking the results with theories, other results and/or research results.

The results begins by presenting the results of the statistical tests in Tables 1 and 2 below:

Table 1. Description of Research Data

Learning	Basic ICT Skills	Mean	Standard Deviation	N
Simulink-Based	Low	78.9113	9.78811	16
	High	81.6089	10.82710	19
	Total	80.3757	10.30475	35
Conventional	Low	72.7938	12.06881	13
	High	74.8358	9.47605	19
	Total	74.0063	10.46712	32
Total	Low	76.1690	11.10565	29
	High	78.2224	10.60623	38
	Total	77.3336	10.79068	67

Table 2. ANOVA Test Results

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	773.581[a]	3	257,860	2,351	.081
Intercept	388,073.811	1	388,073.811	3,537.453	.000
Learning	679,101	1	679,101	6,190	.016
Basic_ICT_Skills	91,808	1	91,808	.837	.364
Learning * Basic_ICT_Skills	1,757	1	1,757	.016	.900
Error	6,911.372	63	109,704		
Total	408,377.308	67			
Corrected Total	7,684.952	66			

Significant Differences in Critical Thinking Skills Between Students in Simulation-Based Circuit Learning and Conventional Learning

The results of the two-way ANOVA test to examine differences in critical thinking skills, as shown in Table 2, between students who participated in circuit simulation-based learning and those who participated in conventional learning indicate a significance level (sig) of 0.016. Since this value is less than 0.05 (i.e., $0.016 < 0.05$), it can be concluded that there is a significant difference in critical thinking skills between students who participated in circuit simulation-based learning and those who participated in conventional learning. These results indicate that circuit simulation-based learning has a significant effect on students' critical thinking skills.

Circuit simulation-based learning presents material in a more interactive and practical manner. Circuit simulation software is typically used in the context of system modeling and simulation, which allows students to apply their theoretical knowledge to real-world situations. This interactivity can foster the development of critical thinking skills through problem-solving and contextual analysis. Circuit simulation software is a high-tech tool that can enhance students' skills in using technology. The use of technology in this learning process encourages students to think critically because they can integrate conceptual knowledge with the use of tools or software. In contrast, conventional teaching methods may rely more on lectures, textbooks, and class discussions without direct involvement in modeling and simulation. This approach provides fewer opportunities than circuit simulation-based learning to apply knowledge in more practical situations. Circuit simulation software is often used for technical problem-solving. Learning that encourages problem-solving can hone students' critical thinking skills, as they need to identify problems, analyze options, and make decisions.

Significant Differences in Critical Thinking Skills Between Students with Low and High Basic ICT Skills

The results of a two-way ANOVA test to examine differences in critical thinking skills, as shown in Table 2, between students with low ICT proficiency and those with high ICT proficiency, indicate a significance value (sig) of 0.364. Since this value is greater than 0.05 (i.e., 0.364 > 0.05), it can be concluded that there is no significant difference in critical thinking skills between students with low ICT proficiency and those with high ICT proficiency. This result suggests that basic ICT proficiency does not have a significant effect on students' critical thinking skills.

The lack of a significant influence of students' ICT proficiency on their critical thinking skills is because ICT proficiency is only one of many factors that can influence critical thinking skills. It is possible that other factors, such as teaching methods, the learning environment, and motivation, have a more significant impact on the development of critical thinking skills. Although students have different levels of ICT proficiency, there may be similarities in the educational experiences they receive. If teaching methods or the curriculum do not provide significant differences in content that stimulates critical thinking skills, then differences in ICT proficiency may not have a significant impact. If ICT is not effectively integrated into teaching methods or the curriculum, students with high ICT proficiency may not gain a significant advantage. Ineffective integration can result in a lack of opportunities for students to develop critical thinking skills through the use of technology. Each individual has a unique learning style and way of thinking. ICT proficiency alone may not directly correlate with critical thinking skills because other individual factors play an important role. Different educational contexts, both at the school and national levels, may play a role in the research results. An educational system that is more focused on the overall development of critical thinking skills may make differences in ICT proficiency less pronounced in the final research results.

The Effect of the Interaction Between Learning Media and Basic ICT Skills on Students' Critical Thinking Skills in Digital Electronics

The results of the two-way ANOVA test to examine the interaction effect between the applied learning strategies and basic ICT skills on critical thinking skills, as shown in Table 2, indicate a significance value (sig) of 0.900. Since this value is greater than 0.05 (i.e., 0.900 > 0.05), it can be concluded that there is no interaction effect between the implemented learning strategies and basic ICT skills on critical thinking skills.

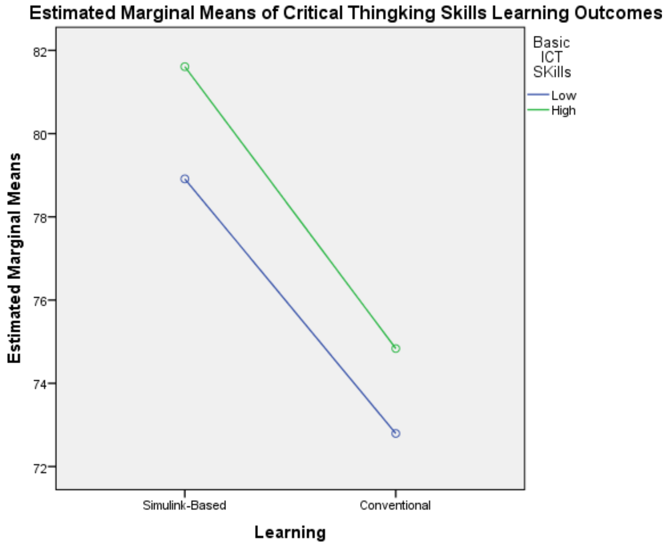

Figure 2. Interaction Pattern Between Learning and Basic ICT Skills on Critical Thinking Skills

The test of the interaction effect between the implemented learning strategies and basic ICT proficiency on critical thinking skills in this study can also be supported by examining the interaction patterns among the variables. The research results based on the interaction pattern are illustrated and explained in Figure 2. The interaction pattern shows no intersection of lines between either low or high levels of basic ICT proficiency and the two types of learning methods regarding critical thinking skills; thus, it can be interpreted that there is no interaction between the learning methods and basic ICT proficiency on students' critical thinking skills.

These results indicate that the independent variable and the moderator variable exert independent effects on the dependent variable, where the independent variable (learning method) and the moderator variable (basic ICT proficiency) have equally strong effects on the dependent variable, namely critical thinking skills. According to Hare et al. (1995), if the effect is not significant, then the independent variables have independent effects. Independence in a factorial design means that the effect of one treatment is as strong as that of the other treatments.

When examining the mean values in Table 1 for critical thinking skills among student groups using circuit simulation-based learning and conventional learning, the mean score for the circuit simulation-based learning group is significantly higher than that of the conventional learning group. Descriptive statistical data show an average score of 80.37 for circuit simulation-based learning and 74.00 for conventional learning. This indicates that circuit simulation-based learning has a more positive effect than conventional learning. Another finding pertains to students with low and high basic ICT skills. The average scores for students with high basic ICT skills exceeded those of students with low basic ICT skills for both types of instruction. Therefore, it can be concluded that students with high basic ICT skills demonstrate better performance in terms of critical thinking skills.

Circuit simulation-based learning presents material in a more interactive and practical way. Circuit simulation software is typically used in the context of system modeling and simulation, which allows students to apply their theoretical knowledge to real-world situations. This interactivity can foster the development of critical thinking skills through problem-solving and contextual analysis. Circuit simulation software is a high-tech tool that can enhance students' skills in using technology. The use of technology in this learning approach encourages students to think critically because they can integrate conceptual knowledge with the use of tools or software. In contrast, conventional learning methods may rely more on lectures, textbooks, and class discussions without direct involvement in modeling and simulation. This approach provides fewer opportunities than circuit simulation-based learning to apply knowledge in more practical situations. Circuit simulation software is often used for technical problem-solving. Learning that encourages problem-solving can hone students' critical thinking skills, as they need to identify problems, analyze options, and make decisions.

The significant differences in critical thinking skills observed between students using circuit simulation software and those receiving conventional instruction can be attributed to several key factors. First, the use of circuit simulation software allows students to participate in simulations that replicate real-world conditions, which require analytical and critical thinking to understand and solve complex problems. Second, the interactive, project-based learning environment offered by circuit simulation software can increase student engagement and foster a deeper understanding of the subject matter. Third, the use of advanced technology in this learning process can boost student motivation and expand their skills in technology and practical applications, all of which contribute to the development of critical thinking skills.

Conversely, the research findings indicate that there is no significant difference in critical thinking skills between students with low ICT proficiency and those with high ICT proficiency. This may be due to several factors. One is that ICT proficiency, while important, may not be the sole factor influencing critical thinking skills. Other factors such as teaching methods, the learning environment, and student motivation may have a greater influence. Furthermore, even though students have different ICT proficiency levels, the educational experiences they receive may be similar, so differences in ICT proficiency do not have a significant impact on their critical thinking skills. Additionally, if technology is not effectively integrated into the curriculum, students with high ICT proficiency may not derive significant benefits. Teaching that does not make full use of technology does not provide students with the opportunity to develop their critical thinking skills through the use of technology.

The analysis results also indicate that there is no interaction effect between the implemented learning strategies and basic ICT proficiency on critical thinking skills. This suggests that the two independent variables—learning strategies and basic ICT proficiency—have independent effects on students' critical thinking skills. In other words, each of these variables influences critical thinking skills separately, without any significant interaction between them. When the interaction is not significant, the independent variables have independent effects in a factorial design, meaning that the effect of one treatment is just as strong as that of the other.

The use of simulation tools in engineering education provides students with the opportunity to explore concepts in greater depth through virtual experiments. This approach allows students to directly observe the relationships between variables and test various possible solutions to a problem. Simulation-based learning also offers a more interactive learning experience compared to conventional teaching methods, which tend to be teacher-centered. Previous research has shown that integrating simulation technology into engineering education can improve students' conceptual understanding, problem-solving skills, and critical thinking abilities (Maknun, 2019; Samani et al., 2019; Wrahatnolo & Munoto, 2018). Thus, the use of simulation media can serve as an effective alternative instructional strategy for enhancing the quality of learning in vocational education.

CONCLUSION

There is a significant effect of circuit simulation-based learning on students' critical thinking skills. There is no significant effect of students' basic ICT proficiency-whether high or low-on their critical thinking skills. There was no interaction effect between the implemented learning strategy and students' basic ICT skills on their critical thinking skills.

These results indicate that circuit simulation-based learning has a positive and significant impact on the improvement of students' critical thinking skills. This learning method can be considered an effective strategy for developing critical thinking skills. On the other hand, students' basic ICT proficiency-whether high or low-does not make a significant contribution to the development of critical thinking skills. This suggests that, in the context of enhancing critical thinking skills, factors other than basic ICT proficiency may be more relevant. The absence of a significant interaction between the learning strategy and basic ICT proficiency on students' critical thinking skills indicates that the success of circuit simulation-based learning in enhancing critical thinking skills does not depend on students' level of basic ICT proficiency.

Overall, these results can help researchers, educators, and educational practitioners understand the importance of using specific learning methods (such as circuit simulation media) in developing students' critical thinking skills, while acknowledging that basic ICT skills may not be a determining factor in this context.

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