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ORIGINAL

Digital Technology Innovation in TVET: Rifdarmon-Based E-Learning Model Enhancing Learning Outcomes and 4C Skills

Innovación tecnológica digital en la EFTP: El modelo de aprendizaje electrónico de Rifdarmon mejora los resultados del aprendizaje y las competencias 4C

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ABSTRACT

Automotive Electrical Electronics courses require effective learning models that can develop both technical knowledge and 21st-century skills. E-learning approaches offer potential solutions to enhance educational outcomes in this field. This study examined the effectiveness of the Rifdarmon-Based E-Learning Model in improving learning outcomes and 4C skills (creativity, critical thinking, collaboration, and communication) in an Automotive Electrical Electronics course at Universitas Negeri Padang's Automotive Engineering Department. The research employed an experimental design comparing an experimental group using the Rifdarmon-Based E-Learning Model with a control group using conventional learning methods. Pre-tests and post-tests were conducted to measure learning outcomes, while specialized assessments evaluated 4C skills development. The experimental group showed significant improvements in learning outcomes, with pre-test scores increasing from 69,1 to 87,2 in post-test, compared to the control group's increase from 64,9 to 84,4. The 4C skills assessment revealed higher scores in the experimental group (86,6) versus the control group (74,95). Statistical analyses confirmed the model's effectiveness with a large effect size (point estimate -2,511) and significant multivariate test results ($F=29,356$, $p<0,001$). The Rifdarmon-Based E-Learning Model proved effective in enhancing both learning outcomes and 4C skills development in Automotive Electrical Electronics education. The integration of e-learning with the Rifdarmon model demonstrated significant improvements in students' academic performance and complex skill development compared to conventional learning methods.

Keywords: 4C Skills; Learning Outcomes; Rifdarmon-Based E-Learning Model; Vocational Education.

RESUMEN

Los cursos de Electrónica Eléctrica Automotriz requieren modelos de aprendizaje efectivos que puedan desarrollar tanto conocimientos técnicos como habilidades del siglo XXI. Los enfoques de e-learning ofrecen soluciones potenciales para mejorar los resultados educativos en este campo. Este estudio examinó la efectividad del Modelo de E-Learning Basado en Rifdarmon para mejorar los resultados de aprendizaje y las habilidades 4C (creatividad, pensamiento crítico, colaboración y comunicación) en un curso de Electrónica Eléctrica Automotriz en el Departamento de Ingeniería Automotriz de la Universidad Estatal de Padang. La investigación empleó un diseño experimental comparando un grupo experimental que utilizó el Modelo de

E-Learning Basado en Rifdarmon con un grupo de control que utilizó métodos de aprendizaje convencionales. Se realizaron pruebas previas y posteriores para medir los resultados del aprendizaje, mientras que evaluaciones especializadas valoraron el desarrollo de las habilidades 4C. El grupo experimental mostró mejoras significativas en los resultados de aprendizaje, con un aumento en las puntuaciones de la prueba previa de 69,1 a 87,2 en la prueba posterior, en comparación con el aumento del grupo de control de 64,9 a 84,4. La evaluación de habilidades 4C reveló puntuaciones más altas en el grupo experimental (86,6) versus el grupo de control (74,95). Los análisis estadísticos confirmaron la efectividad del modelo con un tamaño del efecto grande (estimación puntual -2,511) y resultados significativos en las pruebas multivariadas ($F=29,356$, $p<0,001$). El Modelo de E-Learning Basado en Rifdarmon demostró ser efectivo para mejorar tanto los resultados de aprendizaje como el desarrollo de habilidades 4C en la educación de Electrónica Eléctrica Automotriz. La integración del e-learning con el modelo Rifdarmon demostró mejoras significativas en el rendimiento académico de los estudiantes y en el desarrollo de habilidades complejas en comparación con los métodos de aprendizaje convencionales.

Palabras clave: Habilidades 4C; Resultados del Aprendizaje; Modelo de E-Learning Basado en Rifdarmon; Formación Profesional.

INTRODUCTION

Vocational education plays a strategic role in developing competent and adaptive human resources for industrial development. Vocational education institutions are responsible for developing curricula and learning models that align with industry needs.[1] The formation of specific competencies and practical experiences relevant to the workplace is the main focus of vocational education.[2] In the context of Industry 4.0, vocational education challenges are becoming more complex as graduates are required to master not only technical skills but also 21st-century skills encompassing creativity, critical thinking, collaboration, and communication (4C).[3] The 4C skills have become fundamental components in the global competency framework for facing modern workplace dynamics.[4] Digital transformation across various industrial sectors has changed the learning paradigm in vocational education. Adaptation to the new normal era has accelerated digital technology integration in vocational learning.[5] Mastery of 4C skills has become increasingly crucial in preparing graduates to face digital industry challenges.[6] The ability to integrate technology and 4C skills is a significant predictor of graduate success in modern industry.[7]

The Automotive Engineering Department at the Faculty of Engineering, Universitas Negeri Padang (UNP), as a vocational education provider, faces challenges in preparing automotive professionals. The automotive engineering program needs to adjust its curriculum and learning models to meet the increasingly complex needs of the modern automotive industry. Observations at the Automotive Engineering Department show a gap between industry demands and student learning outcomes, particularly in the Automotive Electrical Electronics course, which is an important foundation for understanding modern vehicle systems. Final semester grade analysis shows that only 62 % of students achieve a minimum B grade, while 38 % still obtain grades below B.

The Rifdarmon-Based E-Learning Model emerges as a solution to overcome various learning challenges faced in implementing the PBL model in the Automotive Electrical Electronics course, and to bridge the weaknesses of the Jigsaw cooperative model and peer tutoring. This is evidenced through effectiveness test results showing significant impact on student learning outcomes in three assessment aspects: cognitive ($\eta^2 = 0,263$), performance ($\eta^2 = 0,579$), and portfolio ($\eta^2 = 0,595$).[8] The integration of e-learning into problem-based learning models can increase learning effectiveness, as evidenced by research finding that PBL model development through virtual learning environments can improve students' problem-solving abilities and learning motivation.[9] This is reinforced by previous researchers' findings validating the Rifdarmon-Based E-Learning Model[10] and strengthened by evidence that e-learning environments integrated with PBL can create more interactive and in-depth learning experiences.[11] Other research demonstrates the positive impact of virtual learning environments designed according to the PBL approach.[12] In the vocational education context, PBL implementation in interactive learning media can increase student engagement[13] and has proven effective in improving student learning outcomes in basic electronics courses.[14] E-learning systems play an important role in developing creative thinking for higher education students.[15] Recent studies show that integrating e-learning innovations into problem-based learning can improve learning outcomes,[16] while mobile technology utilization can enhance student skill development[17] and has a positive influence on learning outcomes in STEM education.[18]

Various efforts have been made to integrate 4C skills development in vocational learning. Previous research shows that blended learning approaches combined with Problem-Based Learning (PBL) are effective in improving students' critical thinking abilities and learning activities.[8] Recent studies reveal the effectiveness of blended

learning in the new normal era,[19] and blended learning implementation with synchronous and asynchronous settings has proven effective in improving students' self-efficacy and learning achievement.[20] Learning models integrating digital technology in vocational education have shown promising results in developing higher-order skills.[21,22,23,24,25,26,27,28]

Although various studies have shown the effectiveness of learning models and the benefits of e-learning integration in learning, there are still several research gaps that need to be addressed. First, no research specifically examines the effectiveness of the Rifdarmon-Based E-Learning Model integrated with e-learning, particularly in the context of Automotive Electrical Electronics learning. Second, although previous research has examined the impact of the Rifdarmon-Based E-Learning Model on student learning outcomes,[9] no studies have investigated its influence on developing 4C skills that are highly needed in the digital era. The urgency of this research is supported by the rapid transformation of automotive technology, the need for learning models that can integrate 4C skills development with digital technology utilization, and Industry 4,0 demands requiring vocational education graduates to possess both technical competencies and 4C skills. This research aims to analyze the effectiveness of the Rifdarmon-Based E-Learning Model on student learning outcomes and 4C skills in the Automotive Electrical Electronics course.

METHOD

This research employs a quantitative approach with a quasi-experimental pretest-posttest control group design to test the effectiveness of the e-learning-based Rifdarmon-Based E-Learning Model. This design was chosen as it allows researchers to compare learning outcomes and 4C skills between the experimental group using the e-learning-based Rifdarmon model and the control group using conventional learning, while controlling variables that could affect the research's internal validity. The research subjects consist of 40 students from the Automotive Engineering Department, Faculty of Engineering, Universitas Negeri Padang, who are enrolled in the Automotive Electrical Electronics course during the odd semester of the 2024/2025 academic year. Subject selection used purposive sampling technique, considering the homogeneity of students' academic characteristics based on previous learning outcomes. Subjects were divided into two groups: the experimental group (20 students) using the e-learning-based Rifdarmon model and the control group (20 students) following conventional learning. Furthermore, the stages or flow in this research consist of three main phases: preparation, implementation, and analysis phases, as shown in figure 1 below.

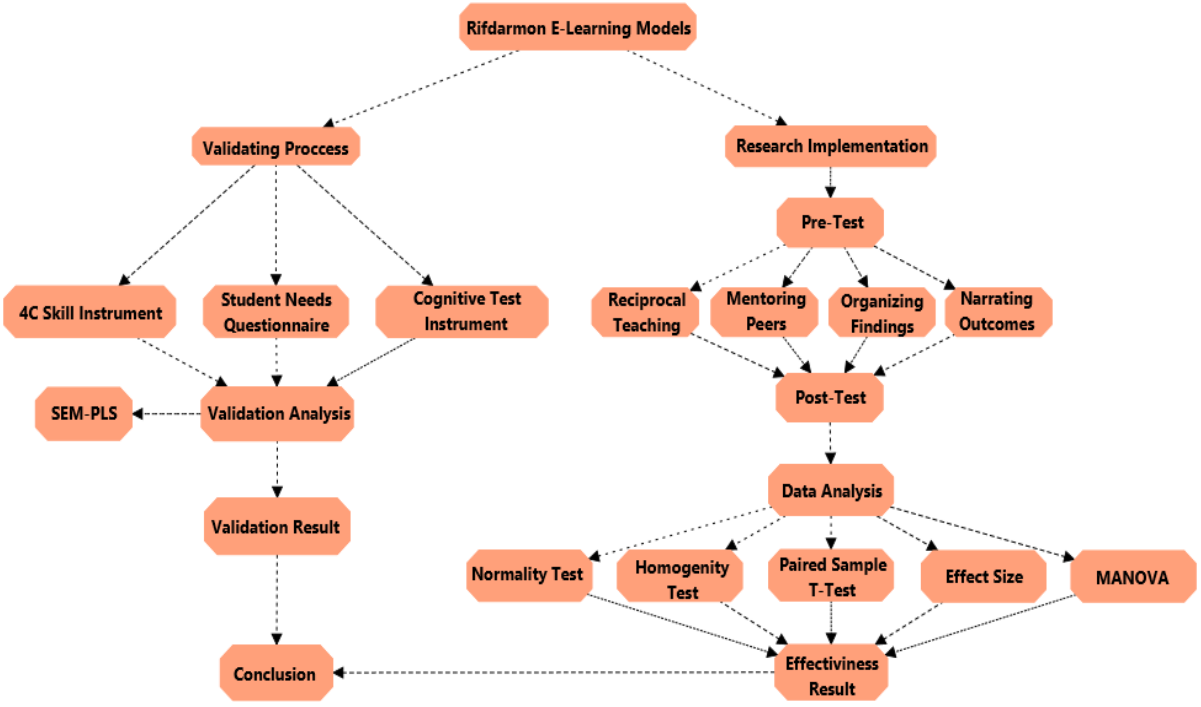

Figure 1. Research Flow

The preparation phase includes instrument development, expert validation, and instrument trials to determine empirical reliability and validity. The instruments in this research consist of three main components: First, a questionnaire on student needs response toward learning model implementation. Second, learning outcome tests in the form of pretest and posttest covering cognitive aspects in the Automotive Electrical Electronics course. Third, 4C skills assessment rubrics developed based on indicators of creativity, critical

thinking, collaboration, and communication. These three instruments will undergo validation by vocational education experts, learning evaluation experts, and automotive industry practitioners to ensure content and construct validity. This research uses Structural Equation Modeling-Partial Least Square (SEM-PLS) analysis in SmartPLS version 4.0 software to ensure the construct validity of the e-learning-based Rifdarmon model. This validation analysis includes evaluation of the measurement model for each aspect covering internal consistency reliability shown by Cronbach's alpha values, composite reliability (rho_c), reliability coefficient (rho_a), and convergent validity reflected in average variance extracted (AVE) values. After instrument validation, the next stage is implementation.

The implementation phase begins with pretests for both groups, followed by implementing the e-learning-based Rifdarmon model in the experimental group for 5 meetings. In its implementation, the syntax of the e-learning-assisted Rifdarmon-Based E-Learning Model harmoniously combines online and offline learning through four main stages: reciprocal teaching, mentoring peers, organizing findings, and narrating outcomes. The reciprocal teaching phase begins with administering a pre-test conducted online through the e-learning platform to measure students' initial knowledge. In this stage, students perform reciprocal teaching by combining online and offline sessions. Online, students access digital materials such as video tutorials, interactive simulations, and learning documents through the learning management system (LMS). Meanwhile, offline laboratory sessions allow students to conduct demonstrations and direct practice using props and physical models. In the mentoring peers phase, the guidance process is implemented in a hybrid manner. Students acting as mentors can provide intensive guidance through various digital channels such as video calls and online discussion groups outside practicum hours. Meanwhile, laboratory mentoring sessions enable hands-on practice with direct supervision. Mentors share additional digital learning resources through LMS, such as articles, demonstration videos, and interactive exercises. In the organizing findings phase, each group organizes and consolidates their findings in a structured digital format. Students utilize various digital tools such as mind mapping tools and document collaboration platforms to systematically arrange findings while still making physical notes and direct documentation during practicum. Finally, in the narrating outcomes phase, groups prepare multimedia presentations including practicum demonstration recordings, interactive data visualization, and learning process documentation. Presentations are conducted virtually through video conference platforms. Question and answer sessions are conducted synchronously, utilizing online polling features for real-time feedback while maintaining dynamic face-to-face discussions. After these four stages are completed, lecturers can utilize analytics tools in e-learning to track student participation and progress online through post-tests, while still conducting direct observation of their practical skill development.

The final phase in this research is data analysis, which includes quantitative data processing and research results interpretation. Data analysis uses inferential and descriptive statistical approaches. Prerequisite analysis tests include normality testing using Kolmogorov-Smirnov and homogeneity testing using Levene's test. Hypothesis testing uses independent sample t-test to compare learning outcomes between both groups and MANOVA to analyze 4C skills differences simultaneously. Effect size is calculated using Cohen's d to determine the magnitude of intervention effect. Gain score analysis is used to measure improvements in learning outcomes and 4C skills in each group.

RESULTS

The results of this research consist of the validity and effectiveness of implementing the e-learning-assisted Rifdarmon-Based E-Learning Model in the Automotive Electrical Electronics course. The validation results include assessment of student needs questionnaires, cognitive test instruments, and 4C skills assessment instruments. The effectiveness results were obtained from pre-test, post-test, and formative assessments measuring students' intellectual domain understanding and 4C skills.

Validation Results Summary

The validation of research instruments was conducted using the SEM-PLS method in Smartpls4 software. Table 1 presents a comprehensive summary of validation results across all three instruments.

Table 1 shows that all instruments demonstrated adequate validity and reliability. For the student needs questionnaire, collaboration and communication aspects showed the highest reliability values (CR > 0,9). The cognitive test instrument validation indicated strong reliability for material and technical aspects (CR > 0,9). The 4C skills assessment demonstrated excellent reliability across all aspects, with creativity showing the highest Cronbach's alpha (0,966). These findings establish the robust psychometric properties of all research instruments, particularly the 4C Skills Assessment which shows exceptional reliability values across all aspects.

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Table 1. Consolidated Validation Results of Research Instruments

Instruments Variable	Assessment Aspect	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Cronbach's Alpha	AVE
Validity of Student Needs Questionnaire	Collaboration	0,946	0,964	0,944	0,900
	Creativity	0,755	0,787	0,566	0,583
	Kognitif	0,773	0,834	0,700	0,632
	Communication	0,872	0,909	0,846	0,772
	Critical Thingking	0,710	0,824	0,671	0,616
Cognitive Test Instrument	Language	0,869	0,845	0,757	0,606
	Cognitive	0,841	0,889	0,835	0,667
	Construction	0,885	0,839	0,739	0,583
	Material	0,911	0,928	0,894	0,765
	Technical	0,907	0,916	0,876	0,735
4C Skills Assessment	Collaboration	0,954	0,948	0,931	0,785
	Communication	0,944	0,946	0,927	0,779
	Creativity	0,961	0,966	0,955	0,849
	Critical Thinking	0,912	0,922	0,892	0,704

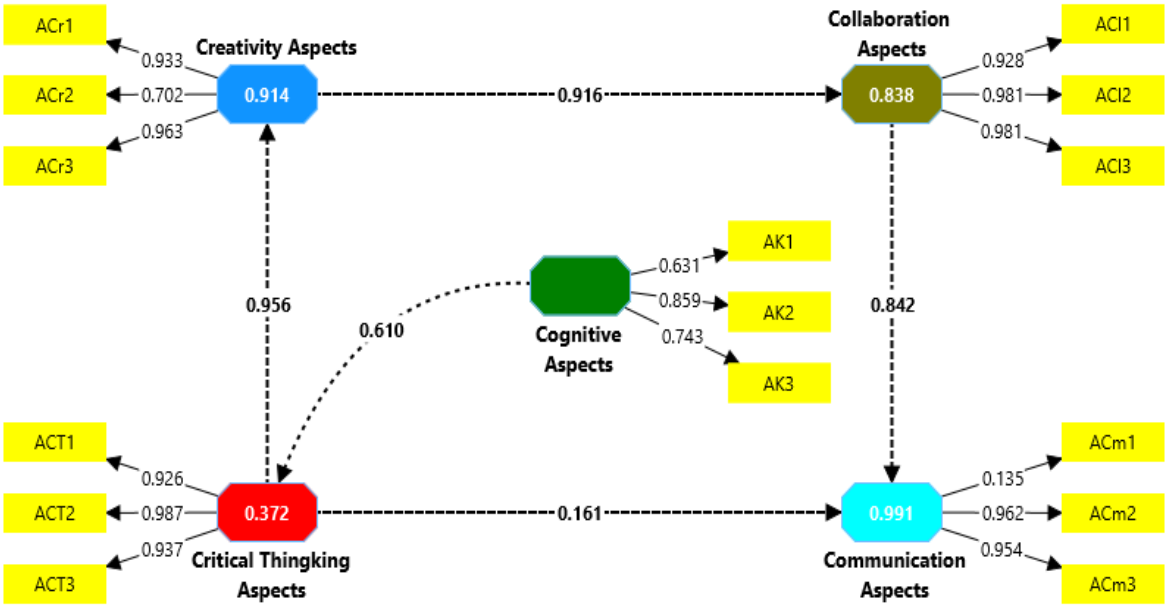

Figure 2. Graphical Output of Student Needs Questionnaire

Figure 2 shows the path model for the Student Needs Questionnaire, highlighting strong connections between aspects. The relationship between Creativity and Collaboration (0,916) demonstrates the strongest connection, followed by Critical Thinking and Creativity (0,956). The model shows significant path coefficients between all five aspects (Creativity, Collaboration, Cognitive, Communication, and Critical Thinking), with factor loadings ranging from 0,631 to 0,981 for their respective indicators.

Figure 3 displays the path model for the Cognitive Test Instrument, revealing interconnections among Language, Cognitive, Construction, Material, and Technical aspects. The relationship between Technical and Construction (0,753) shows a strong connection, while factor loadings for indicators range from 0,292 to 0,951, indicating varying levels of construct representation. Notable connections include Material to Cognitive (0,756) and Construction to Language (0,790).

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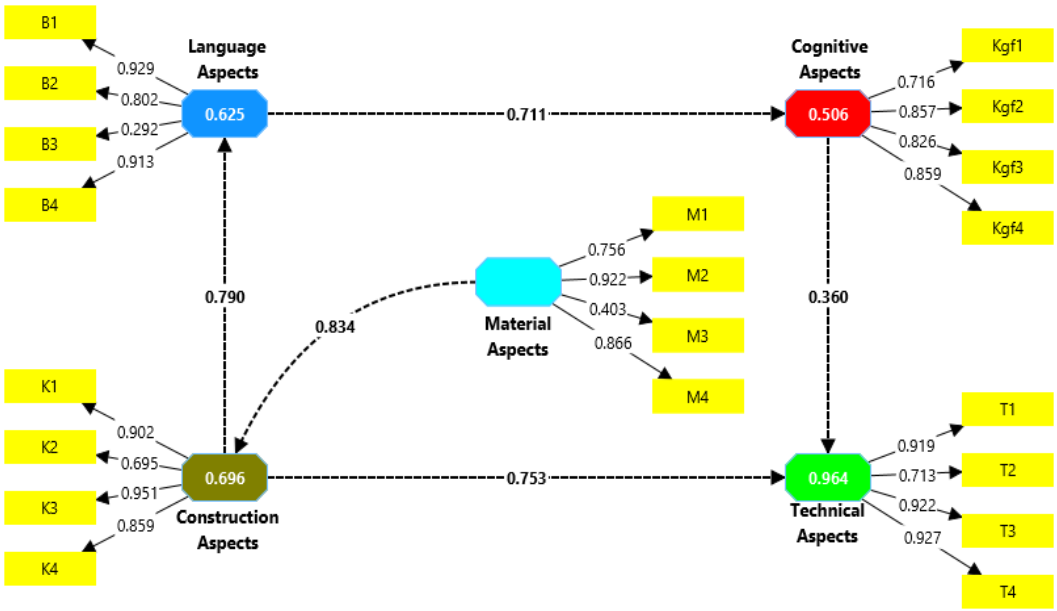

Figure 3. Graphical Output of Cognitive Test Instrument Validation

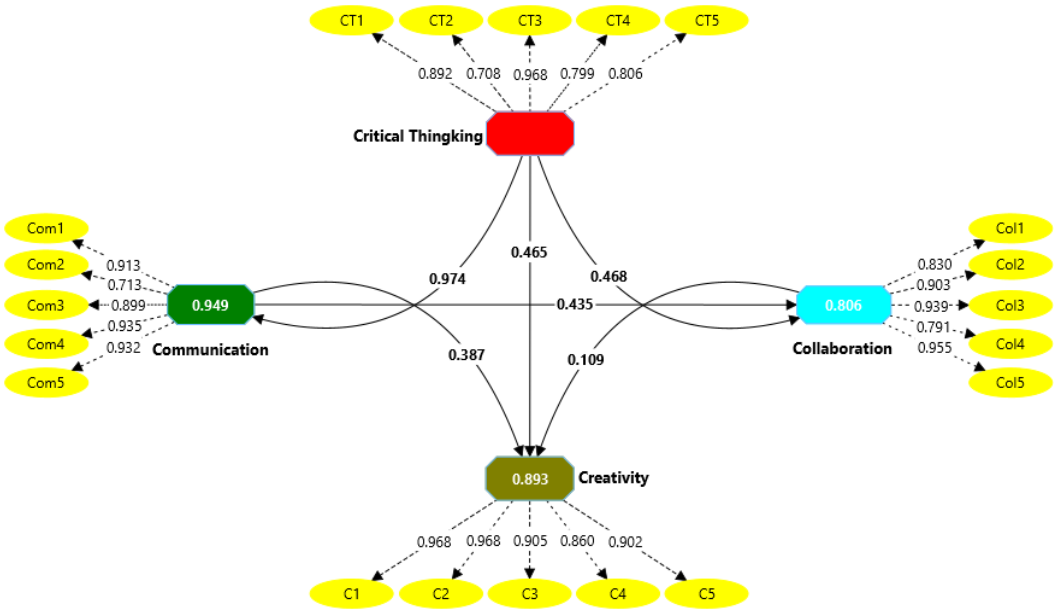

Figure 4. Graphical Output of 4C Skills Assessment Validation

Figure 4 illustrates the path model for 4C Skills Assessment, showing a network of relationships among Critical Thinking, Communication, Collaboration, and Creativity. This supports theoretical frameworks by Facione[29], Griffin et al.[30], Trilling et al.[31] and Sternberg[32] which emphasize the interconnected nature of these 21st century skills. The strongest connection appears between Critical Thinking and Communication (0,974), while the relationship between Critical Thinking and Creativity (0,435) and Critical Thinking and Collaboration (0,468) shows moderate strength. The factor loadings for indicators are consistently high (mostly above 0,8), indicating excellent representation of measured constructs.

Efectiveness Result

The effectiveness of the Rifdarmon-Based E-Learning Model was assessed by comparing learning outcomes and 4C skills between control and experimental classes. Figure 5 presents these results graphically.

Based on the analysis of the graph of student learning outcomes and 4C skills, it can be explained that the pre-test results show that both classes have relatively equal initial abilities, with the control class obtaining an average score of 69,9 and the experimental class 70,4. This slight difference in scores indicates that both groups have almost the same level of basic knowledge before being given treatment. After the implementation of the learning model, the post-test results showed a significant increase in both classes. The control class achieved an average score of 81,1, while the experimental class showed higher results with an average score of 88,2. The difference in post-test scores indicates that the Rifdarmon-Based E-Learning Model has a positive impact

on student learning outcomes. In the aspect of 4C skills, there is a substantial difference between the two classes. The control class obtained an average score of 71,95, while the experimental class achieved an average score of 86,6. This considerable gap in scores indicates that the application of the Rifdarmon-Based E-Learning Model has a better influence in developing students' 4C skills compared to conventional learning. Based on the three aspects of the assessment, it can be identified that the experimental class using the Rifdarmon-Based E-Learning Model consistently shows superior results compared to the control class, especially in the aspect of 4C skills and learning outcomes (post-test). Based on the description of the learning outcomes data, it is then analyzed through a series of statistical tests to validate its effectiveness. The analysis begins with prerequisite tests including normality and homogeneity tests, followed by paired sample t-test, effect size calculation, and MANOVA analysis. This series of statistical tests aims to measure the significance of the effectiveness of the Rifdarmon-Based E-Learning Model on learning outcomes and 4C skills of Automotive Electronics students comprehensively.

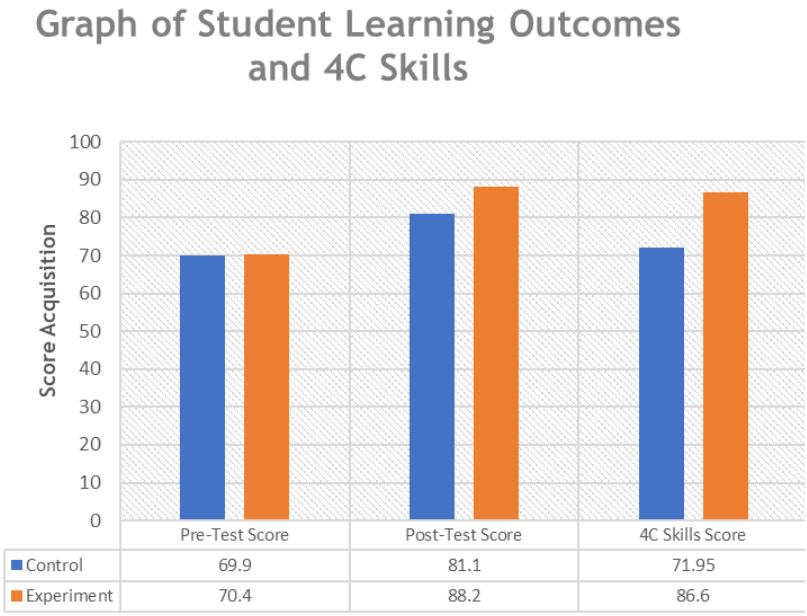

Figure 5. Graph of Student Learning Outcomes and Students' 4C Skills

Statistical Analysis Results

Table 2. Combined Statistical Test Results

Statistical Test	Pair	Value	Statistical Significance	Practical Significance
Paired Sample T-Test	Pre-test * Post-test	t = -15,880	p < 0,001 (highly significant)	-
	Pre-test * 4C Skills	t = -10,892	p < 0,001 (highly significant)	-
	Post-test * 4C Skills	t = 3,798	p < 0,001 (highly significant)	-
Effect Size (Cohen's d)	Pre-test * Post-test	d = -2,511	-	Very large effect (d > 0,8)
	Pre-test * 4C Skills	d = -1,722	-	Very large effect (d > 0,8)
	Post-test * 4C Skills	d = 0,600	-	Moderate effect (0,5 < d < 0,8)
MANOVA	Treatment effect	F = 29,356	p < 0,001 (highly significant)	-
	Pillai's Trace	0,710	p < 0,001	-
	Wilks' Lambda	0,290	p < 0,001	-
	Hotelling's Trace	2,446	p < 0,001	-
	Roy's Largest Root	2,446	p < 0,001	-

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The normality test using Shapiro-Wilk and homogeneity test using Levene's test both confirmed that all data met the assumptions for parametric testing (all p-values > 0,05).

Table 2 presents the consolidated results of the paired sample t-test, effect size analysis, and multivariate test (MANOVA). The paired sample t-test results showed highly significant differences (p < 0,001) between pre-test and post-test scores, pre-test and 4C skills, and post-test and 4C skills. The effect size analysis using Cohen's d revealed very large effects for the comparisons between pre-test and post-test (d = -2,511) and between pre-test and 4C skills (d = -1,722). A moderate effect was observed between post-test and 4C skills (d = 0,600). The MANOVA results indicated that the treatment had a highly significant effect on all dependent variables simultaneously (F = 29,356, p < 0,001). All four test statistics (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root) confirmed the statistical significance of the treatment effect.

Summary of Findings

The validation results established that all research instruments met feasibility standards for use in the study. The effectiveness analysis demonstrated that the Rifdarmon-Based E-Learning Model had a significant positive impact on students' learning outcomes and 4C skills development. The experimental class consistently outperformed the control class, particularly in developing 4C skills. Statistical analyses confirmed both the statistical significance and practical importance of these differences, with very large effect sizes observed in most comparisons. These findings indicate that the e-learning-assisted Rifdarmon-Based E-Learning Model is an effective approach for enhancing both learning outcomes and 21st century skills in Automotive Electrical Electronics education.

DISCUSSION

The statistical analysis results of this study show significant findings that support the research objectives, namely proving the effectiveness of the Rifdarmon-Based E-Learning Model on learning outcomes and 4C skills of Automotive Electronics students. Regarding learning outcomes, the research shows substantial improvement. The experimental class demonstrated an increase in pre-test scores from 69,1 to 87,2 in the post-test, while the control class improved from 64,9 to 84,4. This difference is reinforced by the paired sample t-test which produced a mean difference of -18,800 with significance <0,001. In the development of 4C skills, the experimental class obtained a score of 86,6, considerably higher than the control class which only reached 74,95. This aligns with Kassymova et al.[11] which also found significant improvement in 4C skills through e-learning integration. Multivariate test analysis with four test statistics confirmed the significance of the treatment with an F value = 29,356 and significance <0,001.

The fundamental difference from Rifdarmon et al.[8] lies in focus and context. The previous research focused on three assessment aspects, while this study was more specific on learning outcomes and 4C skills with special emphasis on the Automotive Electronics course. Although both use the Rifdarmon model, this study makes a new contribution by integrating e-learning more comprehensively. The effect size test results in this study obtained a point estimate of -2,511 (very large effect), higher than Rifdarmon's[8] which obtained a value of d ≥ 0,831 (large effect). The 4C skills aspect became an important focus in this study. Analysis showed significant improvement with a mean difference of -13,775 between pre-test and 4C skills. This finding supports previous research examining e-learning integration with a problem-based learning approach, which successfully improved 4C skills, particularly in critical thinking and collaboration aspects.[11] The success of this skill development is further corroborated by research proving that virtual learning environments effectively improve students' problem-solving abilities.[9]

When comparing our findings with similar studies, several interesting patterns emerge. Herayanti et al.[20] reported that blended learning models based on inquiry collaborative tutorials improved students' problem-solving skills with an effect size of 0,78, considerably lower than our effect size of -2,511. This suggests that the Rifdarmon-Based E-Learning Model may offer superior benefits for developing complex cognitive skills. Similarly, Andrini[6] found that blended learning increased 4C competence, but with less dramatic improvements in critical thinking (15,6 % increase) compared to our results showing a 15,7 % difference between experimental and control groups. Mobile technology integration, as demonstrated by Arpan et al.[17] and Yu et al.[18], has shown enhanced skill development in STEM education with effect sizes ranging from 0,70 to 0,85. Our study extends this line of research by specifically focusing on automotive electronics and achieving stronger effects. Nurhayati et al.[19] highlighted teachers' difficulties in implementing problem-based learning models to improve students' 4C skills. Our research addresses these concerns by providing a structured framework through the Rifdarmon model.

The remarkable effectiveness of the Rifdarmon-Based E-Learning Model stems from its holistic integration of pedagogical and technological elements that directly address specific vocational education needs. This model fundamentally restructures the learning experience to emphasize problem-solving in authentic contexts. The significantly higher effect size indicates that the model's strength lies in its ability to bridge theoretical knowledge with practical applications. The substantial improvement in 4C skills demonstrates that properly designed

e-learning environments can transcend traditional classroom limitations in developing complex competencies. The 15,7 % difference between experimental and control groups in 4C skills scores is particularly noteworthy as these skills are typically challenging to develop in conventional educational settings. The unique contribution of this study lies in the comprehensive integration of e-learning technology and innovative pedagogical models. These findings have significant implications for vocational education practice. The model's effectiveness suggests that institutions should consider more comprehensive approaches to e-learning integration rather than piecemeal adoptions of digital tools. Furthermore, the development of 4C skills should not be treated as secondary to technical knowledge in vocational education but as equally essential components for workforce readiness in the digital age.

CONCLUSIONS

The conclusion of research on the effectiveness of the Rifdarmon-Based E-Learning Model in the Automotive Electronics Electricity course resulted in two main findings, including first, the Rifdarmon model assisted by e-learning effectively improved the learning outcomes of Automotive Electronics Electricity students, with the experimental class experiencing an increase in the pre-test score of 69,1 to a post-test of 87,2, compared to the control class which increased from 64,9 to 84,4. This effectiveness is evidenced by the paired sample t-test with a mean difference of -18,800 and significance <0,001, and strengthened by a very large effect size value (point estimate -2,511). Second, the Rifdarmon model assisted by e-learning is effective in developing students' 4C skills, with the experimental class obtaining a 4C skill score of 86,6 compared to the control class which only reached 74,95. This effectiveness is proven through a paired sample t-test which shows a mean difference of -13,775 between the pre-test and 4C skills. Multivariate test analysis with four test statistics confirmed the significance of the treatment with a value of F = 29,356 and significance <0,001, indicating a meaningful improvement in the development of students' complex skills.

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