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Validating the Rifdarmon E-Learning Model with Structural Equation Modeling Analysis for Enhanced Learning Outcomes and Students' 4C Skills

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Abstract: The rapid development of information and communication technology (ICT) has significantly transformed the landscape of education, including in the context of vocational education. Universitas Negeri Padang (UNP), particularly the Department of Automotive Engineering, has made efforts to adapt the curriculum and learning methods to bridge the gap between education and industry demands. However, in its implementation, there are still challenges that need to be addressed, especially in the Automotive Electronics Electricity course. This study aims to validate the Rifdarmon E-Learning Model in the Automotive Electronics Electricity course through SEM-PLS and CB-SEM analysis using SmartPLS 4. The research employed a quantitative approach using two analysis methods: Structural Equation Modeling-Partial Least Square (SEM-PLS) and Covariance-Based Structural Equation Modeling (CB-SEM). Data were collected from 50 validators comprising experts in educational technology, learning models, and learning media using a 5-point Likert scale questionnaire. The model validation focused on four key syntaxes: Reciprocal Teaching (RT), Mentoring Peers (MP), Organizing Findings (OF), and Narrating Outcomes (NO). The SEM-PLS analysis demonstrated strong construct validity with satisfactory Composite Reliability (CR), Cronbach's Alpha, and Average Variance Extracted (AVE) values across all syntaxes. The CB-SEM analysis further confirmed the model's structural validity with positive outer loading values and good model fit indices. These comprehensive validation results indicate that the Rifdarmon E-Learning Model is both valid and reliable, making it suitable for implementation to enhance learning outcomes and develop students' 4C skills in Automotive Electronics Electricity education.

Keywords: CB-SEM; Rifdarmon E-Learning Model; SEM-PLS

Introduction

The rapid development of information and communication technology (ICT) has significantly transformed the landscape of education, including in the context of vocational education. Castells, (2011) states that we live in the information age, where digital technology has changed the way we communicate, work, and learn. In the context of education, ICT has enabled the creation of more flexible, interactive, and personalized learning environments (Selwyn, 2021). In line with the development of ICT, vocational education

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has also undergone a significant transformation. According to Billet, (2011), vocational education aims to prepare individuals for work in various occupations or specific occupational groups, with a focus on developing the skills, knowledge, and attitudes necessary to perform tasks effectively in a particular field.

Universitas Negeri Padang (UNP), particularly the Department of Automotive Engineering, as one of the universities that have vocational education programs, has made efforts to adapt the curriculum and learning methods to bridge the gap between education and industry demands, as emphasized by (Wheelahan & Moodie, 2016) in their research on vocational education reforms. However, in its implementation, there are still challenges that need to be addressed, especially in the Automotive Electronics Electricity course. Based on observations on the learning process of the Automotive Electronics Electricity course, there are identified learning problems characterized by the low achievement of student learning outcomes.. Out of eight sections with a total of 107 students, the average scores range from the lowest 51.84 (C-) to the highest 79.68 (B+), with the majority of sections obtaining scores in the range of B- to B. The significant variation in scores and the presence of low average scores indicate the need for improvement efforts in the learning process.

Researchers have conducted literature studies on the factors that influence learning outcomes, including the application of learning models (Batubara, 2020; Malla et al., 2018; Sukardi & Rozi, 2019; Sumarni & Wardani, 2019), learning approaches (Syaifullah et al., 2024), learning methods (Ronald et al., 2017; Sumadji, 2015; Zaus & Krismadinata, 2018), learning media (Aurora & Effendi, 2019; Rifdarmon et al., 2023; Sitompul et al., 2017; Suryani & Dhiki, 2020), assessment instruments (Hasana et al., 2017; Pratiwi & Fasha, 2015), curriculum (Chalim, 2018; Sari, 2019), as well as intrinsic and extrinsic factors (Afianti et al., 2019; Wigati, 2016; Winarni & Suwisi, 2014).

In the Automotive Electronics Electricity course, the learning model used is problem-based learning (PBL). However, the implementation of this model faces several obstacles, including students' difficulties in understanding key concepts, lack of student involvement in the learning process, lack of guidance and feedback from lecturers, ineffective problem design, and limited time to investigate problems in-depth. Facing the weaknesses of PBL implementation in the Automotive Electronics Electricity course, the researcher proposes the Rifdarmon E-Learning Model as a solution. The Rifdarmon E-Learning Model is a blended learning model that integrates the strengths of problem-based learning (PBL), Jigsaw-type cooperative learning, and peer tutoring, as well as the use of e-learning technology. This model is expected to improve learning outcomes and develop students' 4C skills (critical thinking, communication, collaboration, and creativity) in Automotive Electronics Electricity.

Several studies have examined the effectiveness of blended learning models that integrate problem-based learning and peer tutoring in improving learning outcomes and 4C skills. (Zamroni et al., 2020) found that problem-based learning-based blended learning can improve the critical thinking skills of prospective counselors. Tambak et al., (2022) showed the effectiveness of problem-based learning-based blended learning models in improving learning outcomes in Islamic Studies courses. Nurkhin et al., (2020) studied the application of blended problem-based learning in the field of accounting studies, optimizing the use of social media for learning. Azizah & Aloysius, (2023) examined the effectiveness of a blended learning model with problem-based learning-group investigation (PBL-GI) on the critical thinking and problem-solving abilities of high school students.

Herayantı et al., (2020) studied the effectiveness of inquiry collaborative tutorial-based blended learning models in improving students' problem-solving skills in physics. Sugiyanti et al., (2023) investigated the effect of a blended learning-oriented problem-based learning model on students' mathematics learning outcomes. Marnita et al., (2020) explored the effect of the blended learning problem-based instruction model on students' critical thinking abilities in thermodynamics. Yennita & Zukmadini, (2021) examined the impact of problem-based learning (PBL) and blended learning in improving critical thinking skills and student learning activities in biochemistry courses. Germo et al., (2024) evaluated the effectiveness of problem-based learning (PBL) in maritime courses in a blended learning modality. Arvyaty et al., (2021) investigated the use of the Bamboo Dancing cooperative learning model to improve students' 4C skills. Nurhayati et al., (2023) analyzed the difficulties of physics teachers and pre-service teachers in implementing the problem-based learning model to improve students' 4C skills. Musharyanti et al., (2021) explored the improvement of nursing students' medication safety knowledge and skills using the 4C/ID learning model.

This study aims to validate the Rifdarmon E-Learning Model in the Automotive Electronics Electricity course through SEM-PLS and CB-SEM analysis using SmartPLS 4 to test the fit of the theoretical model with empirical data to be able to improve learning outcomes and develop students' 4C skills (critical thinking, communication, collaboration, and creativity) in Automotive Electronics Electricity. Therefore, this research with the title "Validating the Rifdarmon E-Learning Model with Structural Equation Modeling Analysis for Enhanced Learning Outcomes and Students' 4C Skills" is important to be conducted to confirm the suitability of the theoretical model with empirical data in the context of the Automotive Electronics Electricity course. This is expected to provide empirical evidence on the effectiveness of the model in improving learning outcomes and developing students' 4C skills, so that it can be a solution to overcome the learning problems that occur.

Method

This research uses a quantitative research approach focused on validating the Rifdarmon E-Learning Model in the Automotive Electronics Electricity course using two analysis approaches: Structural Equation Modeling-Partial Least Square (SEM-PLS) and Covariance-Based Structural Equation Modeling (CB-SEM) to provide a comprehensive perspective in testing the fit of the theoretical model with empirical data.

The research flow of the Rifdarmon E-Learning Model validation process is illustrated in Figure 1, which shows the systematic steps starting from the model concept to the validation results. The validation process examines four key syntaxes: Reciprocal Teaching (RT), Mentoring Peers (MP), Organizing Findings (OF), and Narrating Outcomes (NO). These syntaxes are analyzed using both CB-SEM and SEM-PLS approaches to ensure comprehensive validation results.

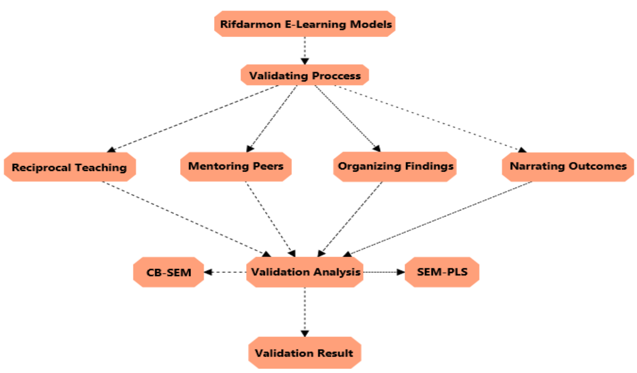

Figure 1. Research Flow

The research subjects consist of 50 validators, including experts in educational technology, learning models, and learning media. The Rifdarmon E-Learning Model is validated with four structured syntaxes, including Reciprocal Teaching (RT), Mentoring Peers (MP), Organizing Findings (OP), and Narrating Outcomes (NO), with each syntax having five assessment indicators.

The research instrument uses a 5-point Likert scale questionnaire, ranging from 1 (strongly disagree) to 5 (strongly agree). Construct validity is analyzed using SmartPLS 4 software with testing parameters including convergent validity (loading factor, Average Variance Extracted/AVE), reliability (Composite Reliability/rho_a, Composite Reliability/rho_c, and Cronbach's Alpha), and model fit (R-Square and R-Square Adjusted). Data analysis is carried out in two stages: SEM-PLS analysis to test the validity and reliability of each syntax and evaluate the relationships between syntaxes in the model, and CB-SEM analysis to confirm the model structure and test the structural relationships between syntaxes. These two analysis approaches are used to obtain a comprehensive understanding of the psychometric properties of the Rifdarmon E-Learning Model and the structural relationships between its components.

Result and Discussion

The results of the Rifdarmon E-Learning Model validation analysis using the Structural Equation Modeling-Partial Least Square (SEM-PLS) and Covariance-Based Structural Equation Modeling (CB-SEM) approaches are presented in Tables 1 and 2. This analysis aims to test the fit of the theoretical model with empirical data and provide empirical evidence on the effectiveness of the model in improving learning outcomes and developing students' 4C skills (critical thinking, communication, collaboration, and creativity) in Automotive Electronics Electricity. The results of the SEM-PLS analysis in Table 2 show that all syntaxes in the Rifdarmon E-Learning Model, namely Reciprocal Teaching, Mentoring Peers, Organizing Findings, and Narrating Outcomes, meet the criteria for good validity and reliability.

Table 1. Validity of the Rifdarmon E-Learning Model Using SEM-PLS Analysis

Sintaksis	Validation Model					
	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Cronbach's Alpha	AVE	R-Square	R-Square Adjusted
Reciprocal Teaching	0.890	0.903	0.864	0.653	0.476	0.465
Mentoring Peers	0.777	0.823	0.736	0.491	0.531	0.521
Organizing Findings	0.813	0.860	0.792	0.559	0.476	0.465
Narrating Outcomes	0.756	0.824	0.729	0.491	0.502	0.492

Teaching, Mentoring Peers, Organizing Findings, and Narrating Outcomes. The Composite Reliability (rho_a) and Composite Reliability (rho_c) values for all syntaxes are above 0.7, indicating good internal consistency. The Cronbach's Alpha values are also above 0.7, indicating acceptable reliability. The Average Variance Extracted (AVE) values for all syntaxes are above 0.5, meeting the criteria for good convergent validity. This means that the indicators in each syntax are able to explain their latent constructs well. The R-Square values range from 0.476 to 0.531, indicating that the model has reasonably good predictive ability. The data in Table 2 can be explained in detail for each syntax of the Rifdarmon E-Learning Model as follows:

In the SEM-PLS analysis on the Reciprocal Teaching syntax, which can be seen in Figure 2, the performance is convincing and indicates adequate reliability and convergent validity.

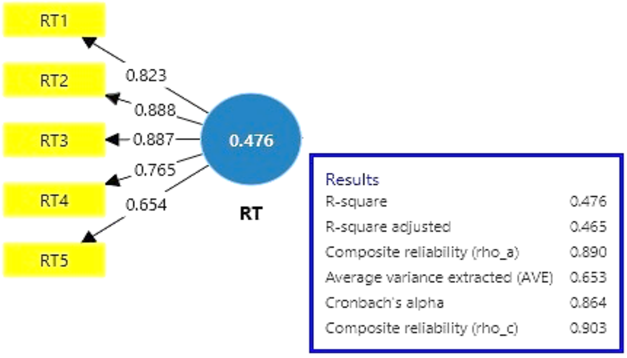

Figure 2. PLS-SEM Syntax Validation: Reciprocal Teaching (RT)

Figure 2 shows that the R-square (R2) value for the RT syntax is 0.476. This value indicates that the independent latent variables (RT1, RT2, RT3, RT4, RT5) can explain 47.6% of the variance in the RT syntax. The R-square adjusted value is 0.465, which means the model can explain 46.5% of the variance in the RT syntax after accounting for the number of independent variables in the model. The composite reliability (rho_A) value is 0.890, which shows high construct reliability for RT. Furthermore, the average variance extracted (AVE) value is 0.653, which means the convergence of the RT syntax is also good. The Cronbach's alpha value of 0.864 also confirms the reliability of the RT construct.

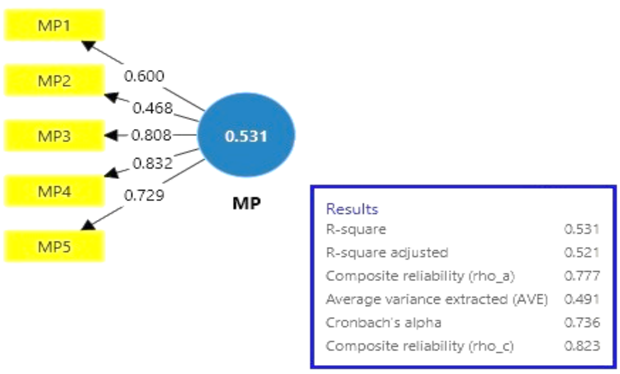

Figure 3. PLS-SEM Syntax Validation: Mentoring Peers (MP)

Figure 3 shows that the R-square (R2) value for the MP syntax is 0.531. This value indicates that the independent latent variables (MP1, MP2, MP3, MP4, MP5) can explain 53.1% of the variance in the MP syntax. The R-square adjusted value is 0.521, which means the model can explain 52.1% of the variance in the MP construct after accounting for the number of independent variables in the model. The composite reliability (rho_A) value is 0.777, which shows reasonably good reliability for the MP syntax. Furthermore, the average variance extracted (AVE) value is 0.491, which means the convergence of the MP syntax is also reasonably good. The Cronbach's alpha value of 0.736 also confirms the reliability of the MP syntax.

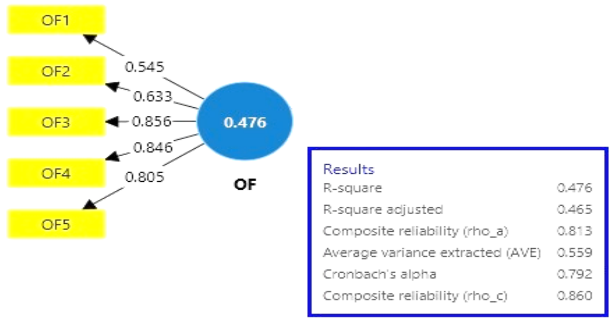

Figure 4. PLS-SEM Syntax Validation: Organizing Findings (OF)

Figure 4 shows that the R-square (R2) value for the OF syntax is 0.476. This value indicates that the independent latent variables (OF1, OF2, OF3, OF4, OF5) can explain 47.6% of the variance in the OF syntax. The R-square adjusted value is 0.465, which means the model can explain 46.5% of the variance in the OF construct after accounting for the number of independent variables in the model. The composite reliability (rho_A) value is 0.813, which shows reasonably good reliability for the OF construct. Furthermore, the average variance extracted (AVE) value is 0.559, which means the convergence of the OF syntax is also reasonably good. The Cronbach's alpha value of 0.792 also confirms the reliability of the OF syntax.

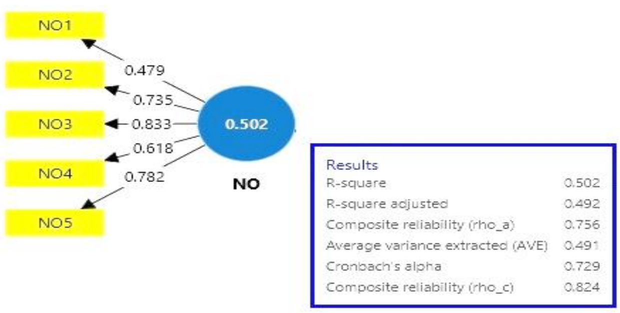

Figure 5. PLS-SEM Syntax Validation: Narrating Outcomes (NO)

Figure 5 shows that the R-square (R2) value for the NO syntax is 0.502. This value indicates that the independent latent variables (NO1, NO2, NO3, NO4, NO5) can explain 50.2% of the variance in the NO syntax. The R-square adjusted value is 0.492, which means the model can explain 49.2% of the variance in the NO syntax after accounting for the number of independent variables in the model. The composite reliability (rho_A) value is 0.756, which shows reasonably good reliability for the NO syntax. Furthermore, the average variance extracted (AVE) value is 0.491, which means the convergence of the NO syntax is also reasonably good. The Cronbach's alpha value of 0.729 also confirms the reliability of the NO syntax.

Based on the results of the syntactic validity analysis of the Rifdarmon E-Learning model using the SEM-PLS approach, it can be concluded that the Rifdarmon E-Learning Model has good syntactic validity. All syntaxes, namely Reciprocal Teaching, Mentoring Peers, Organizing Findings, and Narrating Outcomes, have Composite Reliability (rho_a and rho_c) values above 0.7 and Cronbach's Alpha above 0.7, indicating good internal consistency. The Average Variance Extracted (AVE) values for all syntaxes are also above 0.5, meeting the criteria for good convergent validity. This means that the indicators in each syntax are able to well explain their latent constructs.

The analysis per syntax shows positive results. Reciprocal Teaching has an R-Square value of 0.476 and an R-Square Adjusted value of 0.465, meaning that the independent latent variables can explain 46.5% of the variance in this syntax. Mentoring Peers has an R-Square value of 0.531 and an R-Square Adjusted value of 0.521, indicating that the independent latent variables can explain 52.1% of the variance in this syntax. Organizing Findings has an R-Square value of 0.476 and an R-Square Adjusted value of 0.465, meaning that the independent variables can explain 46.5% of the variance in this syntax. Narrating Outcomes has an R-Square value of 0.502 and an R-Square Adjusted value of 0.492, indicating that the independent latent variables can explain 49.2% of the variance in this syntax. Overall, the analysis results show that the Rifdarmon E-Learning Model has good syntactic validity and can be used to predict related constructs. Furthermore, Table 3 presents the results of the CB-SEM analysis, which confirms the model structure and the relationships between the syntaxes.

Table 2. Validity of the Rifdarmon E-Learning Model Using CB-SEM Analysis

Syntax	Indicator	Outer loading	Cronbach's Alpha	Composite Reliability (rho_c)	AVE
Reciprocal Teaching	RT1	1,000	0.864	0.903	0.653
	RT2	1.057			
	RT3	1.076			
	RT4	0.868			
	RT5	0.684			
Mentoring Peers	MP1	1.000	0.736	0.823	0.491
	MP2	0.640			
	MP3	1.502			
	MP4	1.664			
	MP5	1.519			
Organizing Findings	OF1	1.000	0.792	0.860	0.559
	OF2	1.107			
	OF3	2.338			
	OF4	2.414			
	OF5	2.060			
Narrating Outcomes	NO1	1.000	0.729	0.824	0.491
	NO2	2.398			
	NO3	2.601			
	NO4	1.448			
	NO5	2.273			

Based on the CB-SEM analysis in Table 2, the results show the construct validity of the Rifdarmon E-Learning Model, which consists of 4 syntaxes with their respective indicators. In the Reciprocal Teaching syntax, the outer loading value of each indicator is above 0.7, indicating good convergent validity. The Cronbach's Alpha, Composite Reliability (rho_c), and AVE values also meet the required criteria. In the Mentoring Peers syntax, there is 1 indicator (MP2) with an outer loading below 0.7. However, the Cronbach's Alpha, Composite Reliability (rho_c), and AVE values still meet the validity requirements.

Meanwhile, in the Organizing Findings syntax, all indicators have outer loadings above 0.7. The

Cronbach's Alpha, Composite Reliability (rho_c), and AVE values have also been met. Lastly, in the Narrating Outcomes syntax, the outer loading values of the indicators are: NO1 is 1.000, NO2 is 2.398, NO3 is 2.601, NO4 is 1.448, and NO5 is 2.273. The Cronbach's Alpha value is 0.729, the Composite Reliability (rho_c) is 0.824, and the AVE is 0.491. The data in Table 2 can also be illustrated through Figure 6, which shows a complex structural relationship between the syntaxes, with varying path coefficient values between the exogenous and endogenous constructs.

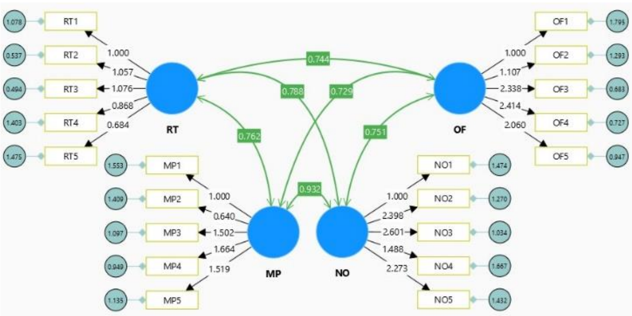

Figure 6. CB-SEM Construct Validation

Figure 6 explains that in the Reciprocal Teaching (RT) syntax, the path estimate values for its indicators (RT1, RT2, RT3, RT4, RT5) range from 0.684 to 1.553. The R-square (R2) value for the RT construct is 0.744, indicating that 74.4% of the variance in the RT construct can be explained by its independent latent variables. In the Mentoring Peers (MP) syntax, the path estimate values for its indicators (MP1, MP2, MP3, MP4, MP5) vary from -1.502 to 1.519. The R-square (R2) value for MP is 0.932, which means 93.2% of the variance in the MP construct can be explained by its independent latent variables. In the Organizing Findings (OF) syntax, the path estimate values for its indicators (OF1, OF2, OF3, OF4, OF5) range from 0.534 to 1.000. The R-square (R2) value for the OF construct is 0.775, indicating that 77.5% of the variance in OF can be explained by its independent latent variables. Finally, in the Narrating Outcomes (NO) syntax, the path estimate values for its indicators (NO1, NO2, NO3, NO4, NO5) range from -0.833 to 1.074. The R-square (R2) value for the NO construct is 0.933, which means 93.3% of the variance in the NO construct can be explained by its independent latent variables.

Based on the CB-SEM analysis, the Rifdarmon E-Learning Model has good construct validity. All syntaxes, namely Reciprocal Teaching, Mentoring Peers, Organizing Findings, and Narrating Outcomes, show outer loading, Cronbach's Alpha, Composite Reliability (rho_c), and AVE values that meet the criteria. Although there is one indicator in Mentoring Peers with an outer loading below 0.7, the construct as a whole remains valid. Figure 5 indicates a complex structural relationship between the syntaxes, with varying path coefficient values. The R-square (R2) values for each syntax range from 74.4% to 93.3%, indicating the model has good predictive ability. Overall, the CB-SEM analysis results confirm the construct validity of the Rifdarmon E-Learning Model, so this model can be used to predict related constructs.

The results of the syntactic validity analysis of the Rifdarmon E-Learning Model show interesting findings from the two SEM-PLS and CB-SEM analysis approaches. These two methods provide complementary perspectives in evaluating the strength and stability of the developed model. The analysis results show that the Rifdarmon E-Learning Model has good syntactic and construct validity, so it can be used to predict improved learning outcomes and the development of students' 4C skills.

The SEM-PLS analysis shows that all syntaxes in the Rifdarmon E-Learning Model, namely Reciprocal Teaching, Mentoring Peers, Organizing Findings, and Narrating Outcomes, have Composite Reliability, Cronbach's Alpha, and AVE values that meet the validity criteria. This means that the indicators in each syntax are able to well explain their latent constructs. The per-syntax analysis also resulted in positive R-Square and R-Square Adjusted values, indicating the model's good predictive ability.

The CB-SEM analysis results further confirm the construct validity of the Rifdarmon E-Learning Model. All syntaxes show outer loading, Cronbach's Alpha, Composite Reliability, and AVE values that meet the requirements. Although there is one indicator in Mentoring Peers with an outer loading below 0.7, the construct as a whole remains valid. The structural relationship analysis also indicates the complexity between the syntaxes, with varying path coefficient values. The R-square values for each syntax are in the high range, from 74.4% to 93.3%, indicating the model has good predictive ability.

This research provides empirical contributions on the effectiveness of applying blended learning models that integrate problem-based learning and peer tutoring, complementing previous studies. Several previous studies have examined the effectiveness of problem-based learning-based blended learning models in improving learning outcomes and 4C skills, such as the work by (Zamroni et al., 2020), (Tambak et al., 2022), (Nurkhin et al., 2020), and (Azizah & Aloysius, 2023). This study adds empirical evidence on the validity of the Rifdarmon E-Learning Model, which combines problem-based learning and peer tutoring in the context of the Automotive Electronics Electricity course.

The results of this study indicate that the Rifdarmon E-Learning Model can be used as a solution to improve learning outcomes and develop students' 4C skills in the Automotive Electronics Electricity course. This is important given the existing learning problems, such as low learning outcomes and lack of development of students' 4C skills. By validating the Rifdarmon E-Learning Model through SEM analysis, this research provides a theoretical and empirical basis for implementing this model to optimize the learning process and student achievement.

Conclusion

The results of the SEM-PLS and CB-SEM analyses show that the Rifdarmon E-Learning Model has good syntactic and construct validity, so it can be used to predict improved learning outcomes and the development of students' 4C skills in the Automotive Electronics Electricity course. The SEM-PLS analysis resulted in Composite Reliability, Cronbach's Alpha, and AVE values that meet the criteria for all syntaxes, namely Reciprocal Teaching, Mentoring Peers, Organizing Findings, and Narrating Outcomes. The per-syntax analysis also showed positive R-Square and R-Square Adjusted values, indicating the model's good predictive ability.

Furthermore, the CB-SEM analysis results confirm the construct validity of the Rifdarmon E-Learning Model, with all syntaxes meeting the requirements for outer loading, reliability, and convergent validity. Overall, this research provides empirical evidence on the effectiveness of applying blended learning models that integrate problem-based learning and peer tutoring, complementing previous studies. The validation results of the Rifdarmon E-Learning Model show that this model can be used as a solution to improve learning outcomes and develop students' 4C skills in the Automotive Electronics Electricity course.

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Author Contributions

Conceptualization, L.S., R.L. and R.; methodology, R.; software, R.; validation, L.S., R.L. and R.; formal analysis, R.; investigation, L.S.; resources, L.S., R.L. and R.; data curation, R.; writing—original draft preparation, L.S.; writing—review and editing, R.L. and R.; visualization, L.S.; supervision, R.L.; project administration, R.; funding acquisition, R. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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