Enhancing Academic Achievement and Critical Thinking through e-Learning: Exploring Motivation, Creativity, Participation, and Gadget Utilization in Higher Education

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***Abstract*—The development of information technology has changed the world of education, including the application of e-learning in universities. This study explores how e-learning can improve the academic achievement and critical thinking skills of automotive engineering students who rely on gadgets. Using the Partial Least Squares Structural Equation Modeling (PLS–SEM) method on data collected through purposive sampling, this study analyzed verbal communication, motivation, creativity, learner interaction with content, gadget use intensity, peer collaborative engagement, academic achievement, and critical thinking. The results showed that verbal communication and learner interaction with content significantly increased motivation and creativity, while excessive gadget use intensity had a negative impact. The indirect effect of learner interaction with content on academic achievement through motivation showed a P-coefficient of 0.027. In contrast, the impact of verbal communication on academic achievement through motivation showed a P-coefficient of 0.014. These findings emphasize the importance of a holistic approach in designing e-learning programs that support verbal communication, active participation, and balanced use of gadgets to improve education quality. Educational institutions are advised to develop effective e-learning programs and explore other factors, such as educational access, that affect learning outcomes in e-learning.**

***Keywords*—e-learning, academic achievement, critical thinking, motivation, educational access**

I. Introduction

Information technology has substantially transformed education, particularly in implementing e-learning in higher education [1]. E-learning is both a pedagogical tool and a platform that enhances students' academic performance and fosters their critical thinking ability [2, 3]. Universities need to help efficiently utilize e-learning to maximize student learning results, notwithstanding technical developments [4, 5]. E-learning facilitates a more adaptable form of cooperative learning, enabling students to acquire knowledge at their preferred speed and by their learning preferences [6, 7]. E-learning can enhance student engagement and motivation, enhancing academic performance [8, 9]. E-learning supports more dynamic interactions between students and lecturers and between fellow students, which can enrich the learning experience [10].

Effective e-learning should include interactive components allowing for direct feedback, discussion, and student collaboration [11]. This shows that technology is a content provider and facilitator of social interaction, which is essential in learning [12]. When considering e-learning in higher education, it is crucial to address the students' demand for active communication and collaboration and recognize the significance of interaction and communication in enhancing the overall quality of online learning [13]. E-learning is be positioned as a complement to maximize structured and independent learning in the semester credit system through student interaction and collaboration [14].

This research investigates vital factors influencing students' academic achievement and critical thinking within an e-learning environment. The selected variables—verbal communication, motivation, creativity, participation with content, participation with fellow students, and the intensity of gadget use—were chosen based on their significant roles in the learning process [15]. Verbal communication and active participation are crucial for fostering collaborative learning and deeper engagement [16]. However, motivation and creativity are vital for sustaining students' interest and promoting innovative problem-solving [17, 18]. The intensity of gadget use is also examined because of its dual role in facilitating access to learning resources and potentially leading to distractions [19]. These variables collectively contribute to a comprehensive understanding of how e-learning can be optimized to enhance academic outcomes and critical thinking skills.

Students who use e-learning can develop better time management, goal-setting, and self-reflection skills [20, 21]. Students in the e-learning environment tend to have higher satisfaction levels and better learning outcomes [22, 23]. Creativity is critical to innovative learning, allowing students to explore new ideas and develop creative solutions to complex problems [24, 25]. Within the realm of e-learning, using tools and technologies that facilitate creativity can potentially enhance student engagement and motivation [26, 27].

This study explores how integrating e-learning can improve the academic achievement and critical thinking skills of automotive engineering students who are heavily dependent on gadgets. The research also examines the crucial role of creativity within the e-learning environment. One of the primary objectives of this study is to assess the direct impact of e-learning on academic accomplishment and

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critical thinking ability while also investigating the role of motivation and creativity as mediators. These characteristics act as mediators because motivation is often the driving force behind a student's willingness to engage with learning materials, and creativity enhances the ability to approach problems from innovative perspectives. By understanding how motivation and creativity influence the relationship between e-learning and academic outcomes, this study aims to identify critical elements that can be optimized to maximize the benefits of e-learning. Additionally, it offers practical advice for institutions in designing and implementing effective e-learning programs. This approach contributes significantly to the academic literature and higher education practices and aims to foster a more inventive and adaptable learning environment that advances the use of information technology.

II. Methods

This study evaluates the measurement and structural models using the Partial Least Squares Structural Equation Modeling (PLS–SEM) method, implemented with the help of SmartPLS 4 software [28]. The population for this study consisted of automotive engineering students at Padang State University. Eighty-nine students were selected as the sample using purposive sampling techniques on the basis of specific criteria to ensure that they represented the target population. Data were collected through a detailed questionnaire specifically designed to measure the critical variables in this study: Gadget Use Intensity (GUI), Verbal Communication (VC), Learner Interaction with Content (LIC), and Collaborative Engagement with Peers (CEP). These variables were carefully selected based on their relevance to the e-learning environment and potential impact on student outcomes. The intervening variables analyzed include Motivation (MO) and Creativity (CR), which are hypothesized to mediate the relationship between the independent variables and the dependent outcomes. The dependent variables measured in this study are Academic Achievement (AA), which includes Grade Point Average (GPA) and affective assessment, and Critical Thinking (CT) skills, which are considered separate dependent variables. The questionnaire was administered online via the university's e-learning platform, and the respondents completed it voluntarily over one month. This data collection approach ensured that the responses reflected the students' genuine experiences and interactions with the e-learning environment.

To enrich and strengthen the conceptual framework of this study, the theoretical foundations from a previous article emphasizing technological determinism and reflective education theory have been integrated [29]. The theory of technological determinism offers a deep understanding of the positive and negative impacts of technological advancements on education, particularly in the context of intensive gadget use in e-learning [30]. This findings our analysis of how the intensity of gadget use can influence students' motivation and creativity [18]. Additionally, the reflective education theory reinforces the importance of verbal communication and interaction in e-learning to foster critical reflection and more profound development of critical thinking skills [24]. This integration allows our conceptual framework not only to focus on interaction and motivation but also to account for factors such as technological accessibility and digital literacy, which are crucial in maximizing the potential of e-learning.

The measurement model in PLS–SEM is evaluated to verify the construct's validity and reliability. Convergence validity was assessed using Average Variance Extracted (AVE), where an AVE value greater than 0.5 indicates that the indicators consistently monitored the same construct. The Discriminant Validity Benchmark is used to assess the validity of discrimination. It states that the AVE square root should be higher than the correlation between other constructs. The Heterotrait-Monotrait Ratio (HTMT) should be less than 0.9 [31]. Reliability is assessed using Composite Reliability and Cronbach's Index, which should exceed 0.7 to guarantee internal solid consistency among the indicators inside a single construct [32, 33].

The structural model is assessed to examine the correlation between the constructs in the model. The path coefficient is a metric used to quantify the magnitude and direction of the association between components. It is considered statistically significant when the P-coefficient is less than 0.05. R-squared (R^2) is a statistical measure used to quantify how external constructs can explain the variations in an endogenous construct. The predicted value of R^2 varies across different fields of study. However, generally, a value of 0.25 indicates a weak relationship, 0.50 indicates a moderate relationship, and 0.75 indicates a strong realationship. To verify that there is no substantial multicollinearity among the predictor variables, the Variance Inflation Factor (VIF) was computed. A VIF value below 5 suggests no significant multicollinearity issue in the model [34].

The adequacy of the overall model fit in PLS–SEM was assessed using many indices. The Standardised Root Mean Square Residual (SRMR) is a metric used to evaluate the overall fit of a model. A value below 0.08 indicates an acceptable model fit [35]. This analysis process is carried out using SmartPLS software, where data is imported, measurement and structural models are built, and PLS–SEM algorithms are run to produce outputs that are interpreted based on relevant values. Thus, the results of this study are expected to provide significant practical, theoretical, and policy implications while still considering the limitations of the research and providing suggestions for further research. For additional details regarding the variable measurements, please refer to Table 1, which was provided by the researcher.

For more details, the model framework of this study is further described in Fig. 1.

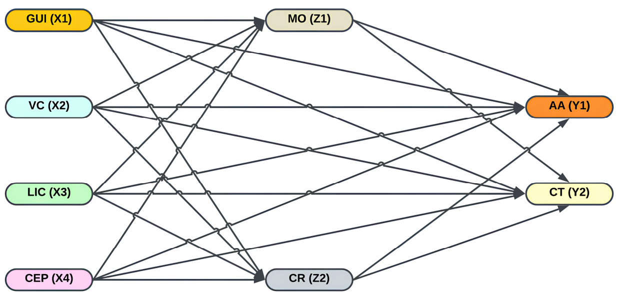

Fig. 1. Model framework.

Table 1. Investigation variables

Parameter	Survey Items	Index
GUI	X1.A	Using gadgets to access materials for more than two hours daily
	X1.B	Using gadgets to interact with video content and communicate with lecturers
	X1.C	Checking notifications from e-learning platforms
	X1.D	Using gadgets to complete assignments and take quizzes or exams
	X1.E	Downloading materials or assignments and accessing discussion forums in e-learning
VC	X2.A	Asking questions to the lecturer
	X2.B	Answering questions in class
	X2.C	Actively participating in verbal discussions
	X2.D	Giving oral presentations
	X2.E	Engaging in verbal Q&A sessions with peers
LIC	X3.A	Actively reading materials and following e-learning instructions carefully
	X3.B	Watching instructional videos to the end and completing assignments
	X3.C	Taking notes or summarizing key points from materials
	X3.D	Participating in quizzes or exams
	X3.E	Utilizing discussion forums and further exploring topics discussed in e-learning
CEP	X4.A	Discussing with peers and collaborating on projects
	X4.B	Exchanging information and giving feedback to peers
	X4.C	Receiving and considering feedback from peers
	X4.D	Engaging in Q&A sessions and supporting peers struggling with materials
	X4.E	Forming study groups and actively participating in group discussions
MO	Z1.A	Motivation to learn automotive technology through e-learning or face-to-face
	Z1.B	Enthusiastic and eager to complete e-learning assignments on time
	Z1.C	Setting clear learning goals and satisfied with learning progress
	Z1.D	Actively seeking additional information and participating in discussions
CR	Z2.A	Trying various methods and seeking creative solutions
	Z2.B	Combining knowledge from various sources and creating unique projects (e.g., video assignments)
	Z2.C	Getting new ideas and inspired to think creatively
	Z2.D	Using creative tools (interactive tutorials, video editing apps) and exploring new learning methods (project-based, problem-based, collaborative)
AA	Y1.A	Grade Point Average (GPA)
	Y1.B	Respect for Opinions and Participation
	Y1.C	Discipline and Responsibility
	Y1.D	Communication Skills and Confidence
CT	Y2.A	Analyzing and questioning information
	Y2.B	Evaluating arguments and identifying weaknesses
	Y2.C	Constructing arguments based on data
	Y2.D	Comparing information from various sources
	Y2.E	Testing or reviewing assignments before submission
	Y2.F	Debating with peers and drawing logical conclusions

III. Results and Discussion

PLS–SEM analysis has become increasingly prevalent for investigating the connections between variables within conceptual models, particularly in educational research. In this research, SmartPLS4 was employed to perform PLS–SEM analysis was used to gain a deeper understanding of the interconnections between the variables. As a result, we present graphs that depict the model's validation and illustrate the extent to which the elements involved exhibit a significant correlation within this research, as shown in Fig. 2.

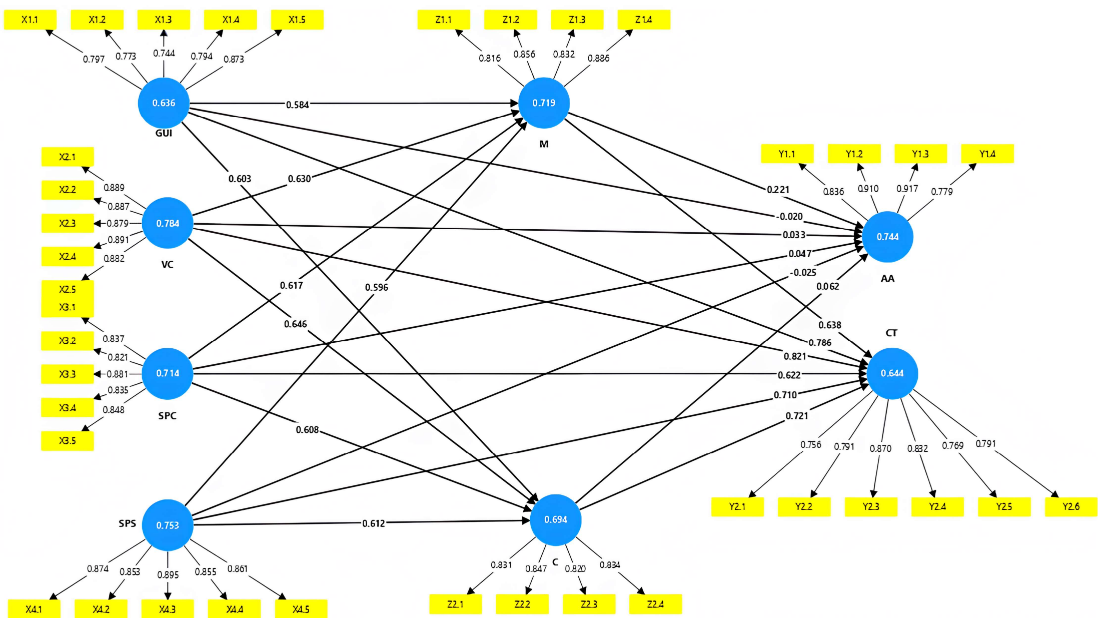

Fig. 2. Result output PLS–SEM.

The measurement model's evaluation aims to ascertain the validity and reliability of the instruments employed in this investigation. The instrument's validity was assessed using AVE and discriminant validity. The Composite Reliability and Cronbach's Index are utilized to determine the reliability of instruments [32]. Tables 2–3 display the findings from assessing the accuracy and consistency of the tools employed in this research.

Table 2. Validity and reliability of instruments

Parameter	Survey Items	Outer Coefficient	Cronbach's Index	Composite reliability	AVE
GUI	X1.A	0.797	0.856	0.897	0.636
	X1.B	0.773			
	X1.C	0.744			
	X1.D	0.794			
	X1.E	0.873			
VC	X2.A	0.889	0.931	0.948	0.784
	X2.B	0.887			
	X2.C	0.879			
	X2.D	0.891			
	X2.E	0.882			
LIC	X3.A	0.837	0.900	0.926	0.714
	X3.B	0.821			
	X3.C	0.881			
	X3.D	0.835			
	X3.E	0.848			
CEP	X4.A	0.874	0.918	0.939	0.753
	X4.B	0.853			
	X4.C	0.895			
	X4.D	0.855			
	X4.E	0.861			
MO	Z1.A	0.816	0.870	0.911	0.719
	Z1.B	0.856			
	Z1.C	0.832			
	Z1.D	0.886			
CR	Z2.A	0.831	0.853	0.901	0.694
	Z2.B	0.847			
	Z2.C	0.820			
	Z2.D	0.834			
AA	Y1.A	0.836	0.895	0.920	0.744
	Y1.B	0.910			
	Y1.C	0.917			
	Y1.D	0.779			
CT	Y2.A	0.756	0.889	0.915	0.644
	Y2.B	0.791			
	Y2.C	0.870			
	Y2.D	0.832			
	Y2.E	0.769			
	Y2.F	0.791			

Table 3. Fornell-Larcker standard

	AA	CR	CT	GUI	MO	LIC	CEP	VC
AA	0.863							
CR	0.062	0.833						
CT	−0.005	0.721	0.802					
GUI	−0.020	0.603	0.786	0.797				
MO	0.221	0.751	0.638	0.584	0.848			
LIC	0.047	0.608	0.622	0.641	0.617	0.845		
CEP	−0.025	0.612	0.710	0.881	0.596	0.767	0.868	
VC	0.033	0.646	0.821	0.878	0.630	0.511	0.660	0.885

According to the findings of the PLS–SEM test presented in Table 2, all variables examined in this study satisfy the requirements for Validity and reliability. All external loading indicators surpass the 0.7 criterion, signifying their Validity in assessing the construct under consideration. Furthermore, the AVE value for all constructions exceeds 0.5, meaning that the construct in issue can account for over 50% of the variation in the indicators. The Cronbach's Index and Composite reliability values for all variables exceeded the thresholds of 0.7 and 0.8, respectively, suggesting that the measuring equipment demonstrated strong internal consistency. Hence, the instruments employed in this study possess Validity and reliability, ensuring that the analysis results may be relied upon for subsequent interpretation [34].

Discriminant Validity indicates a construct's capacity to differentiate itself from other constructs within the model. The Discriminant Validity Benchmark is utilized to assess the strength of discriminant Validity. It stipulates that the square root of the AVE for each construct should surpass the correlation between that construct and any other construct in the model [31].

The results indicate that all constructs in the model possess discriminatory solid validity. The square root of the AVE for each construct surpasses the correlation between other constructs. This suggests that each construct is more effective in explaining the variability of its indicators compared to the variability explained by other constructs. Therefore, the authenticity of discrimination in this model is ensured [33].

Furthermore, the HTMT test findings presented in Table 4 are utilized to assess discriminating validity. HTMT is a measure that compares the correlation between traits and methods to the correlation between the same trait and other methods. Lower values of the HTMT suggest greater discriminatory validity [33].

Table 4. HTMT

	AA	CR	CT	GUI	MO	LIC	CEP	VC
AA								
CR	0.115							
CT	0.102	0.827						
GUI	0.079	0.706	0.897					
MO	0.240	0.872	0.722	0.671				
LIC	0.097	0.687	0.692	0.733	0.692			
CEP	0.102	0.688	0.784	1.002	0.662	0.843		
VC	0.053	0.720	0.896	0.975	0.690	0.546	0.706	

The HTMT score for all concept pairs is below 0.90, indicating that the discrimination validity has been achieved based on the established criteria. The strong discriminating validity of this model ensures that each construct is more effective at explaining the variances of its indicators than are those described by other constructs [33].

The Coefficient of Determination (R^2) is a statistical metric that estimates the proportion of variability in a dependent variable that can be accounted for by an independent variable in a particular model. A higher R^2 value indicates a more robust ability of the model to explain the variation. A high R^2 value signifies a strong model. However, it is essential to acknowledge that R^2 adjusted accounts for the number of predictors in the model [36]. Table 5 displays the R^2 and R^2 adjusted values for each construct in the model.

Table 5. Coefficient of determination (R^2).

	R^2	R^2 adjusted
AA	0.098	0.032
CR	0.564	0.543
CT	0.764	0.747
MO	0.556	0.535

The evaluation results indicated that the R^2 for AA was 0.098, suggesting that approximately 9.8% of the variability in AA could be accounted for by the independent components in the model. The R^2 for the CR is 0.564, which signifies that independent components can account for 56.4% of the variability in the CR. The R^2 for CT is 0.764, which means that independent factors can account for 76.4% of the variability in CT. The R^2 score for MO is 0.556, which signifies that independent factors can account for 55.6% of the variability in MO. The adjusted R^2 value is marginally lower than R^2, suggesting that it has been modified to account for the number of predictors in the model.

Furthermore, the outcomes of the VIF test are employed to assess the presence of multicollinearity among constructs. VIF is a quantitative metric that measures the degree to which multicollinearity contributes to an increase in the variance of the estimated regression coefficient [37]. The VIF test results are displayed in Table 6.

Table 6. Test results VIF

	AA	CR	CT	MO
CR	2.827		2.827	
GUI	17.216	15.273	17.216	15.273
MO	2.777		2.777	
LIC	2.819	2.551	2.819	2.551
CEP	9.577	8.707	9.577	8.707
VC	8.206	6.003	8.206	6.003

The VIF test results indicate that the GUI variables (17,216, 15,273), CEP (9,577, 8,707), and VC (8,206, 6,003) experience high multicollinearity, which can affect the stability and interpretation of the coefficients in the structural model. On the other hand, the variables CR (2,827), MO (2,777), and LIC (2,819) had a VIF values lower than 5, indicating low to moderate multicollinearity and were acceptable. Although some variables have a high degree of multicollinearity, the model can still make the necessary adjustments, such as deleting or merging highly correlated predictor variables, to ensure the stability and accuracy of the model's estimates.

Bootstrapping analysis is employed to assess the statistical significance of the coefficient path in structural models. This method entails repeatedly sampling the initial data to generate an empirical distribution of the path coefficients. This enables a more precise evaluation of the variability and statistical significance [38]. Fig. 3 displays the bootstrapping output data, illustrating the correlation between the variables in the study model.

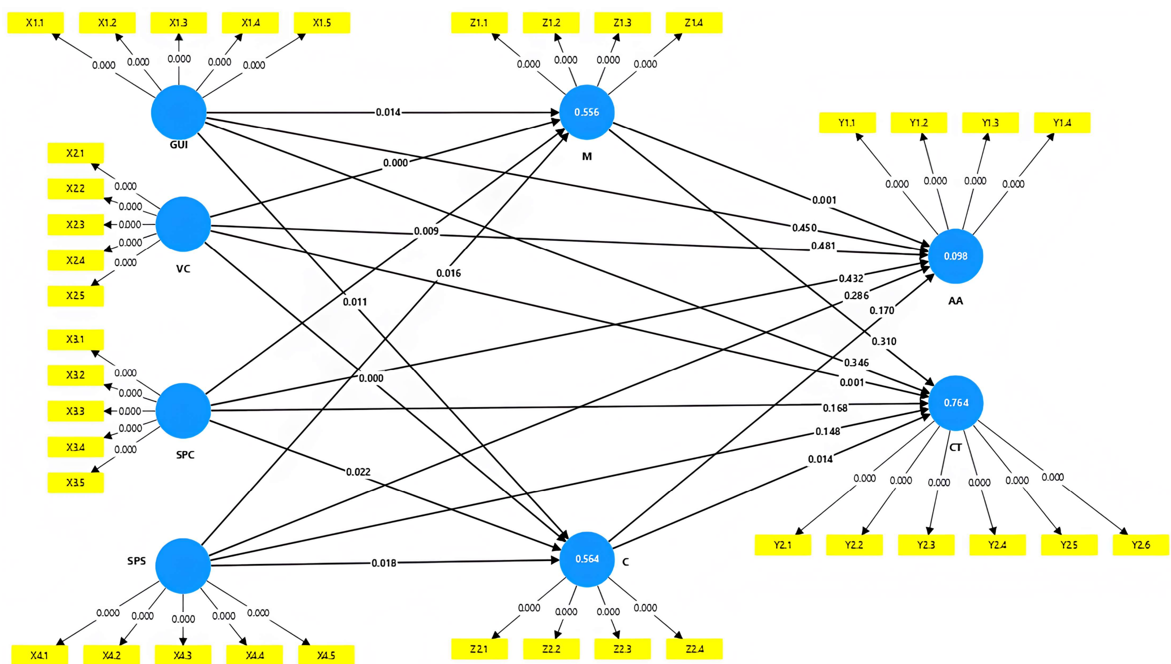

Fig. 3. Bootstrapping analysis graphic.

Table 7 displays the outcomes of the statistical significance analysis and the importance of pathway coefficients for the study hypothesis. The T-test value and P-coefficient are utilized to ascertain the significance of the correlation between variables, where P-coefficients below 0.05 indicate a significant link. The accepted hypothesis demonstrated a substantial correlation, but the denied hypothesis exhibited the opposite outcome [32].

Table 7. Statistical relevance and path coefficient analysis

Hypothesis		Base Sample	Mean of Sample	Standard deviation	T-test Value	P-coefficients	Result
H1	CR -> AA	−0.158	−0.140	0.164	0.961	0.168	Rejected
H2	CR -> CT	0.243	0.247	0.109	2.225	0.013	Accepted
H3	GUI -> AA	−0.049	−0.004	0.387	0.127	0.449	Rejected
H4	GUI -> CR	−0.781	−0.790	0.337	2.319	0.010	Accepted
H5	GUI -> CT	−0.124	−0.071	0.312	0.398	0.345	Rejected
H6	GUI -> MO	−0.785	−0.783	0.345	2.275	0.011	Accepted
H7	MO -> AA	0.462	0.456	0.149	3.103	0.001	Accepted
H8	MO -> CT	−0.050	−0.045	0.099	0.506	0.307	Rejected
H9	LIC -> AA	0.029	0.016	0.166	0.172	0.432	Rejected
H10	LIC -> CR	0.262	0.251	0.132	1.984	0.024	Accepted
H11	LIC -> CT	0.109	0.097	0.111	0.976	0.165	Rejected
H12	LIC -> MO	0.314	0.303	0.133	2.363	0.009	Accepted
H13	CEP -> AA	−0.173	−0.172	0.306	0.566	0.286	Rejected
H14	CEP -> CR	0.546	0.569	0.254	2.147	0.016	Accepted
H15	CEP -> CT	0.218	0.193	0.209	1.041	0.149	Rejected
H16	CEP -> MO	0.498	0.509	0.231	2.156	0.016	Accepted
H17	VC -> AA	−0.013	−0.055	0.267	0.047	0.481	Rejected
H18	VC -> CR	0.837	0.838	0.184	4.560	0.000	Accepted
H19	VC -> CT	0.604	0.579	0.186	3.246	0.001	Accepted
H20	VC -> MO	0.830	0.827	0.224	3.701	0.000	Accepted

The results indicate that multiple paths exhibit strong statistical significance. For example, the pathway H2 (CR -> CT) has a T-test value of 2.225 and a P-coefficient of 0.013. Similarly, the pathway H4 (GUI -> CR) has a T-test value of 2.319 and a P-coefficient of 0.010. Pathway H7 (MO -> AA) also has a T-test value of 3.103 and a P-coefficient of 0.001. Additional notable pathways comprise H6, H10, H12, H14, H16, H18, H19, and H20.

To comprehend the dynamics of cause–and–effect linkages in the model, we assessed the structural model with a particular emphasis on the Specific Indirect Effect (SIE).

The purpose of SIE analysis is to discover and quantify the indirect impact of independent variables on dependent variables by examining the role of mediators. By examining these channels of influence, one can acquire a more profound understanding of how the variables in the model interact and affect one another. The significance of this assessment lies in its ability to reliably identify and analyze all causal effects in the model, including both direct and indirect effects [39]. The results of the SIE analysis conducted in Table 8 are as follows:

Table 8. Specific indirect effects

Variable	Base Sample	Mean of Sample	Standard deviation	T-test Value	P-coefficients	Result
GUI -> MO -> CT	0.039	0.038	0.088	0.450	0.326	Rejected
LIC -> MO -> AA	0.145	0.137	0.075	1.932	0.027	Accepted
GUI -> CR -> AA	0.123	0.110	0.150	0.825	0.205	Rejected
CEP -> MO -> AA	0.230	0.236	0.142	1.623	0.052	Rejected
LIC -> MO -> CT	-0.016	-0.015	0.035	0.456	0.324	Rejected
VC -> MO -> AA	0.383	0.382	0.175	2.195	0.014	Accepted
GUI -> CR -> CT	-0.190	-0.204	0.139	1.364	0.086	Rejected
LIC -> CR -> AA	-0.041	-0.036	0.052	0.797	0.213	Rejected
CEP -> MO -> CT	-0.025	-0.023	0.056	0.446	0.328	Rejected
CEP -> CR -> AA	-0.086	-0.083	0.112	0.771	0.220	Rejected
VC -> MO -> CT	-0.042	-0.039	0.087	0.479	0.316	Rejected
LIC -> CR -> CT	0.064	0.065	0.048	1.333	0.091	Rejected
VC -> CR -> AA	-0.132	-0.113	0.141	0.936	0.175	Rejected
CEP -> CR -> CT	0.133	0.143	0.097	1.370	0.085	Rejected
VC -> CR -> CT	0.204	0.211	0.113	1.811	0.035	Accepted
GUI -> MO -> AA	-0.362	-0.364	0.214	1.696	0.045	Accepted

The results of SIE analysis revealed several statistically significant pathways, such as LIC -> MO -> AA with a T-test value of 1.932 and a P-coefficient of 0.027, and VC -> MO -> AA with a T-test value of 2.195 and a P-coefficient of 0.014. Other significant pathways include VC -> CR -> CT and GUI -> MO -> AA. This analysis provides deeper insights into how the model's variables interact and affect each other.

Model fit evaluation seeks to determine the degree to which the proposed model aligns with the observed data. The assessment relies on two primary metrics: the SRMR and the squared Euclidean distance (d_ULS) [35]. Table 9 displays the following information:

The model match test results indicate that the SRMR value for the saturated model is 0.085, while for the estimated model, it is 0.088. These values are close to the threshold of 0.08, suggesting that the model match is pretty good. The d_ULS value for the saturated model was 5.302, whereas, for the estimation model, it was 5.742. This suggests a moderate discrepancy between the observed and predicted covariance matrices. Overall, the model can be considered a good match with the observed data, although some adjustments may be required to improve the fit.

Table 9. Model fit test results

	Saturated model	Estimated model
SRMR	0.085	0.088
d_ULS	5.302	5.742

This study provides significant insight into how e-learning can improve automotive engineering students' academic achievement and critical thinking skills through various variables analyzed. In this context, the GUI and VC significantly influence CR and MO [30, 40]. The results of PLS–SEM analysis revealed that GUI significantly affects CR and MO, which shows that although gadgets can improve information accessibility, excessive use can reduce students' creativity and motivation [41, 42]. In contrast, VC has a positive and significant effect on CR and MO, emphasizing the importance of verbal communication in increasing student engagement and creativity in e-learning [43, 44]. In addition, LIC and CEP are significantly related to MO, where LIC had a positive effect on MO and AA, and CEP had a substantial impact on CR and MO [45, 46].

Self-motivation theory states that a learning environment supporting autonomy, competence, and interconnectedness can increase intrinsic motivation, positively impacting academic achievement and critical thinking skills [47]. This study also found that the indirect effects of independent variables such as LIC and VC on AA through MO were quite significant [48, 49]. LIC showed a crucial indirect impact on AA through MO (T-test Value = 1.932, P-coefficient = 0.027); these findings suggest active engagement with content can increase motivation, improving academic achievement [50]. These findings suggest that active participation and engagement in learning can increase intrinsic motivation, contributing to better educational outcomes [51].

Thus, this study not only enriches the literature on e-learning and its influence on academic achievement and critical thinking skills but also emphasizes the importance of considering the variables of motivation and creativity as significant mediators in structural models. This study provides practical implications that educational institutions must design e-learning programs emphasizing verbal communication and active participation and manage the intensity of gadget use to remain optimal and support the learning process.

This study offers a new perspective on using e-learning to enhance academic achievement and critical thinking, particularly in the context of automotive engineering students. While much of the previous literature has focused on the benefits of e-learning in terms of accessibility and flexibility, our research highlights the crucial role of verbal communication and interaction with content as critical drivers for increasing motivation and creativity. This nuanced understanding emphasizes the need for balance in gadget use, where excessive use can lead to distractions, but moderated and purposeful use can foster better learning outcomes.

A key novelty of this research lies in its focus on verbal communication and learner interaction with content as mediating factors between e-learning and academic performance. Unlike earlier studies, which primarily focused on general e-learning benefits, our research uniquely identifies that active engagement through communication plays a pivotal role in motivating students, enhancing creativity, and improving academic performance. Additionally, the findings related to gadget intensity provide a fresh look at how digital tools can aid and hinder learning, depending on their application and balance in the learning process.

This study not only strengthens the existing literature by providing empirical evidence from a specific cohort of students in automotive engineering but also offers practical insights for designing more effective e-learning systems. By addressing the critical role of communication, creativity, and motivation, educational institutions can better tailor their e-learning platforms to meet the needs of students, promoting both academic excellence and critical thinking skills. The implications of this study suggest that future research could explore similar dynamics in other disciplines, further broadening the understanding of how e-learning influences various aspects of student development.

IV. Conclusion

This study demonstrates that e-learning in higher education, particularly in automotive engineering, holds significant promise for enhancing students' academic performance and fostering their critical thinking abilities. Factors such as gadget usage, verbal interaction, engagement with information, and peer interaction significantly influence motivation and creativity, which in turn affect academic achievements. Findings from the PLS–SEM analysis indicate that engaging in verbal communication and active participation in learning substantially boost motivation and creativity, whereas excessive use of gadgets has a detrimental effect.

These results underscore the importance of a comprehensive strategy in developing e-learning programs. Educational institutions should design e-learning environments that facilitate efficient verbal communication and active engagement through discussion forums and collaborative projects. It is crucial to regulate gadget usage to focus on learning-enhancing activities, maximizing benefits without diminishing creativity and motivation. Providing training for lecturers to manage e-learning interactions effectively is also essential.

For future research, it is advisable to investigate additional variables that influence academic performance and critical thinking skills in online education, such as cultural factors or technological proficiency. Conducting longitudinal and interdisciplinary studies would offer a more comprehensive understanding of the long-term effects of e-learning and inform the development of more effective educational strategies.

Conflict of Interest

The authors declare no conflicts of interest.

Author Contributions

Wagino Wagino: Conceptualization, design, analysis, writing; Habibullah: Editing/reviewing, supervision; Ichsan Nasution: Data acquisition, data curation, visualization; M Giatman: Securing funding, project administration, resources; Rahmat Desman Koto: Data acquisition, data analysis/interpretation, drafting manuscript, conceptualization, methodology; Agariadne Dwinggo Samala: Statistical analysis, writing - review & editing; Santiago Criollo-C: Editing/reviewing, supervision; Ken Polin: Editing/reviewing, supervision; all authors had approved the final version.

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