

Synergistic Effects of Motivation and Cognition on Academic Success in Engineering Education

Ilmiyati Rahmy Jasril^{1,*}, Usmeldi², and Krismadinata²

¹Departement of Electronics Engineering, Faculty of Engineering, Universitas Negeri Padang, Indonesia

²Departement of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang, Indonesia

Email: ilmiyatihmyjasril@ft.unp.ac.id (I.R.J.); usmeldy@yahoo.co.id (U.); krisma@ft.unp.ac.id (K.)

*Corresponding author

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Abstract—This study aims to examine the influence of self-regulated learning, self-efficacy, critical thinking, and problem-solving skills on academic performance in simulation-based engineering education. Technology-enhanced learning, particularly through simulation, provides an interactive and autonomous environment that encourages students to engage cognitively and manage their own learning. In this context, virtual circuit simulation projects are used to foster deeper thinking, sustained effort, and practical problem-solving. A total of 372 electronics engineering students from Universitas Negeri Padang participated in the study, completing a structured questionnaire. Data were analyzed using Structural Equation Modeling (SmartPLS) and network analysis (JASP). The findings show that self-regulated learning and self-efficacy significantly predict students' critical thinking, problem-solving skills, and academic performance. Moreover, problem-solving was the strongest cognitive predictor of academic achievement. These results highlight the importance of cultivating motivation and cognition through simulation-based learning, which supports the development of essential skills and improves academic outcomes in higher education. Notably, the combined effects of these variables explained 76.8% of the variance in academic performance ($R^2 = 0.768$).

Keywords—motivation, cognition, engineering education, structural equation modeling, network analysis

I. INTRODUCTION

What drives individuals to engage in learning? This fundamental question has long intrigued scholars in the field of educational psychology. Throughout life, every person undergoes diverse learning experiences, whether formal or informal, structured or spontaneous. As educational thought has evolved over time, numerous experts have offered differing interpretations of what constitutes learning. According to one perspective, learning is a deliberate process of action that brings about internal change within the individual [1, 2]. Meanwhile, Patsiomitou [3] defines it as a cognitive or psychological effort that arises through active engagement with one's environment, resulting in a relatively permanent transformation in behavior or understanding. The conceptualization highlights the integration of psychological engagement and interactive learning tools, including those mediated by educational technologies, which support such transformations. Another viewpoint by Ismail *et al.*, suggests that learning is a gradual acquisition of abilities, competencies, and attitudes achieved through sustained effort [4]. Synthesizing these views, it can be concluded that learning is fundamentally an intentional pursuit aimed at fostering change whether in knowledge, skills, or disposition. It is this promise of meaningful transformation that fuels an

individual's willingness to learn.

In the context of educational transformation, a multitude of factors both internal and external shape the learning process. Among these, the most pivotal and influential determinant is the internal factor, which originates from within the learner [5]. This intrinsic drive is essential, as the choice to engage in learning is ultimately rooted in personal agency, self-awareness, and internal motivation. As noted by Tasrif *et al.* [6], students are primarily motivated to learn due to the presence of internal motivational forces. In contrast, G. Pezzulo *et al.* [7] emphasize that student learning is deeply intertwined with gradually evolving cognitive processes. Their framework, based on active inference and generative models, provides insight into how technology-enhanced environments, such as simulation-based learning systems, can support cognitive development by simulating real-world dynamics and facilitating adaptive learning pathways. Building on these perspectives, this study centers on two core components that significantly impact students' persistence and sustained engagement in learning: motivation and cognitive abilities.

Motivation in its essence, serves as a primary catalyst for engaging in the learning process. However, it does not arise in isolation rather, it is shaped by a constellation of underlying factors, including intellectual curiosity and the presence of personally meaningful goals [8]. The intrinsic satisfaction derived from mastering and internalizing new knowledge often reinforces the desire to learn [9]. It is this internalized sense of fulfillment and purpose that ultimately drives individuals to pursue and sustain their learning endeavors.

Motivation can be nurtured through a variety of mechanisms, particularly when students assume responsibility for their own learning and demonstrate confidence in their abilities [10–12]. These two essential facets of motivation are embodied in the constructs of self-regulated learning and self-efficacy. In contrast, cognitive skills refer to an individual's ability to synthesize, analyze, and evaluate information effectively. Within the academic setting, students are regularly confronted with new knowledge drawn from diverse sources ranging from instructors and textbooks to digital platforms and multimedia content [13, 14]. In such a dynamic learning environment, cognitive skills are indispensable. Learners are not passive recipients of information but rather active participants who construct meaning from complex and varied inputs. This process of cognitive engagement is most clearly demonstrated through two foundational competencies: critical thinking and problem-solving skills.

Self regulated learning exemplifies motivational strength, as it involves intentional effort and strategic self management such as initiative, goal-setting, and self control directed toward achieving academic objectives. In a similar vein, self-efficacy reflects students' belief in their capacity to overcome obstacles, maintain perseverance, and remain resilient in the face of academic challenges. On the cognitive side, critical thinking embodies a core intellectual competency. It empowers students to engage in thorough analysis and reflective judgment, encouraging them to critically examine each component of the learning experience. By applying reasoned thought, students aim to reduce cognitive biases and circumvent logical fallacies. Complementing this, problem solving skill represents a higher-order cognitive function that is inherently connected to critical thinking. It extends the analytical process by enabling students to systematically identify problems, assess potential solutions, and execute effective strategies to reach resolutions [15].

A comprehensive review of existing literature indicates that motivational and cognitive factors have been widely studied for their influence on students' academic performance [16]. However, much of this research has treated these constructs in a broad and generalized manner, often overlooking their distinct subcomponents. As a result, a significant gap persists in the empirical literature regarding how specific motivational dimensions namely self regulated learning and self-efficacy and cognitive dimensions specifically critical thinking and problem solving skills individually and collectively contribute to academic achievement, particularly within the context of higher education. To address this gap, the present study offers an integrated analysis of both motivational and cognitive factors within a unified conceptual framework. The relationships among these constructs are illustrated in the research model presented in Fig. 1.

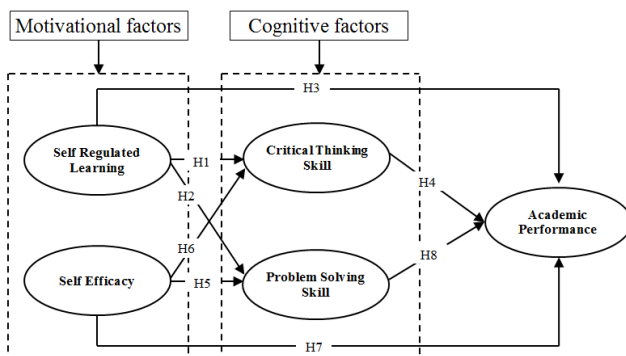


Fig. 1. Research framework.

Based on the research framework presented in Fig. 1, several direct effects among the variables can be formulated, which constitute the core focus of the analysis in this study. These effects are further articulated in the form of the following research questions:

H1: Does self regulated learning significantly affect critical thinking skill?

H2: Does self regulated learning significantly affect problem solving skill?

H3: Does self regulated learning significantly affect academic performance?

H4: Does critical thinking skill significantly affect academic performance?

H5: Does self-efficacy significantly affect problem solving skill?

H6: Does self-efficacy significantly affect critical thinking skill?

H7: Does self-efficacy significantly affect academic performance?

H8: Does problem solving skill significantly affect academic performance?

II. LITERATURE REVIEW

A. Self-Regulated Learning

Self-regulated learning is broadly defined as students' capacity to independently direct and manage their own learning processes. This involves setting academic goals, selecting and adapting effective learning strategies, and continuously assessing their progress toward desired outcomes. Barry J. Zimmerman, a prominent figure in the development of self-regulated learning theory, emphasizes that '*self-regulated learners are aware when they know a fact or possess a skill and when they do not*' [17]. This highlights the essential role of metacognitive awareness students' ability to accurately monitor their understanding and apply corrective strategies to enhance their learning. As students navigate the learning journey, they inevitably face disruptions caused by various factors, such as ineffective instructional approaches or the inherent difficulty of the subject matter. In such contexts, self-regulated learning becomes especially critical. It empowers students to take initiative, apply self-discipline, and persist in the face of challenges, ultimately allowing them to sustain momentum and continue progressing toward academic success.

In the pursuit of effective self regulation and the development of purposeful learning strategies, students are fundamentally driven by a core determinant, motivation. Motivation represents an intrinsic psychological force that shapes the direction, intensity, and persistence of one's learning efforts [18]. Among the most prominent expressions of this internal drive is goal setting defined as the establishment of clear, specific, and meaningful academic objectives [19]. Goal setting serves as a primary catalyst for self regulated learning, as students with well-defined goals are more likely to engage in strategic planning, ongoing self monitoring, and independent evaluation of their academic performance. In this regard, self regulated learning can be viewed as both a manifestation and practical extension of intrinsic motivation within the academic context.

B. Self-Efficacy

Self-efficacy refers to an individual belief in their capacity to execute tasks and achieve specific goals. This construct was first introduced by Albert Bandura and Nancy E. Adams in 1977 as a central component of social cognitive theory [20]. Self-efficacy influences not only the selection of activities but also the intensity of effort and persistence individuals exhibit when confronting challenges. Bandura asserted that the stronger an individual belief in their likelihood of success, the more probable it is that success will be realized. Importantly, self-efficacy extends beyond mere outcome expectancy. It is also deeply tied to one commitment to the

learning process itself. Students with high self-efficacy are more inclined to take initiative, remain resilient in the face of adversity, and maintain confidence in their ability to overcome academic hurdles.

Self-efficacy also constitutes a fundamental dimension of motivation [21]. The belief in one's own capabilities acts as a critical catalyst in fostering a positive disposition toward learning, particularly in the adoption and execution of self-regulated learning strategies. Students who possess strong confidence in their abilities are more likely to exhibit consistency in setting academic goals, actively monitoring their progress, and engaging in reflective evaluation of their learning outcomes.

C. Critical Thinking Skill

Critical thinking is a higher-order cognitive skill that empowers individuals to objectively analyze, evaluate, and synthesize information prior to forming judgments or making decisions. The origins of critical thinking can be traced back to ancient Greece, where Socrates played a pivotal role in its development through his method of disciplined questioning, now known as the Socratic Method [22, 23]. This approach encourages continuous inquiry, critical examination of assumptions, and resistance to accepting information at face value even when it is presented by authoritative figures, thereby addressing the fallacy of appeal to authority. True critical thinking involves more than the passive absorption of knowledge, it demands an active, reflective engagement with information to assess its accuracy, coherence, and relevance.

In contemporary education, critical thinking is widely regarded as an essential skill and functions as a key indicator of the effectiveness of the learning process. Its importance is particularly pronounced in disciplines that require advanced analytical and evaluative capabilities such as engineering education where students are frequently tasked with solving complex, real-world problems. According to P. A. Facione [23], a critical thinker possesses the ability to analyze, interpret, and evaluate information or situations with clarity and depth. This highlights the centrality of critical thinking as a fundamental component of cognitive competence, playing a vital role in fostering intellectual rigor and informed decision-making across academic contexts.

D. Problem Solving Skill

The foundational framework for problem solving was established by Newell and Simon in 1972, who introduced means-ends analysis as a conceptual model to describe the cognitive steps involved in resolving problems [24]. At its core, problem solving serves as an internal mechanism that bridges learning and performance. Anderson further emphasized that problem solving functions as a conduit linking knowledge to behavior, particularly cognitive behavior, within the learning process [25]. Over time, problem solving has evolved beyond addressing abstract or theoretical challenges, it has become an essential skill applied to real-world, practical situations. As the field has progressed, research on problem solving has increasingly intersected with studies on human learning both converging on a shared emphasis the development and refinement of cognitive skill acquisition.

In terms of education, problem solving skills are an obvious application of critical thinking. After having

information analyzed and evaluated through the critical thinking process, students use problem solving skills to implement solutions through reasoning and reflection.

E. Academic Performance

The term academic performance is often used interchangeably with related expressions such as learning achievement, learning outcomes, and others. While each term has a distinct nuance, they generally refer to the outcome of learning, indicating how well an individual has achieved the intended educational goals [26]. Academic performance can be assessed through a variety of methods, including standardized test scores, project-based evaluations, classroom participation, and the demonstration of specific competencies

III. MATERIALS AND METHODS

This study employed a quantitative approach to analyze the influence of motivational factors namely self-regulated learning and self-efficacy and cognitive factors, including critical thinking and problem-solving skills, on students' academic performance. The research focused on undergraduate students enrolled in the department of electronic engineering at Universitas Negeri Padang, located in West Sumatra, Indonesia. The participants were selected based on their active involvement in a series of class sessions and their completion of a virtual breadboard simulation project. For the purpose of the study, students were organized into small collaborative groups, with each group assigned a specific electronic circuit project, presented in Fig. 2a. This hands-on assignment was deliberately designed to assess students' levels of self-regulation and self-efficacy, while simultaneously fostering and measuring their critical thinking and problem solving abilities within an applied learning environment. An illustration of the virtual simulation process is presented in Fig. 2b, which depicts the steps involved in the simulation activity.

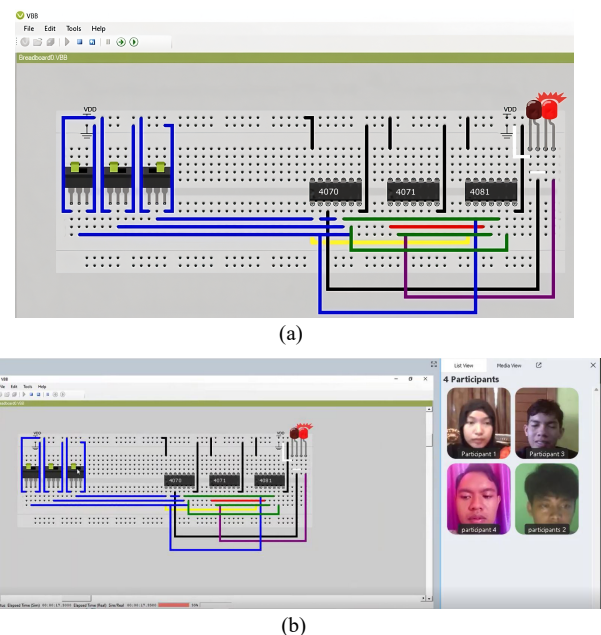


Fig. 2. Simulation project Student: (a) Virtual breadboard project design; (b) Virtual breadboard simulation.

Upon completion of the group project, data were gathered through a structured survey administered at the end of the

semester. The survey was designed to assess students' learning strategies, self-efficacy beliefs, and cognitive responses specifically their critical thinking and problem solving skills as demonstrated during the execution of the project. This instrument served as the primary tool for capturing students' reflective insights and self perceived competencies related to the learning experience. The questionnaire consisted of 28 items, each rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The scale was designed to capture students' self-perceptions of their motivation and cognitive skills within the simulation-based learning environment. To illustrate, one sample item from each construct is provided below:

- 1) Self-Regulated Learning (SRL): "I can manage my time well in completing the simulation project".
- 2) Self-Efficacy (SE): "I am confident in my ability to complete academic tasks successfully".
- 3) Critical Thinking Skill (CTS): "I am able to analyze the information or instructions available in the simulation software".
- 4) Problem Solving Skill (PSS): "I am able to identify the core problem in the simulation project".
- 5) Academic Performance (AP): "I feel that I have successfully achieved the learning objectives of this course".

Participants in this study were selected using a purposive sampling technique. This method was chosen to ensure alignment between the respondents' characteristics and the specific context of the research namely, the implementation of simulation based learning and the course content in which they were enrolled. The purposive sampling approach was deemed appropriate, as the selected students had direct engagement with the use of virtual simulation media and were actively involved in learning activities closely related to the competencies being evaluated, particularly in the areas of motivation and cognitive skill development [27, 28]. A total of 372 students contributed to the study, each possessing specific characteristics.

Table 1. Respondent description

Sample characteristics		Frequency	Percentage
Current year of study	Year 1	136	36.6%
	Year 2	71	19.1%
	Year 3	118	31.7%
	Year 4	37	9.9%
	Year 5	10	2.7%
	Total	372	100%
Gender	Male	293	78.8%
	Female	79	21.2%
	Total	372	100%
Age	17–18 years old	58	15.6%
	19–20 years old	176	47.3%
	21–22 years old	124	33.3%
	23–24 years old	13	3.5%
	> 24 years old	1	0.3%
	Total	372	100%

All procedures involving human participants in this study were conducted in accordance with institutional and national research ethics guidelines. Prior to data collection, the study received ethical approval from the Research Ethics Committee of Universitas Negeri Padang. Participation was voluntary, and informed consent was obtained from all participants. Respondents were assured of anonymity and the confidentiality of their responses. No personally identifiable

information was collected, and participants were free to withdraw from the study at any point without penalty. These characteristics are presented in Table 1.

This study employed a quantitative data analysis approach utilizing advanced statistical software. The primary analytical method implemented was Structural Equation Modeling (SEM) using SmartPLS, selected for its capacity to simultaneously evaluate both the measurement model (outer model) and the structural model (inner model) [29–31]. SEM was particularly suitable for examining the complex relationships among latent constructs and observed variables. To enhance the rigor and interpretability of the findings, a complementary network analysis was also performed using JASP (Jeffrey's Amazing Statistics Program). This analysis provided a visual representation of the interrelationships and the strength of associations among the key variables, offering additional insight into the structural dynamics within the proposed model.

IV. RESULT AND DISCUSSION

This section presents the empirical findings derived from field data. The initial analysis was conducted using Structural Equation Modeling (SEM) to evaluate the relationships within the proposed research framework (see Fig. 1). Through this method, the research hypotheses were systematically tested and validated. Following the SEM analysis, a network analysis was performed to visually map the interconnections among the key variables. The interpretation of results from both analytical techniques was grounded in relevant theoretical frameworks and guided by established methodological criteria and rules of thumb specific to each approach.

A. Instrument Validity and Reliability

The validity and reliability of the statement items used as instruments to measure the research variables were the first analyses conducted using SmartPLS. The instrument used must accurately measure the object of the study. Therefore, instrument validity testing was performed. The standard value for an instrument to be considered valid is an outer loading above 0.7. In addition, the Average Variance Extracted (AVE) value can also serve as a basis for determining the validity of the instrument. The threshold value for AVE is above 0.5 [32].

Beyond establishing validity, the measurement instrument must also demonstrate reliability. In this context, reliability refers to the consistency and stability of the instrument items when administered across different samples or over multiple time points. A reliable instrument ensures that the results are not only accurate but also reproducible, thereby enhancing the credibility of the research findings. This study employed Cronbach's Alpha and Composite Reliability (CR) as the primary indicators of reliability, with a recommended minimum threshold of 0.70 [33, 34]. Although some sources suggest that reliability values above 0.60 may still be acceptable [35, 36], this study adopts a stricter criterion, setting ≥ 0.70 as the minimum standard to ensure the internal consistency of the measurement instrument. The results of the validity and reliability analyses are presented in Table 2.

As shown in Table 2, a total of 28 statement items were utilized to measure the five research variables. Self regulated

learning (5 items), self-efficacy (6 items), critical thinking skill (6 items), problem-solving skill (5 items), and academic performance (6 items). All measurement items demonstrated strong validity, with outer loading values exceeding the recommended threshold of 0.70 and (AVE) values surpassing 0.50. In addition, the instrument exhibited high reliability, as evidenced by Cronbach's Alpha and CR values for all constructs, each exceeding the 0.70 benchmark. These findings confirm that the measurement model meets the established criteria for both validity and reliability, thereby affirming its suitability for subsequent structural analysis.

Table 2. Instrument validity and reliability

Variable	Item	Outer loading	Cronbach's alpha	CR	AVE
Self Regulated Learning (SRL)	SRL1	0.827	0.869	0.905	0.657
	SRL2	0.781			
	SRL3	0.859			
	SRL4	0.766			
	SRL5	0.817			
Self-efficacy (SE)	SE1	0.860	0.926	0.942	0.732
	SE2	0.881			
	SE3	0.893			
	SE4	0.863			
	SE5	0.818			
	SE6	0.814			
Critical Thinking Skill (CTS)	CTS1	0.904	0.938	0.951	0.764
	CTS2	0.869			
	CTS3	0.847			
	CTS4	0.880			
	CTS5	0.850			
	CTS6	0.894			
Problem Solving Skill (PSS)	PSS1	0.867	0.924	0.943	0.768
	PSS2	0.882			
	PSS3	0.896			
	PSS4	0.875			
	PSS5	0.859			
Academic Performance (AP)	AP1	0.854	0.932	0.947	0.748
	AP2	0.845			
	AP3	0.866			
	AP4	0.898			
	AP5	0.885			
	AP6	0.839			

B. Hypothesis Result

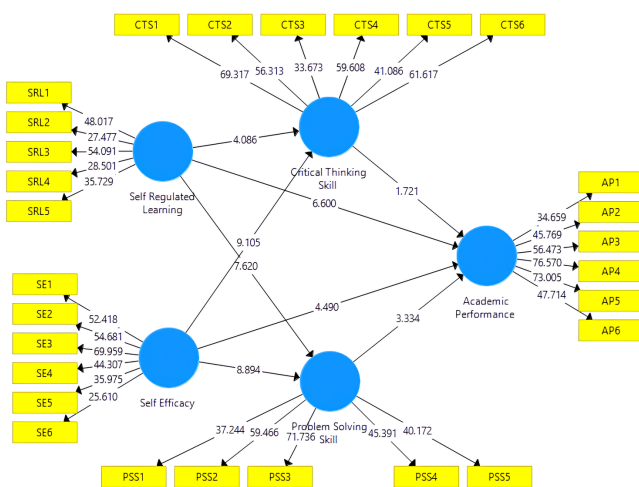


Fig. 3. T-statistic result.

A total of eight hypotheses were statistically tested using the SEM method. The decision to accept or reject each hypothesis was based on the t-statistic, with hypotheses considered accepted if the t-statistic was ≥ 1.96 [37]. This threshold indicates a statistically significant relationship

between variables at the 95% confidence level. In addition, the significance of the relationships was determined by the p-value, with effects deemed significant when the p-value was ≤ 0.05 [38]. The magnitude of the influence between variables was interpreted through the beta coefficient, which reflects the strength and direction of the relationship, ranging from -1 (perfect negative effect) to 1 (perfect positive effect) [39]. The results of this analysis are presented in Fig. 3, Fig. 4, and Table 3.

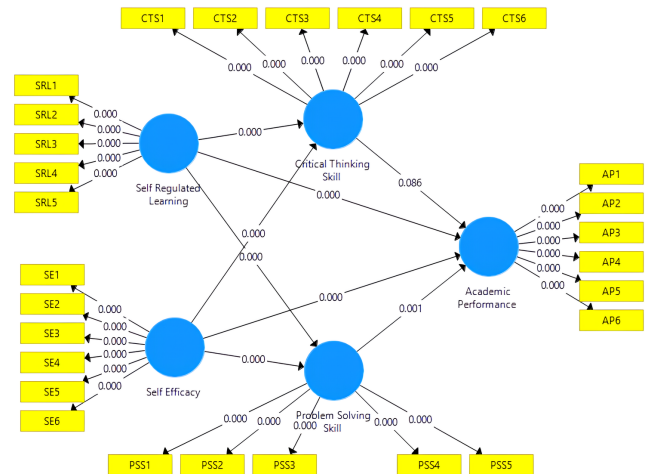


Fig. 4. P-value result.

Table 3. Hypothesis result

Hypothesis	T-Statistic	P-Value	β	Result
H1 Self Regulated Learning $\rightarrow$ Critical Thinking Skill	4.086	0.000	0.269	Accepted
H2 Self Regulated Learning $\rightarrow$ Problem Solving Skill	7.620	0.000	0.386	Accepted
H3 Self Regulated Learning $\rightarrow$ Academic Performance	6.600	0.000	0.367	Accepted
H4 Critical Thinking Skill $\rightarrow$ Academic Performance	1.721	0.086	0.110	Rejected
H5 Self-efficacy $\rightarrow$ Problem Solving Skill	8.894	0.000	0.462	Accepted
H6 Self-efficacy $\rightarrow$ Critical Thinking Skill	9.105	0.000	0.572	Accepted
H7 Self-efficacy $\rightarrow$ Academic Performance	4.490	0.000	0.299	Accepted
H8 Problem Solving Skill $\rightarrow$ Academic Performance	3.334	0.001	0.202	Accepted

Based on the results of the SEM analysis presented in Table 3, eight direct hypothesis tests were conducted. Of these, seven hypotheses were accepted and one was rejected.

Hypothesis 1 examines the effect of self-regulated learning on critical thinking skill. This suggests that students who proactively set goals, monitor their learning process, and adjust strategies are more likely to develop analytical thinking. This finding suggests that self regulated learning exerts a significant positive influence on the critical thinking skill of electronics engineering students engaged in virtual simulation projects. The results of this analysis are consistent with several previous studies. For instance, study by

Atmojo *et al.*, [40] conducted among students in elementary teacher education programs, demonstrated similar findings. The current study reinforces that effective learning strategies positively influence students' critical thinking abilities. Similarly, study from Anwar *et al.*, [41] conducted in a biochemistry course, found that students with strong self regulated learning skills were better able to evaluate their learning processes effectively. These hypothesis testing results further support the existing body of literature, affirming that improved self regulation in learning is associated with enhanced critical thinking skills. Moreover, the findings suggest that the relationship between these variables remains consistent across disciplines not only among students in engineering education, but also among those in elementary education and natural sciences such as biology and chemistry.

Hypothesis 2 examined the effect of self regulated learning on problem solving skill. Students who manage their learning behavior effectively are better equipped to analyze situations, generate solutions, and execute decisions. This reflects the iterative nature of simulation-based projects, where learners must continuously assess their approaches and revise strategies, consistent with literature on metacognitive development and applied cognition. The findings of the current study are in line with previous research. A prior study conducted among elementary school students reported similar results [42]. Self regulated learning serves as a pathway to achieving learning objectives due to its capacity to enhance metacognitive awareness and problem solving abilities. However, contrasting findings were observed in studies involving university students majoring in physics and chemistry [43]. Self regulated learning and instructional management were found to have limited influence on students' critical thinking during the learning process. This suggests that self regulated learning does not uniformly impact problem solving skills across all fields of study or levels of education. The extent of its influence appears to be shaped by the specific characteristics of the learning context and the nature of the tasks assigned to the research participants.

Hypothesis 3 examined the effect of self regulated learning on academic performance. Beyond cognitive skill development, this relationship reflects the motivational dimension of SRL, where persistent effort and adaptive learning contribute to sustained achievement. In the context of this study, students managing their workflow and time during simulations were better positioned to meet learning outcomes—echoing studies emphasizing SRL as a predictor of academic success. This result indicates that self regulated learning has a significant positive effect on the academic performance of electronics engineering students in completing virtual simulation projects. The findings of this study are supported by several previous investigations. Self regulated learning has been shown to have a positive and significant impact on students' academic achievement at the elementary, middle, and high school levels through extracurricular activities [44]. Consistent with the findings of Hidayat *et al.*, [45], which examined engineering students in higher education using augmented reality technology. The current study reinforces the notion that effective learning management enhances both academic achievement and

competency development. It can be concluded that well managed and organized learning processes serve as a source of motivation, contributing to improved learning outcomes. These results are applicable not only to higher education but across all levels of education, from elementary, middle school, and high school.

Hypothesis 4 examined the effect of critical thinking skill on academic performance. This outcome stem from the assessment focus on project completion and procedural accuracy rather than deep reflective thinking. Although critical thinking remains essential for learning, its impact on performance may be moderated by task characteristics or the weight given to technical execution over cognitive reasoning. The analysis revealed a positive effect, though it was not statistically significant. This finding contrasts with the results of study [46], a meta-analysis which concluded that critical thinking skill has a moderate positive impact on academic performance. Similar results were reported in a prior study involving university students majoring in foreign languages in China by Teng and Yue [47], where critical thinking skill was deemed essential for achieving successful learning outcomes. These findings suggest that although critical thinking is theoretically important in the educational context, its contribution to academic performance in the context of virtual simulation projects in electronics engineering has not proven to be significant. This may be attributed to students placing greater emphasis on the technical completion of the project rather than engaging in critical reflection throughout the learning process.

Hypothesis 5 examined the effect of self-efficacy on problem solving skill. Belief in one's capabilities fosters persistence and initiative. Confident students are more willing to confront complex simulation challenges and to try multiple approaches—behaviors aligned with effective problem-solving strategies. This motivational factor thereby serves as a bridge to cognitive application. One study conducted among university students in China reported similar findings [48]. Self-efficacy positively influences problem solving disposition. Likewise, research involving psychology students at an Indonesian university also confirmed this relationship [49], showing that higher levels of self confidence are associated with stronger problem solving skill. Therefore, it can be concluded that the greater a student's belief in their own abilities, the more developed their cognitive capacity for problem solving becomes.

Hypothesis 6 examined the effect of self-efficacy on critical thinking skill. Learners with high academic confidence tend to engage more actively in evaluating evidence and questioning assumptions, which are essential in developing critical perspectives. Within a simulation-based environment, these students may be more explorative and thorough in interpreting software data and outcomes, enhancing critical engagement. Several previous studies support this finding. First, a study conducted among nursing diploma and bachelor students at a university in the Netherlands [50] reported that students' self-efficacy demonstrated a significant positive relationship with critical thinking ability. Second, a study conducted by Hayat and Shateri in Iran involving medical students revealed similar findings [51]. There is a positive association between students' self confidence and their metacognitive strategies,

such as planning, monitoring, and regulating. Therefore, it can be concluded that self-efficacy has a significant positive influence on critical thinking skill. This influence not only among engineering students, but also among students in psychology and health-related disciplines.

Hypothesis 7 indicates the effect of self-efficacy on academic performance. Students who believe in their ability to succeed are more likely to maintain focus, regulate emotions under pressure, and engage more deeply with learning materials. This aligns with the broader motivational theory asserting that belief systems shape behavior and performance outcomes. In line with the study by Kang *et al.*, [52] conducted on 12th-grade students, self-efficacy has a positive and significant effect on students' learning success. Similarly, research conducted on undergraduate students focusing on learning behavior within Chinese cultural contexts revealed comparable results [53]. The study indicated that students' belief in their own abilities can serve as a strong predictor of their academic achievement. Therefore, it can be concluded that the more confident students are in their ability to achieve academic results, the more successful they are in attaining meaningful learning outcomes.

Hypothesis 8 demonstrates the effect of problem solving skill on academic performance. This confirms that cognitive flexibility and the ability to execute practical solutions are central to success in engineering education, particularly when learning involves simulations and iterative task refinement. This finding is consistent with a study by Almulla and Al-Rahmi [54] This study conducted on university students in Saudi Arabia, which showed that problem solving has a positive and significant impact on students' academic performance in an e-learning environment. Similarly, research conducted by Pimdee *et al.*, [55] on prospective teachers in Thailand, found that problem solving skill can enhance their academic achievement. Based on these findings, it can be concluded that the better a person's problem solving ability, the higher their potential to achieve optimal academic performance.

The integration of simulation-based learning within this study played a central role in activating both motivational and cognitive dimensions. Virtual circuit projects provided authentic problem scenarios, requiring students to apply self-regulation strategies such as goal-setting, time management, and reflective evaluation. At the same time, the hands-on simulation tasks demanded critical and problem-solving thinking through iterative testing and troubleshooting. These features of the simulation environment not only supported autonomous learning but also nurtured confidence and engagement, particularly among students with high self-efficacy. By bridging motivation and cognition in an interactive digital space, simulation-based learning served as both a catalyst and context for developing essential academic competencies in engineering education.

In summary, the results demonstrate that motivation and cognition are not isolated contributors to academic performance, but operate synergistically within the simulation-based learning environment. The use of SEM and network analysis provided both statistical rigor and a nuanced visual understanding of these relationships.

Together, these findings validate the research model and confirm that enhancing students' self-regulation, confidence, and thinking skills within an interactive digital context leads to meaningful academic gains.

C. Combined Effect on Academic Performance

The combined effect of motivational factors (self regulated learning and self efficacy) and cognitive factors (critical thinking and problem-solving skills) on academic performance can be observed through the coefficient of determination (R^2). This statistical indicator reveals the proportion of variance in academic performance that can be explained by the four independent variables within the proposed research model. According to established benchmarks by Hair *et al.*, [33], an R^2 value of less than 0.19 is considered weak, values up to 0.33 indicate a moderate effect, and values greater than 0.67 reflect a strong effect. Based on this categorization, the interpretation of the R^2 value in this study will reveal the strength of the combined contribution of motivational and cognitive variables in influencing students' academic achievement. This result is displayed in Table 4.

Table 4. R square

Simultan effect	R-square
Self Regulated Learning, Self Efficacy, Critical Thinking Skill, Problem Solving Skill -> Academic Performance	0.768

As presented in Table 4, the coefficient of determination (R^2) is 0.768, which is categorized as high. This indicates that 76.8% of the variance in academic performance can be explained by the combined influence of motivational factors self regulated learning and self-efficacy and cognitive factors critical thinking and problem-solving skills. These findings suggest that effective self management in learning, confidence in handling academic tasks, the ability to think critically and logically, and the capacity to resolve problems efficiently all contribute substantially to enhancing the academic performance of electronic engineering students. This is particularly evident in the context of completing simulation-based virtual projects, where these competencies are actively applied and assessed.

The presence of a positive contribution is consistent with several previous studies [56–59]. Motivation in task management enabling students to maintain focus and construct well-defined learning strategies. Active engagement in simulation-based learning not only improves academic performance but also strengthens students' self-management, confidence, and readiness for professional challenges. Motivated students tend to exhibit greater maturity in preparing for their future careers, becoming increasingly aware of both academic and professional responsibilities. Similarly cognitive strength, particularly the ability to anticipate and analyze future scenarios using structured reasoning further supports this developmental trajectory. A strong desire for growth and progress emerges. There will be no logical fallacies if students possess strong understanding, critical thinking, and consistent focus that is continuously trained [60]. This cognitive foundation contributes significantly to academic performance.

D. Network Analysis

Network analysis was conducted as a complement to the

SEM analysis to visually examine the relationships between variables [61]. This approach provided additional insight into the strength and structure of associations among the constructs, especially through centrality metrics. The network visualization in this study was analyzed using JASP software. The analysis produced visualizations of four centrality measures, betweenness, closeness, strength, and expected influence [62, 63].

To enhance interpretability for an educational audience, the pedagogical relevance of each centrality metric is described below. Betweenness centrality reflects the degree to which a particular skill serves as a bridge among various learning processes. For instance, when a skill like problem identification demonstrates high betweenness, it indicates that strengthening this competency may help activate and integrate other domains such as motivation and cognition. Closeness centrality, on the other hand, reveals how efficiently a given skill can influence the entire learning network. Skills with high closeness, such as time management, can quickly interact with and impact numerous other abilities, emphasizing their instructional importance. Strength centrality refers to the intensity of direct connections a skill has with others. A skill with high strength, such as analyzing instructional information, suggests strong, immediate ties to both cognitive and motivational elements of learning. Finally, expected influence extends this by considering not only the strength but also the direction of the connections, identifying whether a skill promotes or inhibits related constructs. When a skill demonstrates high positive influence, it becomes a critical leverage point for enhancing multiple aspects of student performance. These insights guide educators in identifying and fostering key competencies that serve as anchors within the broader learning system.

The results of this analysis are presented in Fig. 5, which shows the visual representation of the centrality plot. Table 5 provides the numerical details of the centrality plot. Fig. 6 visualizes the position of each construct's items within the network.

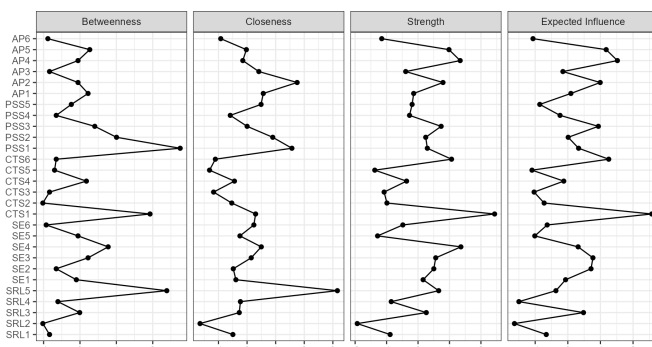


Fig. 5. Centrality plot.

Fig. 5 presents the standardized centrality indices of each observed variable across four types: betweenness, closeness, strength, and expected influence. The results indicate that SE3 (Self-Efficacy), CTS5 (Critical Thinking Skills), and SRL1 (Self-Regulated Learning) exhibit consistently high values across multiple centrality measures, particularly in betweenness, strength, and expected influence. These findings suggest that the three variables function as central nodes within the network, serving not only as influential

connectors between other constructs (as reflected in their betweenness) but also as variables with strong overall associations (strength) and significant net impact (expected influence) on the network structure. Meanwhile, variables such as AP4 (Academic Performance), PSS4 (Project-based Strategy), and CTS4 also demonstrate high closeness centrality, implying their potential to efficiently interact with other nodes in the network. Overall, the results underscore the central role of self-efficacy, critical thinking skills, and self-regulated learning in facilitating meaningful interconnections among constructs in the blended project-based learning environment. These variables may serve as key leverage points in designing interventions aimed at enhancing academic performance and student engagement.

Table 5. Centrality measures per variable

Variable	Betweenness	Closeness	Strength	Expected influence
SRL1	-0.837	-0.496	-0.888	-0.661
SRL2	-1.021	-1.645	-1.933	-1.635
SRL3	-0.008	-0.273	0.262	0.480
SRL4	-0.607	-0.233	-0.852	-1.499
SRL5	2.386	3.159	0.656	-0.365
SE1	-0.100	-0.391	0.161	-0.068
SE2	-0.653	-0.482	0.502	0.712
SE3	0.222	0.145	0.562	0.770
SE4	0.774	0.497	1.362	0.316
SE5	-0.054	-0.249	-1.286	-1.012
SE6	-0.929	0.237	-0.483	-0.632
CTS1	1.925	0.298	2.434	2.575
CTS2	-1.021	-0.535	-0.989	-0.726
CTS3	-0.837	-1.170	-1.078	-1.033
CTS4	0.176	-0.442	-0.365	-0.124
CTS5	-0.699	-1.313	-1.375	-1.098
CTS6	-0.653	-1.109	1.065	1.255
PSS1	2.754	1.568	0.295	0.331
PSS2	1.005	0.898	0.244	0.012
PSS3	0.406	0.002	0.735	0.936
PSS4	-0.653	-0.587	-0.270	-0.238
PSS5	-0.238	0.489	-0.188	-0.859
AP1	0.222	0.567	-0.139	0.094
AP2	-0.054	1.751	0.793	0.993
AP3	-0.837	0.411	-0.393	-0.151
AP4	-0.054	-0.149	1.340	1.520
AP5	0.268	-0.025	0.983	1.176
AP6	-0.883	-0.921	-1.155	-1.067

Fig. 6 presents the network visualization of the observed variables using a regularized partial correlation network generated through the graphical LASSO method. Each node in the network represents an individual variable, while the edges indicate partial correlations between variables after controlling for all other variables in the model. The thickness of the edges reflects the strength of these associations, with thicker edges representing stronger connections. The network is organized into five distinct communities identified through community detection algorithms, each represented by a different color. Group 1 (red) consists of variables related to self-regulated learning (SRL1–SRL5), Group 2 (green) includes critical thinking skills (CTS1–CTS6), Group 3 (yellow) contains self-efficacy variables (SE1–SE5), Group 4 (blue) represents project-based strategy (PSS1–PSS5), and Group 5 (purple) comprises academic performance variables (AP1–AP6). The distinct clustering of variables indicates strong intra-construct coherence, suggesting that variables within the same latent construct are more closely associated

with each other than with variables from other groups. Nevertheless, the presence of inter-cluster connections—such as between self-regulated learning and project-based strategies, or between critical thinking and academic performance—highlights the complex interdependence among constructs. This structure supports the proposed theoretical model, wherein self-efficacy, critical thinking skills, and self-regulated learning interact dynamically within a blended project-based learning environment to influence students' academic outcomes.

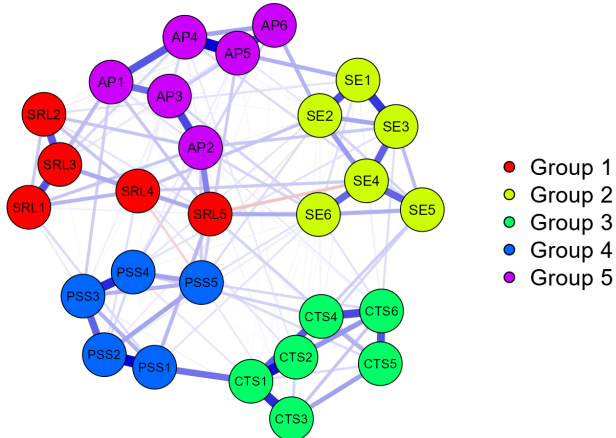


Fig. 6. Network visualization.

There are 28 statement items forming five variable constructs in this study. Based on the analysis results, the highest betweenness value is found in item PSS1. This item contains the statement *'I am able to identify the core problem in the simulation project'*, which represents the construct of problem-solving skills. As shown in the network visualization (see Fig. 6), there is indeed very little distance separating this item from others, making it the main bridge node. The edge (connecting line) of PSS1 also appears to be the thickest in the network. This result indicates that the statement serves as the strongest linking factor between the problem solving skill variable and other variables in the network. The practical implication of this finding is that if lecturers aim to improve students' overall skills, strengthening the ability to identify the core of a problem should be a top priority. As highlighted in the study [64], the more students can recognize the core issue they are facing, the more they unconsciously apply critical thinking, proper regulation and management, and confidence in their ability to solve it.

In terms of closeness centrality, the highest value is found in item SRL5. This item contains the statement *'I can manage my time well in completing the simulation project'*, which represents the construct of self-regulated learning. The network visualization (see Fig. 6) also confirms this finding. This item is positioned at the center of the network, with many edges directly connecting it to items from other constructs. Improvements in this aspect are likely to influence other aspects as well. It can be concluded that the development of time management and learning regulation in students will lead to improvements in self confidence, logical thinking skills, and complex problem-solving abilities. Time management in learning not only affects self regulated learning itself but also contributes to overall learning effectiveness.

In terms of strength centrality, the highest value is shown by item CTS1. The statement reads, *'I am able to analyze the information or instructions available in the simulation software'*. This item represents critical thinking skills. Analyzing information or instructions in the simulation software has strong direct connections with many other items in the variable network. Therefore, strengthening technical information analysis skills is also an important aspect to consider in order to achieve successful learning outcomes for students.

In terms of expected influence, the highest value is still found in item CTS1. *'I am able to analyze the information or instructions available in the simulation software'*. Therefore, focusing on the development of this skill through targeted training and specialized learning modules will enhance both the effectiveness of software usage and overall learning outcomes. The implications of this finding suggest that the direction of feature and guide development within the software should be focused on optimizing components that have a high level of influence within the network structure.

Based on the results of the network analysis, the measurements and visualizations demonstrate strong interconnectivity among nearly all variables. Each of the research variables contributes meaningfully to students' academic achievement. The implication of this finding is that enhancing one specific aspect whether motivational or cognitive can positively influence the others due to their interconnected nature. Furthermore, if all variables are developed concurrently, it can be inferred that students' overall learning performance will be significantly optimized, leading to more effective and sustained academic success in the future.

V. CONCLUSION

Upon completion of the research procedures and data analysis, several key conclusions and broader implications emerged. Both motivational elements namely self regulated learning and self-efficacy and cognitive dimensions such as critical thinking and problem solving ability demonstrated a substantial impact on students' academic achievement. This finding, well-supported by prior scholarly work, transcends the boundaries of educational levels and disciplines. Its relevance is evident not only among students in electronic engineering but also across elementary, middle, and high school populations, as well as university learners. Moreover, its applicability spans a wide spectrum of academic domains, including but not limited to engineering, medicine, the natural sciences (e.g., physics and chemistry), psychology, and beyond. These insights point to a universal dynamic the combined power of motivational and cognitive factors plays a pivotal role in shaping academic success across the educational and disciplinary landscape.

The empirical findings of this study further underscore the necessity of prioritizing motivational and cognitive factors in tandem with the provision of adequate learning facilities and infrastructure. A lecturer's responsibilities extend far beyond the mere transmission of knowledge, they encompass the strategic management of the learning environment and the cultivation of students' confidence in tackling academic tasks. It is essential to foster and continuously sharpen students' critical thinking and problem-solving abilities to nurture

open-mindedness and analytical reasoning key defenses against cognitive missteps. For students who are already well-educated, cognitive skills must be actively reinforced and applied, not only to encourage positive shifts in attitudes and behaviors but also to deepen their capacity for critical analysis and broaden their intellectual outlook. Ultimately, when motivational and cognitive dimensions are elevated, academic outcomes are more likely to align with desired goals confirming that the stronger these internal factors, the higher the level of academic achievement attained.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

I.R.J. conducted the research and wrote the paper; U. analyzed the data; K. conducted the proof-reading paper; all authors had approved the final version.

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