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Metacognitive Awareness in Engineering Students: SEM Analysis of Self-regulated Learning, Self Efficacy, and Learning Motivation

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Abstract
This study aims to explore the impact of self-regulated learning, self efficacy, and learning motivation on the metacognitive awareness of engineering students at the university level. A total of 358 students participated in the research, selected through purposive sampling. The participants had completed at least one semester of coursework, ensuring they had enough academic experience to reliably assess the study variables. Data was gathered via a survey and examined using Structural Equation Modeling (SEM) with the SmartPLS 3 software. Findings reveal that, in direct effect analysis, self-regulated learning and self efficacy do not significantly influence metacognitive awareness, whereas learning motivation does. However, in indirect effect analysis, both of them exert a significant impact on metacognitive awareness through the moderating role of learning motivation. These results suggest that self-regulated learning and self efficacy are not enough to spark awareness of one's own thinking processes, motivation contributes importantly to this relationship.

Keywords: Metacognitive Awareness, Self-regulated Learning, Self Efficacy, Learning Motivation.

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Introduction

Students are not merely engaged in the act of thinking, they possess the cognitive agency to intentionally regulate, orchestrate, and refine their own mental processes a capacity referred to as metacognition. The concept of metacognition is widely understood as the skill to think about one's own thinking (Norman et al., 2019), (Güner & Erbay, 2021). A central manifestation of this capacity is metacognitive awareness, denoting a deliberate consciousness of how one's cognitive activity unfolds, how information is perceived, encoded, interpreted, and critically appraised prior to determining subsequent courses of action. Such heightened awareness empowers learners to strategically harness their cognitive strengths, thereby enhancing performance not only in academic contexts but also within complex professional environments.

In the realm of higher education particularly in engineering programs, metacognitive ability is closely tied to the attainment of competencies (Wengrowicz et al., 2018). Engineering students are challenged to merge theoretical understanding with practical application (Hidayat et al., 2020). The differing perspectives among students reflect the variations in their metacognitive processes. Each student approaches a problem through their own lens, which in turn shapes the execution path they choose. This reality underscores that engineering education cannot be limited to questions aimed solely at definitions, which merely assess factual knowledge. Beyond that, students should be guided to answer how and why questions, those that uncover mechanisms, causal relationships, and deeper explanations behind information. Definition-based questions only measure lower-order cognitive skills, whereas the engineering field demands higher-order thinking to tackle more complex problems (Alkhatib, 2019). Such problem-solving requires the activation of metacognitive awareness, enabling students to monitor, evaluate, and adjust their own thinking and strategies in pursuit of a specific goal.

Several studies have identified a range of factors that trigger the emergence of metacognitive awareness i.e. self-regulated learning approaches, students' belief in their own ability to achieve specific goals, and motivation. Students who employ effective learning strategies encompassing planning, management, and evaluation of their learning activities tend to show a positive impact on their metacognitive awareness (Efklides et al., 2017), (Colthorpe et al., 2019). Furthermore, research by Hayat & Shateri (2019) and Yıldız & Akdağ (2017) highlights that students' self efficacy their belief in capability to accomplish academic goals also acts as a catalyst for developing metacognitive awareness. Another contributing factor is learning motivation, which is widely recognized as an important driver in fostering this awareness (Siqueira et al., 2020), (Trigueros et al., 2020).

Although the relationships between self-regulated learning, self efficacy, and learning motivation with metacognitive awareness have been identified in various studies, most of this research has been conducted in different contexts such as primary and secondary school students or university students in non-engineering fields. Prior researchs examine these variables in isolation rather than in combination. Comprehensive studies that simultaneously investigate all three factors to explain metacognitive awareness among engineering students especially in Indonesia remain scarce. This gap is significant, as engineering students face learning challenges that demand advanced cognitive management skills to achieve both academic success and professional readiness. In response, this study offers a novel contribution by developing an empirical model that examines the simultaneous relationships between self-regulated learning, self efficacy, and learning motivation on metacognitive awareness. Hence, the aim of this research is to analyze self-regulated learning, self efficacy, and learning motivation influence the metacognitive awareness of engineering students in higher education. The study is expected to bridge the existing literature gap and provide practical implications for effective learning strategies in engineering education. The relationships among the variables under investigation are illustrated in Figure 1.

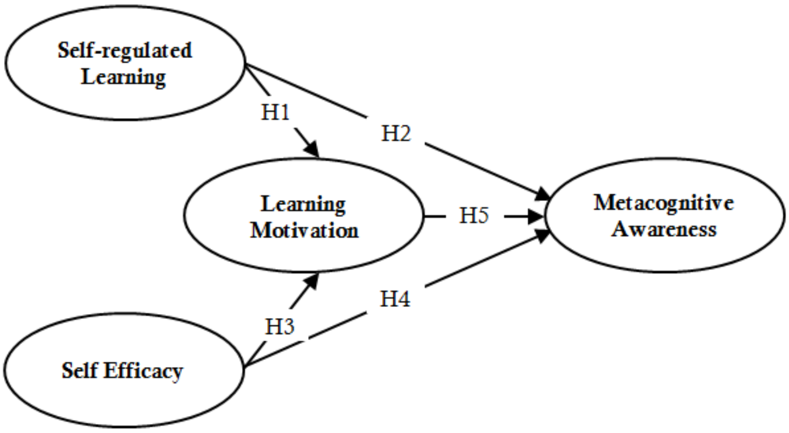

Figure 1. Research Framework

Based on Figure 1, five direct relationship hypotheses were formulated, which also serve as the study's research questions:

1. H1: does self-regulated learning significantly affect learning motivation?
2. H2: does self-regulated learning significantly affect metacognitive awareness?
3. H3: does self efficacy significantly affect learning motivation?
4. H4: does self efficacy significantly affect metacognitive awareness?
5. H5: does learning motivation significantly affect metacognitive awareness?

In addition to these direct relationships, the research framework also suggests potential indirect relationships involving a moderating variable. These lead to two additional research questions:

1. H6: does learning motivation moderate the relationship between self-regulated learning and metacognitive awareness?
2. H7: does learning motivation moderate the relationship between self efficacy and metacognitive awareness?.

Method

Research Model

This study investigates the relationships among the research variables within the context of engineering students at Universitas Negeri Padang. A quantitative, associative research design was employed.

Participant

Eligible participants were those who had completed a minimum of one semester (six months) of study and had successfully undertaken the core courses within their program of study. These inclusion criteria ensured that respondents possessed sufficient academic experience to provide informed evaluations of their self-regulated learning, self efficacy, learning motivation, and metacognitive awareness. A purposive sampling strategy was applied to recruit participants whose characteristics aligned closely with the study's context (Muliadi & Mirawati, 2020). This approach was selected to secure data from respondents whose experiences were directly pertinent to the research objectives, thereby enhancing the validity and contextual accuracy of the findings in representing the target population. A total of 358 engineering students took part in the study, each exhibiting varied demographic characteristics and academic backgrounds. An overview of these attributes is provided in Table 1 within the respondent profile section.

Table 1. Respondent Profile

Sample characteristics		Frequency	Percentage
Current year of study	Year 1	129	36.0%
	Year 2	69	19.3%
	Year 3	114	31.8%
	Year 4	46	12.8%
	Total	358	100%
Gender	Male	279	77.9%
	Female	79	22.1%
	Total	358	100%
Age	17 - 18 years old	57	15.9%
	19 - 20 years old	168	46.9%
	21 - 22 years old	121	33.8%
	23 -24 years old	12	3.4%
	Total	358	100%

This study employed a quantitative data analysis approach using statistical software. The research model comprised four latent constructs, i.e. self-regulated learning, self efficacy, learning motivation, and metacognitive awareness each measured through multiple items on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) (Xi et al., 2019). To analyze these measurement items, Structural Equation Modeling (SEM) was conducted using SmartPLS 3. This analytical technique was selected for its dual capability to simultaneously assess the measurement model (outer model) and the structural model (inner model) (Hair et al., 2014), (Hair Jr et al., 2021). The Partial Least Squares (PLS) approach to SEM allows for rigorous testing of the outer model to evaluate the validity and reliability of the measurement indicators, as well as the inner model to examine the strength and direction of the relationships among variables. This method is both technically and methodologically appropriate, as it aligns with the study's objective of comprehensively testing and predicting the relationships among the research variables

Result and Discussion

The first step in the SEM procedure was to evaluate the measurement model (outer model). In this study, the measurement instruments were required to meet two key criteria, i.e. validity and reliability. Validity meaning they accurately capture the intended data, and reliability, meaning they consistently measure the targeted constructs (Hair et al, 2019). An instrument was deemed valid if its outer loading exceeded 0,7 (Purwanto & Sudargini, 2021). Additionally, the Average Variance Extracted (AVE) served as a secondary validity benchmark, with an acceptable threshold of above 0,5 (Mohd Dzin & Lay, 2021). Alongside validity, the instruments were also required to demonstrate strong reliability. Consistent with established guidelines in the literature, both Cronbach's Alpha and Composite Reliability (CR) were expected to meet or exceed a minimum value of 0,7 (Sumarni & Kadarwati, 2020). The outcomes of the validity and reliability assessments for the study's measurement instruments are reported in Table 2.

Table 2. Instrument Validity and Reliability

Variable	Item	Outer loading	AVE	Cronbach's alpha	CR
Self-regulated Learning (SRL)	SRL1	0,836	0,711	0,898	0,925
	SRL2	0,842			
	SRL3	0,783			
	SRL4	0,863			
	SRL5	0,889			
Self Efficacy (SE)	SE1	0,836	0,697	0,892	0,920
	SE2	0,880			
	SE3	0,862			
	SE4	0,827			
	SE5	0,766			
Learning Motivation (LM)	LM1	0,802	0,599	0,701	0,817
	LM2	0,743			
	LM3	0,774			
Metacognitive Awareness (MA)	MA1	0,867	0,724	0,905	0,929
	MA2	0,850			
	MA3	0,855			
	MA4	0,863			
	MA5	0,818			

As presented in Table 2, the study employed a total of 18 measurement items to evaluate four research constructs: self-regulated learning (5 items), self efficacy (5 items), learning motivation (3 items), and metacognitive awareness (5 items). All items satisfied the validity requirements, as indicated by outer loading values exceeding 0,7. Furthermore, the AVE for each construct was above the 0,5 threshold, demonstrating adequate convergent validity. Regarding reliability, the results showed that all constructs achieved Cronbach's Alpha and CR values more than 0,7, confirming strong internal consistency and measurement stability. With both validity and reliability standards met, the structural model was considered robust and suitable for subsequent analysis to investigate the hypothesized relationships among the study variables.

Once the research instruments were confirmed to meet the validity and reliability criteria, the next stage involved hypothesis testing to address the research questions in line with the conceptual framework illustrated in Figure 1. The model comprised five direct relationships and two indirect relationships, all examined through SEM analysis. The purpose of the hypothesis testing was to determine whether the proposed relationships among variables were supported by empirical evidence. Each hypothesis was assessed based on its statistical significance and the alignment of the relationship's direction with established theoretical expectations. The results were classified as supported when the path coefficients were statistically significant and consistent with the theoretical predictions, or unsupported when these conditions were not met.

A hypothesis was considered supported when the t-statistic value was ≥ 1,96, indicating that the relationship between variables was statistically significant at the 95% confidence level. In addition, the significance of the relationships was evaluated using the p-value, with effects deemed significant when p ≤ 0,05 (Sukamto et al., 2019). The magnitude of each relationship was interpreted through the path coefficient (original sample value), which reflects both the strength and the direction of the relationship, ranging from –1 (perfect negative effect) to 1 (perfect positive effect). The results of this analysis are presented in Figure 2 (t-statistic), Figure 3 (p-value), and Table 3.

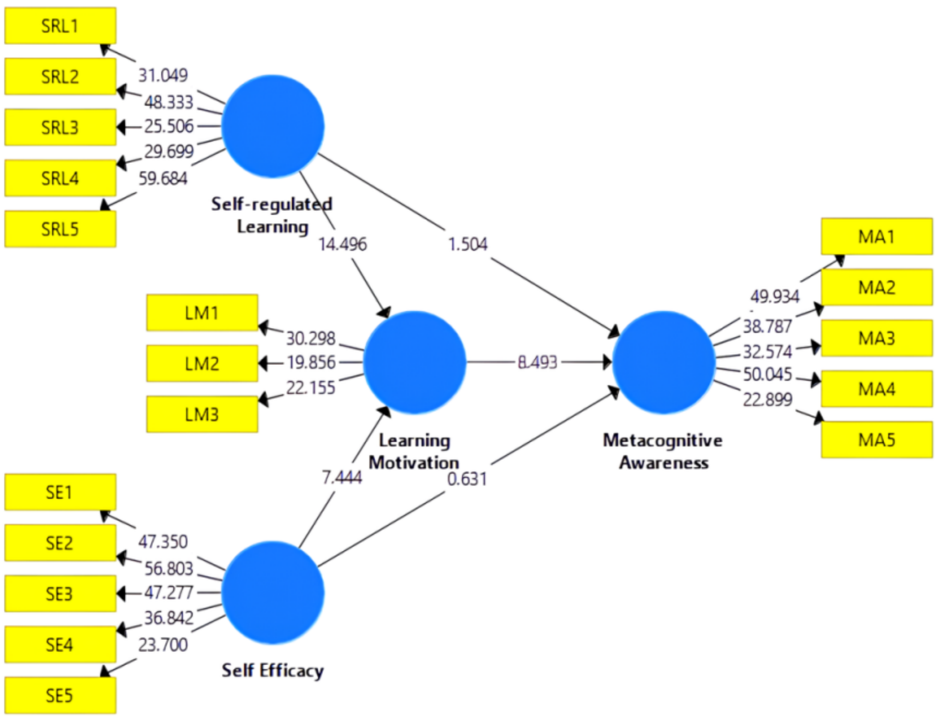

Figure 2. T-statistic

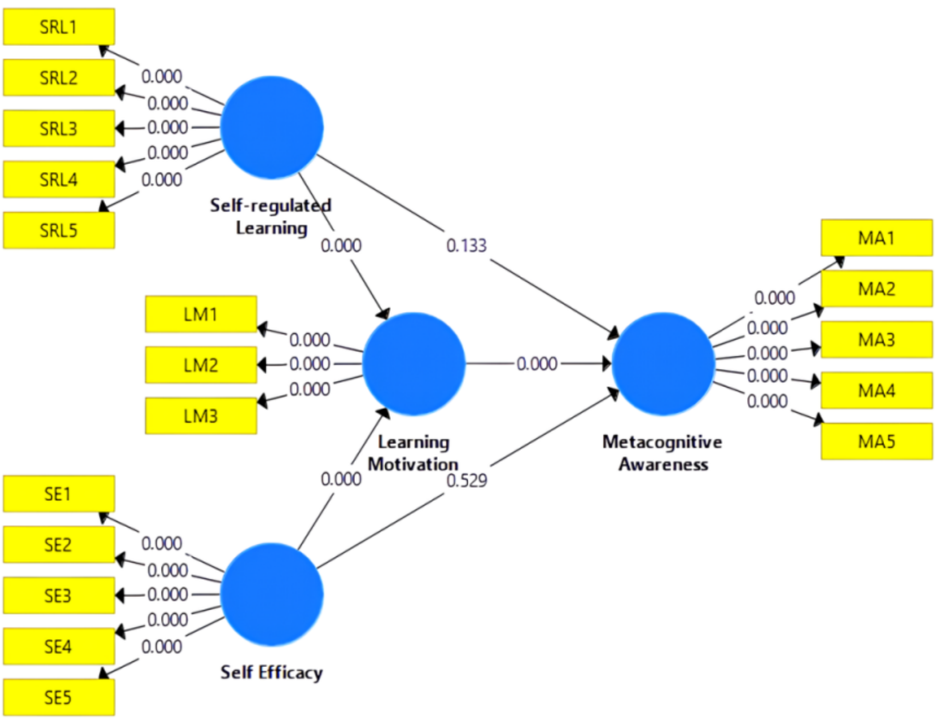

Figure 3. P-value

Table 3. Direct effect

	Hipothesis	T-Statistic	P-Value	Path coefficient	Decision
H1	Self-regulated learning -> learning motivation	14,496	0,000	0,590	Supported
H2	Self-regulated learning -> metacognitive awareness	1,504	0,133	0,115	Unsupported
H3	Self efficacy -> learning motivation	7,444	0,000	0,331	Supported
H4	Self efficacy -> metacognitive awareness	0,631	0,529	0,031	Unsupported
H5	Learning motivation -> metacognitive awareness	8,493	0,000	0,645	Supported

Based on the direct relationship analysis, five hypotheses were evaluated. The findings revealed that three hypotheses were statistically supported, while the remaining two were not. This determination was grounded in established statistical criteria, where a t-statistic higher than 1,96 and p-value lower than 0,05. These results provide a clear empirical basis for distinguishing which proposed relationships are validated by the data and which lack sufficient statistical support.

Hypothesis 1 examined the influence of self-regulated learning on learning motivation. The analysis yielded a t-statistic = 14,496, indicating strong statistical support for the hypothesis. P-value = 0,000, with a path coefficient = 0,590. These results confirm that self-regulated learning exerts a significant and positive influence on the learning motivation of engineering students. The relationship suggests that higher levels of self-regulated learning encompassing planning, monitoring, and evaluating one's own learning strategies correspond to greater intrinsic motivation to achieve learning objectives. This aligns with motivational learning theory, which posits that autonomy in managing the learning process serves as a critical enhancer of motivation, as students perceive greater control over both the process and outcomes of their learning (Mukhalalati & Taylor, 2019), (Fauzi et al., 2020). These findings are consistent with Baars et al. (2017), who demonstrated that strong self-regulated learning skills help sustain high motivation levels even when students face cognitive pressure and heavy workloads. Accordingly, the positive influence of self-regulated learning on learning motivation among engineering students in this study can be interpreted as their capacity to maintain a strong drive to learn, even under conditions that might otherwise undermine motivation.

Hypothesis 2 examined the effect of self-regulated learning on metacognitive awareness. The analysis yielded a t-statistic = 1,504, indicating that the hypothesis was not statistically supported. P-value = 0,133, with a path coefficient= 0,115. These results suggest that the influence of self-regulated learning on metacognitive awareness was not statistically significant within the context of engineering students. This finding contrasts with prior studies, such as those by Ridley et al. (1992), Amini Farsani et al. (2019), Zeng & Goh (2018), which reported a significant relationship between these variables. The divergence in results indicates that the association between self-regulated learning and metacognitive awareness may not be universally consistent across academic disciplines. In engineering education, the emphasis on technical skill acquisition, heavy workload, and stringent time constraints may limit the extent to which students engage in metacognitive processes (Zhang et al., 2021). This aligns with the perspective that fostering metacognitive awareness requires learning environments that allow for reflective practice and deep learning strategies conditions that may be less prevalent in highly structured, practice-oriented technical programs.

Hypothesis 3 examined the effect of self efficacy on learning motivation. The analysis yielded a t-statistic = 7,444, indicating strong statistical support for this hypothesis. The corresponding p-value= 0,000, with a path coefficient= 0,331. These results suggest that self efficacy exerts a positive and significant influence on learning motivation among engineering students. In other words, the greater the students' confidence in their ability to successfully complete academic tasks, the stronger their motivation to learn. This finding is consistent with Schunk & DiBenedetto (2021), who argue that self efficacy is a primary determinant of motivation. Students with higher self efficacy tend to set more challenging goals, persist in the face of obstacles, and demonstrate greater perseverance throughout the learning process.

Hypothesis 4 examined the effect of self efficacy on metacognitive awareness. The analysis yielded a t-statistic = 0,631, indicating that this hypothesis was not statistically supported (p-value = 0,529 and path coefficient = 0,031). These findings suggest that students' confidence in their own abilities does not directly contribute to their awareness of managing cognitive processes metacognitively. Although the relationship between the two variables was positive, the magnitude of the effect was small and did not meet the threshold for statistical significance. While, several prior studies have reported a significant connection between self efficacy and metacognitive awareness (Amal & Mahmudi, 2020), (Tian et al., 2018), the current results indicate that sample characteristics may influence this relationship. Conceptually, these findings imply that self efficacy which primarily reflects confidence in performing specific tasks may not be sufficient to foster a more reflective and strategic form of metacognitive awareness. Other factors, such as structured learning experiences, habitual reflection, and supportive academic environments, have a more prominent role in cultivating metacognitive awareness among engineering students (Santangelo et al., 2021). Consequently, initiatives to strengthen self efficacy should be accompanied by interventions explicitly designed to enhance metacognitive skills in order to achieve optimal learning outcomes.

Hypothesis 5 examines the effect of learning motivation on metacognitive awareness. The analysis yielded a t-statistic = 8,493, indicating strong statistical support for this hypothesis (p-value = 0,000 and path coefficient = 0,645). Students with high learning motivation tend to be more aware of and actively engaged in regulating their cognitive processes, including planning, monitoring, and evaluating their learning strategies (Seli, 2019). Strong learning motivation fosters continuous reflection on learning approaches, thereby enhancing both the efficiency and outcomes of the learning process. This finding aligns with prior research emphasizing the critical role of motivation in activating metacognitive awareness as an integral component of effective learning management strategies (McDowell, 2019). Consequently, fostering learning motivation should be a central focus in developing students' metacognitive competencies particularly in engineering education.

Subsequently, an analysis of indirect relationships was conducted through moderation analysis. Learning motivation functioned as a moderating variable within the model. The results of this indirect relationship analysis are presented in Table 4.

Table 4. Indirect effect

	Hipothesis	T-Statistic	P-Value	Path coefficient	Decision
H6	Self-regulated learning -> learning motivation -> metacognitive awareness	6,979	0,000	0,381	Supported
H7	Self efficacy -> learning motivation -> metacognitive awareness	5,741	0,000	0,214	Supported

Hypothesis 6 examined the effect of self-regulated learning on metacognitive awareness, moderated by learning motivation. The t-statistic value was 6,979, indicating that this hypothesis is statistically supported. The p-value was 0,000, with a path coefficient magnitude of 0,381. These findings indicate that learning motivation significantly moderates the relationship between self-regulated learning and metacognitive awareness among engineering students. Conceptually, this implies that the influence of self-regulated learning on metacognitive awareness becomes stronger when students' learning motivation is high. In other words, students who are capable of independently regulating their learning processes tend to exhibit higher levels of metacognitive awareness when they also possess strong learning motivation.

Hypothesis 7 examined the moderating effect of learning motivation on the relationship between self efficacy and metacognitive awareness. The results revealed a statistically significant moderation, with a t-statistic = 5,741, a p-value = 0,000, and a path coefficient = 0,214. These findings indicate that learning motivation significantly strengthens the positive association between self efficacy and metacognitive awareness among engineering students. Specifically, the influence of self efficacy on metacognitive awareness is amplified when students possess higher levels of learning motivation. This underscores the pivotal role of motivation as a catalyst that enhances the impact of self-belief on the conscious regulation and reflection of one's thinking processes an ability particularly essential in engineering education, where adaptive learning and autonomous problem-solving are critical.

The analysis of both direct and indirect relationships reveals a compelling empirical insight, self-regulated learning and self efficacy. When examined in isolation, do not exhibit a statistically significant effect on metacognitive awareness. Yet, when learning motivation is introduced as a moderating factor, the relationship transforms into one of statistical significance. This finding underscores a critical nuance while the capacity to autonomously manage one's own learning process (self-regulated learning) and the confidence in one's ability to achieve desired outcomes (self efficacy) are widely recognized as important components of academic success, they do not, by themselves, guarantee the activation of metacognitive awareness. Metacognition defined as the conscious reflection on and regulation of one's own thinking requires more than skill and confidence, it demands a compelling internal driver. Here, intrinsic learning motivation emerges as the catalytic force, supplying both the emotional energy and cognitive engagement necessary for students. Without this motivational spark, self-regulated learners may execute strategies mechanically, and highly self efficacious individuals may remain focused solely on outcomes rather than the thinking processes that lead to them. Thus, it is motivation anchored in personal relevance, curiosity, and the pursuit of mastery that transforms latent potential into active, self-aware learning behavior, bridging the gap between capability and conscious cognitive regulation.

From a theoretical standpoint, motivation serves as the fundamental source of energy that activates and sustains learning behaviors, including the awareness of one's own thinking processes. Without sufficient motivation, students may possess both the capability (self-regulated learning skills) and the confidence (sel efficacy) to succeed, yet remain insufficiently driven to consistently and reflectively apply metacognitive strategies. In such cases, learners tend to engage only with the superficial aspects of the information presented, acquiring factual knowledge without fully grasping the underlying mechanisms, causal relationships, or broader conceptual frameworks. In the context of engineering education, motivation becomes even more critical. It compels students to invest the necessary time and effort not merely to comprehend subject matter, but also to consciously manage and optimize their learning strategies for deeper and more meaningful understanding. Thus, learning motivation functions as a moderating variable that strengthens the relationship between self-regulated learning and self efficacy with metacognitive awareness.

Conclusion

A series of rigorous scientific procedures was undertaken to generate empirical data. From the analytical results, several conclusions and implications can be drawn. Overall, effective learning management, confidence in achieving goals, and students' learning motivation exert influence on their cognitive awareness whether statistically significant or otherwise. Supported by prior literature, this influence extends beyond engineering students in higher education to learners across all educational levels, albeit with varying degrees of statistical significance and distinct variable-specific analyses.

The empirical evidence from this study affirms that learning motivation stands as a primary driver in the educational process. A lecturer's role extends far beyond delivering instruction they must also provide cognitive stimulation to their students. No matter how well learning is organized or how strongly students believe in their ability to succeed, these factors will not yield optimal results if they lack the motivation to cultivate awareness of their own thinking processes. Therefore, the stronger the motivation, the greater the capacity for mindful thought management. Students with well-developed cognitive awareness are those who can exercise self-control, recognize their strengths and weaknesses, and make sound decisions in performing and completing tasks.

The findings of this study are anticipated to make a valuable contribution to the existing metacognitive literature. Variables that were previously investigated independently have now been synthesized into a comprehensive framework. This integration empowers educators, researchers, and stakeholders to make more informed decisions when prioritizing key factors in cultivating metacognitive awareness among both instructors and learners. However, this study is limited to statistical data analysis and has yet to incorporate extensive qualitative insights. Additionally, the sample was confined to engineering students from a single university, which may restrict the generalizability of the results. Therefore, future research is recommended to explore these variables through qualitative methodologies and to include a broader participant base, such as learners across multiple universities, in order to address the limitations of this study.

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