From Intention to Innovation: How Guided Inquiry and Metacognition Drive Critical and Creative Thinking among Engineering Students

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Abstract **– This study examines how digital entrepreneurial intention and guided inquiry learning affect engineering students' critical and creative thinking, using metacognitive awareness and self-regulated learning as mediators. This study included 417 Indonesian engineering students. PLS-SEM and Fuzzy C-Means Clustering Analysis were used to analyze questionnaire data. Digital entrepreneurial intention significantly affects metacognitive awareness but not self-regulated learning. Guided inquiry learning improves metacognition and self-regulation. Metacognition and self-regulated learning greatly improved critical and creative thinking. Digital entrepreneurial intention affects critical and creative thinking skills solely through metacognitive awareness, while guided inquiry learning indirectly affects both. The IPMA analysis shows that guided inquiry learning is the biggest factor affecting students' cognitive abilities, while the clustering results show five cognitive engagement clusters. This study recommends inquiry-based learning in technical education to develop advanced cognitive skills in the digital age.**

Keywords **– Digital entrepreneurship, guided inquiry, metacognitive, critical thinking, creative thinking.**

DOI: 10.18421/TEM153-68
https://doi.org/10.18421/TEM153-68

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Received: 17 July 2025.
Revised: 27 January 2026.
Accepted: 04 March 2026.
Published: 27 August 2026.

1. Introduction

In the 21st-century digital economy, college graduates must possess skills that extend beyond academic proficiency; they must also demonstrate creative and critical thinking abilities [1]. Both skills are essential as they enable students to tackle complex problems, generate innovative ideas, and swiftly adjust to new circumstances [1]. Research indicates that the capacity for critical and creative thinking among graduates is the most reliable indicator of their preparedness for the challenging and unpredictable global job market [2].

The significance of digital entrepreneurial intention concept is increasing as higher education becomes increasingly intertwined with digital transformation [3]. Digital entrepreneurial intention (DEI) can assist students in identifying business opportunities, mastering technology utilization, and devising innovative business strategies [4]. However, a desire to become a digital entrepreneur does not guarantee immediate success in that endeavor. Effective critical and creative thinking necessitates the possession of appropriate cognitive skills [5].

The educational approach known as guided inquiry learning is grounded in constructivist principles and has demonstrated efficacy [5]. It emphasizes student participation in the inquiry process under the guidance of an instructor. This approach promotes the systematic cultivation of higher-order thinking skills in students by encouraging them to generate questions, hypothesize, gather data, and draw conclusions [6].

The effectiveness of DEI and guided inquiry learning (GIL) in fostering critical and creative thinking in students is contingent upon the quality of their learning planning [7]. Two significant factors influencing this are metacognitive awareness (MA) and self-regulated learning (SRL) [8]. MA involves self-awareness, thought organization, and evaluation [9].

Self-regulated learning entails establishing objectives, monitoring advancement, and engaging in self-reflection to facilitate autonomous learning [10].

This study examines how digital entrepreneurial intention and guided inquiry learning affect students' creativity and critical thinking. The research examines MA-SRL relationships. This dual mediation approach enhances the understanding of how DEI and GIL influence student cognition. This paper seeks to address the subsequent questions arising from the previously mentioned presentation: *Does SRL influence the relationship between GIL and the ability to think creatively and critically? In what manner does that influence the capacity for critical and creative thinking in relation to MA and SRL?*

This research is expected to facilitate the creation of a comprehensive learning model for digital entrepreneurship and establish a framework for the formulation of higher education policies that foster more intelligent and innovative graduates.

The theory of planned behavior (TPB) posits that intentions are shaped by attitudes towards behavior, subjective norms, and perceived behavioral control [11]. In the digital age, these factors are shaped by digital literacy, emerging technologies, and the ways in which individuals employ digital devices [12]. Recent research indicates that openness to new ideas, technological effectiveness, and perceptions of digital opportunities are reliable indicators of DEI [13], [14].

Digital entrepreneurial intention refers to an individual's predisposition to create and manage enterprises that leverage digital technology in the future [15]. This concept emerged from transformations in the global business landscape, encompassing the digitization of business processes, the evolution of conventional business models, and the rise of a platform-based economy [16].

Digital transformation influences commerce, education, and cognition [17]. DEI represents the aspiration to become a digital entrepreneur, while MA denotes the capacity to manage cognition and learning [18]. Digital entrepreneurs require more than mere ambition and aspiration to thrive in an increasingly complex digital landscape [19]. Their ability to comprehend, structure, and assess their cognition is also significant. Metacognitive awareness synchronizes digital business objectives and activities [20], [21].

Theories of entrepreneurial cognition and self-regulation can elucidate the relationships between DEI and MA [22]. Digital entrepreneurs are encouraged to strategies and evaluate their alternatives. This enhances their cognitive awareness [23]. As shown by [24], the study indicates that students with elevated DEI levels are more inclined to enhance their cognitive abilities and engage in autonomous learning within digital environments [25].

It is asserted that instructing digital entrepreneurship via reflection can enhance students' cognitive awareness.

Based on this theoretical and empirical foundation, the following hypothesis is proposed:

H1: *Digital entrepreneurial intention has a significant effect on metacognitive awareness.*

With the expansion of the digital era, DEI appears to be a significant indicator of individuals' readiness, particularly among students, to initiate and manage technology-driven enterprises [26]. DEI not only indicates an individual's aspiration to become an entrepreneur but also demonstrates their desire for autonomous learning, adaptability, and a defined objective [18]. SRL is the paramount skill for achieving success in the digital realm. Students can employ SRL to establish educational objectives, devise strategies to achieve them, monitor their advancement, and reflect on their learning processes [27]. As shown by [28] , social cognitive theory posits that intrinsic motivation, such as DEI, significantly influences autonomous learning. Students aspiring to be digital entrepreneurs typically exhibit elevated levels of SRL as they recognize the necessity of continuous, adaptable, and individualized education for success in the digital business realm [19]. DEI not only assists students in determining their life aspirations but also cultivates the character of autonomous learners who are adaptable and prepared to confront new challenges in the realm of digital entrepreneurship [18].

Based on this theoretical and empirical foundation, the following hypothesis is formulated:

H2: *Digital entrepreneurial intention has a significant effect on self-regulated learning.*

GIL is a constructivist method that students actively construct knowledge from orientation to reflection [29]. The teacher guides students through questioning, hypothesizing, finding information, and making a decision through discussion and reflection [29]. A typical GIL learning framework includes orientation, conceptualization, investigation, conclusion, and discussion. This method improves students' motivation to learn, critical thinking, creativity, and problem-solving at all levels [30], [31]. Higher education needs GIL to teach students how to learn independently and with others and address real-world issues like digital skills and entrepreneurship. GIL improves students' learning, scientific literacy, communication and collaboration skills [32]. This method works well in 21st-century education, especially with digital technology and project-based learning. GIL helps students understand ideas and become reflective learners who can solve global problems [33].

GIL significantly enhances students' metacognitive awareness by promoting active engagement in critical thinking and self-reflection [34]. In GIL, students are instructed not only to seek answers but also to formulate questions, develop hypotheses, select information retrieval strategies, and assess their learning outcomes and methodologies [31], [35]. This procedure aligns with the three principal components of metacognition: Planning, monitoring, and evaluation. Through a systematic inquiry-based learning framework, students develop awareness of their learning processes, identify the strengths and weaknesses of their strategies, and implement improvements in subsequent learning endeavors [31], [36].

Building upon this theoretical and empirical foundation, the following hypothesis is proposed:

H3: *Guided inquiry learning has a significant effect on metacognitive awareness.*

GIL profoundly impacts students' capacity for SRL [37]. GIL delegates to students the responsibility of formulating enquiries, conducting research, performing experiments, and assessing their acquired knowledge [38]. The core principle of SRL is that students develop the capacity to set learning goals, choose learning strategies, assess their understanding, and autonomously generate ideas [39]. This method aids students in comprehending the learning process and in making autonomous learning decisions [40].

Drawing on this theoretical and empirical foundation, the following hypothesis is proposed:

H4: *Guided inquiry learning has a significant effect on self-regulated learning.*

The ability to recognize and understand one's own cognitive processes is known as metacognitive awareness, encompassing their capacity to comprehend, regulate, and reflect on the learning strategies employed to accomplish cognitive tasks [41]. Metacognitive awareness comprises two primary components: Metacognitive knowledge, which involves understanding cognitive strategies, their appropriate application, and their efficacy; and metacognitive regulation, which comprises the ability to organize, track, and assess mental efforts [42]. To succeed in higher education, students must develop metacognitive awareness, which allows them to learn new strategies for effective learning on their own, engage in critical thinking, and make autonomous academic decisions [42].

Numerous studies indicate that elevated metacognitive awareness correlates with improved learning outcomes, enhanced intrinsic motivation, and the capacity to adapt to technological learning and 21st-century challenges [41].

Students proficient in metacognition can more effectively recognize when they encounter difficulties in learning and adapt their strategies to achieve their educational objectives [43]. Guided inquiry, blended learning, and self-reflection are educational interventions that significantly enhance metacognitive awareness [6]. Metacognitive awareness is not only an indicator of academic success but also a crucial component in cultivating learners capable of reflecting on their learning processes and adapting their strategies in the digital era [6].

Metacognitive awareness is essential for cultivating critical thinking skills, as it enables individuals to actively regulate their cognitive processes necessary for critical analysis [44]. Individuals with high metacognitive awareness can deliberately strategies, monitor, and evaluate their cognitive processes [45]. This assists them in identifying weak arguments, detecting bias, and making decisions that are more logical and rational [45]. Metacognitive awareness facilitates critical thinking in students by enabling them to collect information and subsequently evaluate and reflect on its veracity [42].

Building upon this theoretical and empirical foundation, the following hypothesis is developed:

H5: *Metacognitive awareness has a significant effect on critical thinking skill.*

Metacognitive awareness is essential for creative thinking [42]. Individuals possessing metacognitive awareness can comprehend their cognitive processes and adapt, assess, and direct their thinking strategies with flexibility, this is a crucial skill for innovative thinking [42]. Creative thinking encompasses more than merely generating novel ideas, it is the capacity to contemplate those concepts and assess their uniqueness, utility, and relevance [46]. Individuals with heightened metacognitive awareness are more inclined to embrace diverse perspectives, capable of identifying obstacles to thought processes, and willing to undertake cognitive risks that facilitate the generation of novel ideas [47].

Grounded in this theoretical and empirical foundation, the following hypothesis is proposed:

H6: *Metacognitive awareness has a significant effect on creative thinking skill.*

Students establish personal learning objectives and subsequently monitor, organize, and regulate their thoughts, emotions, and behaviors in accordance with those objectives and their contextual circumstances [48]. SRL comprises three primary stages: Planning (forethought), execution (performance), and evaluation (self-reflection) [49]. Students utilizing self-regulated learning (SRL) can ascertain effective learning strategies, monitor their time management, evaluate their comprehension, and assess their own assignments [49].

SRL is a key indicator of academic success in college, especially when it comes to learning and using technology [50].

In the digital era, the capacity for self-regulation is increasingly vital as students are anticipated to engage in autonomous learning [51]. Inquiry-based, flipped, and blended learning help students take charge of their learning [52]. Thus, SRL is an important part of making sure that people learn for life and are flexible, self-reflective, and independent in their educational pursuits [53].

SRL is essential for students to cultivate and enhance their critical thinking skills. Cognitive and metacognitive processes, including planning, monitoring, and evaluation, empower students to assume control over their cognitive strategies [10]. To engage in critical thinking, one must analyze arguments, comprehend their content, and evaluate their logical coherence [54]. Through SRL, students acquire the skills to identify problems, establish cognitive goals, and recognize and rectify biases or flawed reasoning, this facilitates a reevaluation of their beliefs [55].

Based on this theoretical and empirical foundation, the following hypothesis is developed:

H7: *Self-regulated learning has a significant effect on critical thinking skill*.

SRL promotes the enhancement of students' creative thinking skills by necessitating the active and conscious regulation of their thoughts, emotions, and actions [6]. SRL empowers students to structure their thoughts, set goals, choose strategies, and contemplate their acquired knowledge, thereby fostering the creation of innovative and original ideas [10]. This process allows students to explore diverse solutions, synthesize knowledge from multiple disciplines, and transform their viewpoint on intricate and chaotic scenarios, which is a crucial element of creative thinking [56].

Building upon this theoretical and empirical foundation, the following hypothesis is formulated:

H8: *Self-regulated learning has a significant effect on creative thinking skill.*

Critical thinking enables people to logically and reflectively analyze, evaluate, and synthesize information, make decisions or solve problems [57]. Critical thinking as the ability to interpret, analyze, evaluate, infer, and explain, rooted in openness, skepticism, and a commitment to truth [58]. Critical thinking is an essential element of higher education, as it allows individuals to comprehend complex knowledge, address global issues, and make evidence-based decisions [59].

Students with critical thinking skills can analyze information, avoid cognitive bias, and evaluate diverse perspectives impartially [60].

Critical thinking has become one of the most essential competencies in the 21st century as the fourth industrial revolution and the digital era advance [1]. Recent studies have shown that active learning techniques, including problem-based learning, inquiry-based learning, and cognitive reflection through digital technology, can enhance critical thinking [1], [60].

Creative thinking is the ability to produce original, innovative, and practical ideas for problem-solving or developing new operational methods [61]. Creative thinking consists of four elements: Elaboration (the enhancement of ideas), originality (the distinctiveness of ideas), flexibility (the diversity of ideas), and fluency (the abundance of ideas) [62]. Creative thinking skills are essential 21st-century competencies in higher education, enabling students to navigate a complex, dynamic, and uncertain world [60]. Recent studies suggest that creative thinking results from an amalgamation of domain-specific knowledge, self-regulation, and the propensity to engage in cognitive risks to achieve solutions [63], [64]. In the contemporary educational landscape, which emphasizes innovation and interdisciplinary problem-solving, the development of creative thinking skills is becoming increasingly essential [65]. Various instructional methodologies, such as inquiry-based learning, project-based learning, and digital technology, have been shown to augment students' creativity by encouraging them to reflect, collaborate, and explore their ideas [52], [64].

2. Methodology

This study employs a quantitative research design to investigate the structural relationships between students' critical and creative thinking skills, guided inquiry learning, metacognitive awareness, and digital entrepreneurial intention. Within a digital entrepreneurship context that was enhanced by technology, a survey-based approach was implemented to ascertain students' learning experiences and perceptions. The methodological framework was developed to guarantee the robustness of the model, construct validity, and rigorous hypothesis testing, which were particularly important in light of the study's emphasis on intricate mediation mechanisms. The research integrates Partial Least Squares–Structural Equation Modelling (PLS-SEM) with complementary analytical techniques to achieve these objectives, thereby facilitating both explanatory and predictive insights into higher-order cognitive development among engineering students in higher education.

2.1. Design

A study of higher education techniques that have used mobile application digital entrepreneurship application, where students who have used the applications can complete the questionnaire used in this research, the sample of the apps is shown in Figure 1.

Engineering students must possess knowledge beyond mere technical competencies. They must also understand how to initiate an online business to generate innovative concepts in the era of Industry 4.0.

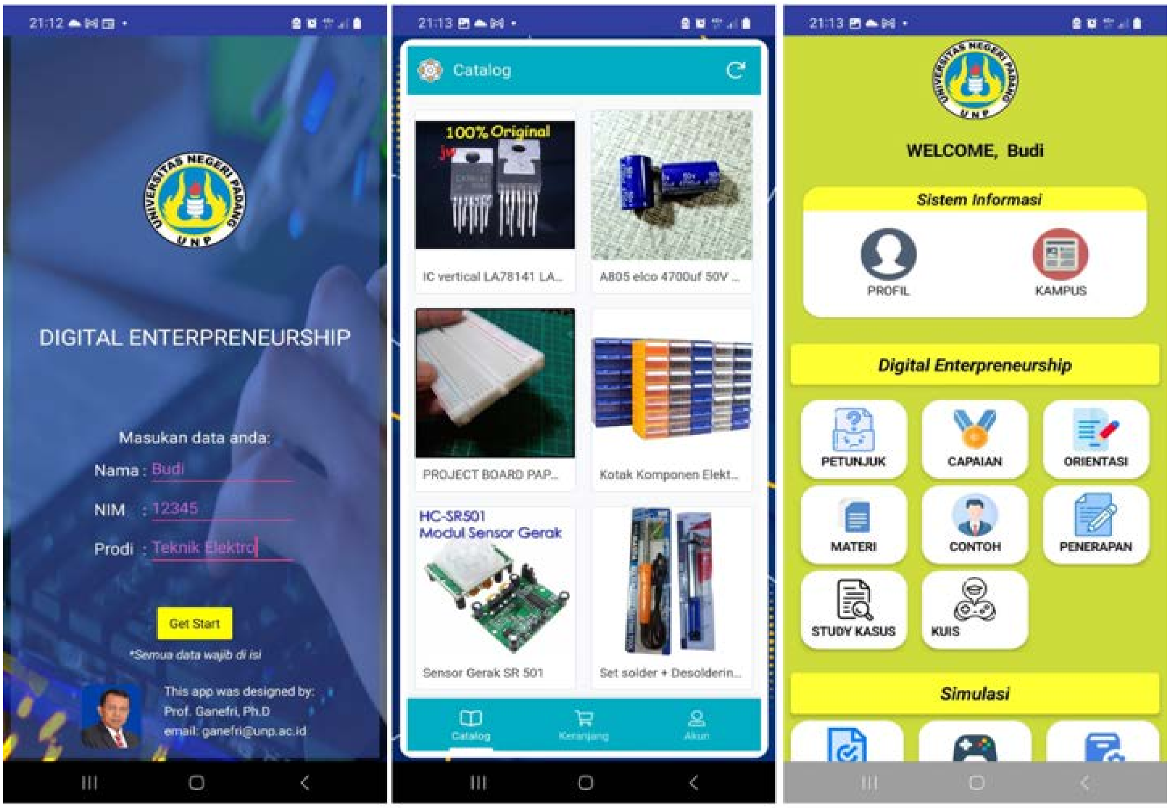

Figure 1. Digital entrepreneurship apps

Digital Entrepreneurship is a mobile application designed to address this requirement. It is an educational platform that integrates technical and digital entrepreneurship competencies within a unified mobile learning environment. The Digital Entrepreneurship app is an interactive resource designed to assist engineering students in mastering fundamental and advanced concepts of digital entrepreneurship. Figure 1 shows the digital entrepreneurship application used in this study, where in the apps, student has option to learn and see catalog about the product that related to their learning needs.

2.2. Sample and Data Collection

A quantitative approach is used to collect and analyze data on higher education engineering students. Due to the large student population, convenience sampling was used to select participants, making the process easier but less rigorous.

Good sample size is crucial because a small sample may not accurately represent the population and lead to unclear results [66]. The study included 417 students who are pursuing engineering education in Indonesia.

Therefore, the decision was made to use a Likert Scale as the assessment method in this study. Each measurement item was assigned a score ranging from 1 (strong disagreement) to 5 (strong agreement). The primary data collection tool in this experiment was questionnaires. This study used previous primary research assessment tools. Research variables are assessed by questionnaire. This questionnaire collects data on digital entrepreneurial intention, guided inquiry learning, metacognitive awareness, self-regulated learning, critical thinking skill and creative thinking skill.

This research assessed digital entrepreneurial intention utilizing seven items derived from a prior study [16], the items reflect students' aspirations regarding digital entrepreneurship, encompassing their intention to create a business utilizing digital technology and their plans to initiate a digital enterprise in the future. Moreover, guided inquiry learning was measured using a seven-item instrument [5]. The instrument evaluates students' capacity to formulate digital business problem statements and to identify relevant information throughout the inquiry process.

Furthermore, seven items that derived from a previous study [42] were employed to assess metacognitive awareness. These items evaluate students' capacity to devise learning strategies that correspond to their unique learning styles, as well as their comprehension of their strengths and weaknesses in the field of digital entrepreneurship. Self-regulated learning was also assessed using seven items that were adapted from a previous study [39] .These items demonstrate students' capacity to independently plan and manage their learning strategies and to establish clear learning objectives for mastering digital entrepreneurship content.

Furthermore, six items were implemented from an earlier investigation [30], to evaluate critical thinking abilities. These items evaluate students' capacity to objectively analyse information and logically identify digital business issues in the context of digital entrepreneurship. Finally, seven items that derived from a previous study [60], were employed to assess creative thinking abilities. These items demonstrate students' ability to generate innovative ideas for digital business innovation and to devise alternative and creative solutions to business-related issues.

2.3. Data Analysis

This study used SmartPLS 4, a variation-based Partial Least Squares (PLS) SEM, to analyze data and create models. The first step was to test the measuring model's accuracy and consistency [67]. Second, AVE and item loading tested convergent validity. This study performed network analysis on this study, network analysis is an analytical approach used to study the structure and dynamics of relationships between entities (nodes) connected through ties (edges) in a network system [68]. This technique allows researchers to systematically describe, visualize, and measure complex social relationships, information, or organizational structures. The importance of network analysis in quantitative research also lies in its ability to combine relational data with advanced statistical analysis, such as network regression, social structure simulation, and graph-based longitudinal analysis.

The aim of methodology section is to describe how research was conducted as well as to enhance credibility of research. In case the research is quantitative, methodology should present the way numerical data was collected and how mathematical analyses are conducted to observe, analyse, access, and test experiments and hypotheses. Qualitative research involves collection and analysis of non-numerical data (e.g.: text, video, or audio) with the aim of explaining concepts, opinions, perspectives, or personal experiences.

3. Results

The results are organised to systematically address the proposed research hypotheses and to assess the relationships between students' critical and creative thinking skills, guided inquiry learning, metacognitive awareness, and digital entrepreneurial intention. The analysis commences with an evaluation of the measurement model to guarantee its reliability and validity, followed by a structural model evaluation to evaluate direct, indirect, and mediating effects using PLS-SEM. Additional analyses, such as Importance–Performance Map Analysis (IPMA) and Fuzzy C-Means Clustering, are reported to offer a more comprehensive understanding of the relative significance of constructs and the patterns of students' cognitive engagement. Collectively, these findings provide a thorough comprehension of the mechanisms that underlie the development of higher-order cognitive skills in engineering education.

3.1. Structural Equation Modelling (SEM) Analysis

The standard component (factor) computing algorithm, PLS-SEM, was performed. This method is recommended for small samples or those with an uncertain or non-normal distribution [69]. Each construct was assessed for the quality of its measurement using Cronbach's alpha, Composite Reliability, Standardized Item Loadings, Average Variance Extracted (AVE), and Heterotrait-Monotrait Ratio of Correlations (HTMT).

Studies evaluated its discriminant validity through the heterotrait-monotrait correlation ratio (HTMT) illustrated in Table 1. All HTMT values among constructs were below the 0.90 threshold, indicating that each construct in the model exhibits adequate conceptual differentiation from other constructs.

Table 1. Heterotrait-monotrait ratio of correlations

	CreaTS	CriTS	DEI	GIL	MA	SLR
CreaTS						
CriTS	0,685					
DEI	0,667	0,704				
GIL	0,683	0,838	0,855			
MA	0,618	0,822	0,825	0,848		
SLR	0,596	0,842	0,704	0,852	0,867	

Table 2 indicates that all Composite Reliability and Cronbach's alpha values exceed 0.70 [67]. The data meets the criteria for convergent validity, as indicated by Table 2. The average variance extracted (AVE) for each construct exceeds 0.50.

Table 2. alpha, CR, AVE

Variable	alpha	CR	AVE
CreaTS	0,857	0,927	0,612
CriTS	0,826	0,839	0,543
DEI	0,902	0,903	0,640
GIL	0,861	0,862	0,546
MA	0,881	0,882	0,585
SLR	0,832	0,858	0,508

Hypothesis testing in PLS-SEM looks at how the structural model's constructs are connected to each other. The bootstrapping method gives the path coefficient, t-statistic, p-value, and confidence interval, which show the test results. It is said that there is a significant relationship between the constructs when the t-statistic is greater than 1.96 (two-tailed, α = 0.05), the p-value is less than 0.05, and the confidence interval does not include zero, as outlined by [69]. The path coefficient indicates the direction and strength of the relationship, while the R^2 value assesses the model's predictive ability regarding endogenous constructs. The test results show that most hypotheses are statistically validated, indicating the strength of the causal relationship in this research model.

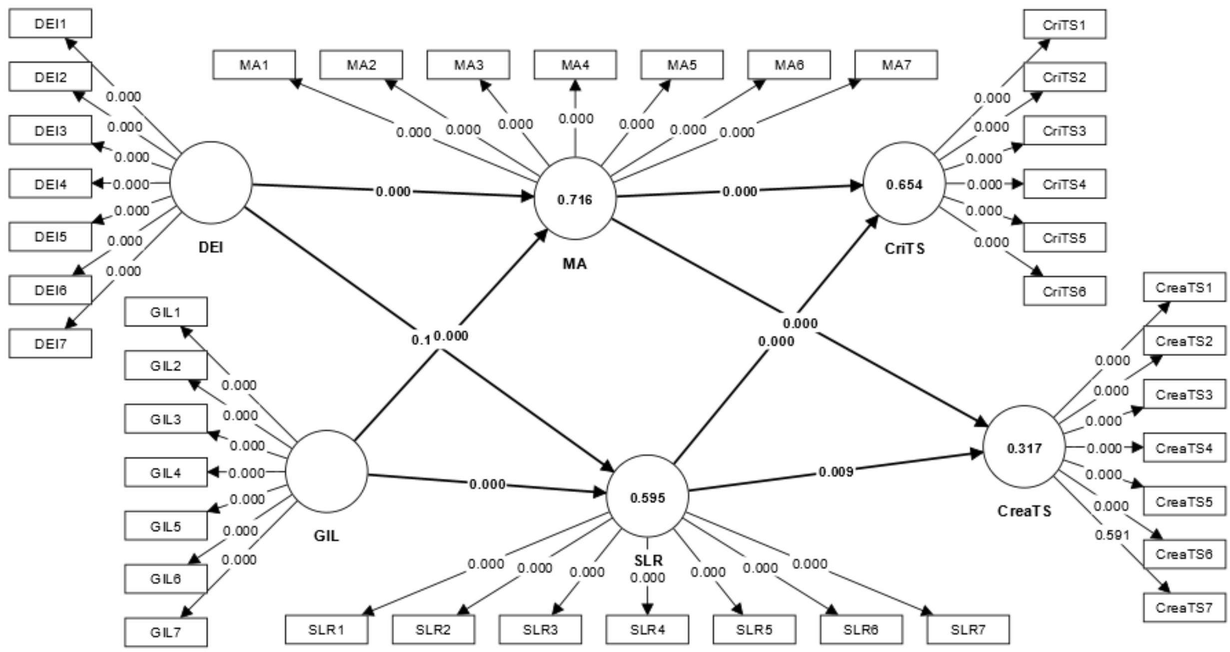

Figure 2. Hypothesis results path

Figure 2 illustrates the trajectory of all hypotheses formulated in this study. Table 3 presents the effect size for each accepted hypothesis, with the results of each effect calculated according to [69].

Among the hypotheses proposed in this study, one hypothesis is rejected. While the indirect effect which 8 indirect effects on this study, and 2 relation is rejected regarded the indirect effect.

Table 3. Hypothesis result

Hypothesis	β	t	ρ	Results
DEI -> MA	0,250	4,262	0,000	Accepted
DEI -> SLR	0,096	1,522	0,128	Rejected
GIL -> MA	0,640	11,792	0,000	Accepted
GIL -> SLR	0,696	11,941	0,000	Accepted
MA -> CriTS	0,280	5,097	0,000	Accepted
MA -> CreaTS	0,383	5,174	0,000	Accepted
SLR -> CriTS	0,568	11,074	0,000	Accepted
SLR -> CreaTS	0,208	2,620	0,009	Accepted
Indirect effect				
DEI -> MA -> CriTS	0,070	3,177	0,001	Accepted
DEI -> MA -> CreaTS	0,096	3,094	0,002	Accepted
DEI -> SLR -> CriTS	0,055	1,492	0,136	Rejected
DEI -> SLR -> CreaTS	0,020	1,147	0,251	Rejected
GIL -> MA -> CriTS	0,179	4,722	0,000	Accepted
GIL -> MA -> CreaTS	0,245	4,810	0,000	Accepted
GIL -> SLR -> CriTS	0,395	7,916	0,000	Accepted
GIL -> SLR -> CreaTS	0,145	2,588	0,010	Accepted

The hypothesis testing indicates that DEI significantly influences MA, with values of β = 0.250, t = 4.262, and ρ = 0.000. This indicates that the hypothesis is valid. The hypothesis is false as DEI exerts a minimal influence on SLR (β = 0.096; t = 1.522; ρ = 0.128). GIL exerted a substantial and significant influence on MA (β = 0.640; t = 11.792; ρ = 0.000) and SLR (β = 0.696; t = 11.941; ρ = 0.000), indicating that this pedagogical approach effectively enhances students' awareness of their cognitive processes and self-regulation abilities. MA significantly influenced Creative Thinking Skill (CreaTS) (β = 0.383; t = 5.174; ρ = 0.000) and Critical Thinking Skill (CriTS) (β = 0.280; t = 5.097; ρ = 0.000).

SLR significantly influences CriTS (β = 0.568; t = 11.074; ρ = 0.000) and CreaTS (β = 0.208; t = 2.620; ρ = 0.009).

Furthermore, indirect effect analysis showed that the influence of DEI on CriTS and CreaTS was significantly mediated by MA (β = 0.070 and β = 0.096, with ρ = 0.001 and 0.002), but not significantly through SLR. On the other hand, GIL showed a significant indirect influence on CriTS and CreaTS both through MA and SLR. This finding confirms that Guided Inquiry Learning is a strategic factor that can improve students' critical and creative thinking skills through strengthening metacognitive and self-regulation skills, while DEI plays a significant role only when mediated by metacognitive awareness, not self-regulated learning.

3.2. Importance-Performance Map Analysis (IPMA)

In order to further ascertain which effects had a significant impact, this study implemented an Importance-Performance Map Analysis [70]. The significance of performance matrix analysis (IPMA) facilitates the extension of basic PLS-SEM results using latent variable scores. The IPMA analysis measurement is illustrated in Figure 3 which is focusing on critical thinking skill and Figure 4 focusing to the creative thinking skill, which employs a structural model to assess digital entrepreneurial attitudes. IPMA assists in the prioritization of improvement areas by identifying factors that are significant to the target audience but are currently underperforming. This enables organizations to allocate resources to areas with the most critical impact [71]. The performance value is ascertained by the latent variable score, whereas the importance value is derived from the total effect experienced by the construct.

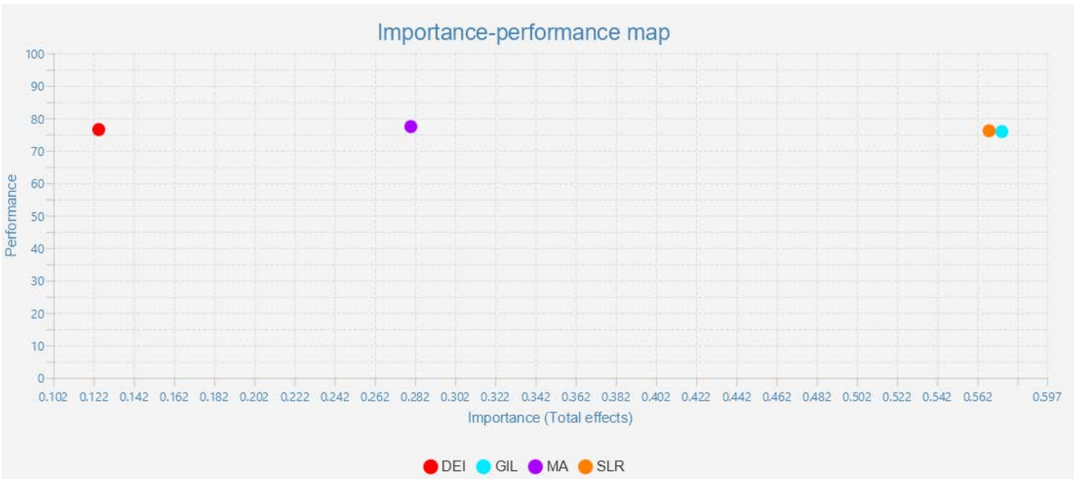

Figure 3. IPMA analysis on critical thinking skill

From Figure 3 it can be seen that in the performance graph almost all variables are on a line that is not too far apart, indicating that in terms of performance, all variables have a performance influence that is not much different. However, when viewed from the importance side, several variables are on a fairly different graph line.

In terms of importance, GIL has the greatest influence which is on the line slightly under 0.582, with a performance level of around over 75. Where at the next level of importance is SLR, which is above the line of GIL, which is also around the performance over 75 lines. Furthermore, MA is on the line of 0.282 with a performance over of 75. And DEI is on the line slightly over 0.122, while for performance it is on slightly over 75.

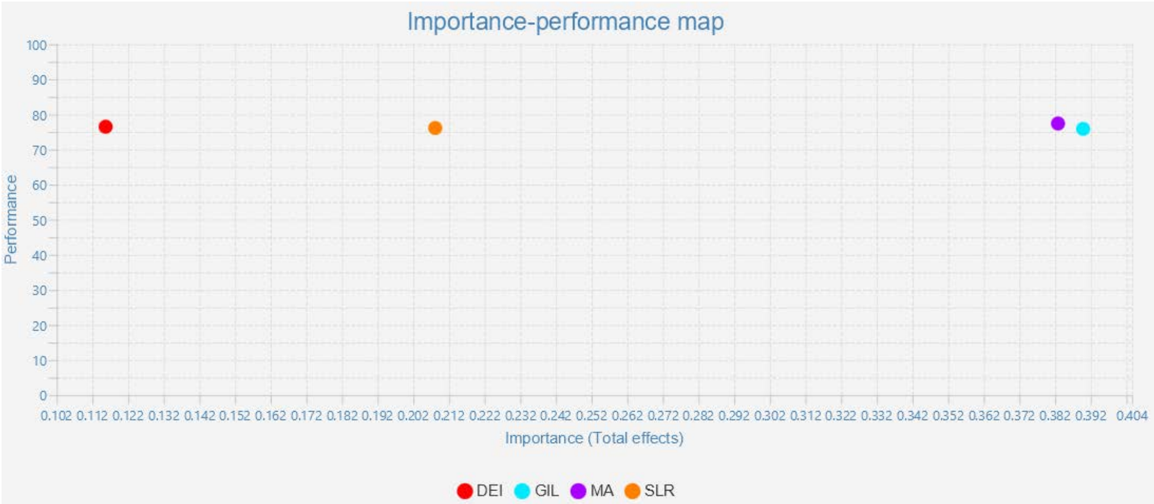

Figure 4. IPMA analysis on creative thinking skill

From Figure 4 it can be seen that in the performance graph almost all variables are on a line that is not too far apart, indicating that in terms of performance, all variables have a performance influence that is not much different. However, when viewed from the importance side, several variables are on a fairly different graph line. In terms of importance, GIL has the greatest influence which is on the line slightly under 0.392, with a performance level of around over 75. Where at the next level of importance is MA, which is above the line of 0.382, thatis the performance over level is slightly higher than GIL. Furthermore, SLR is on the line of 0.202 with a performance over of 75. And DEI is on the line slightly over 0.122, while for performance it is on slightly over 75.

3.3. Fuzzy C-Means Clustering Analysis

As a first step utilized fuzzy C-means clustering to categorize the indications according to their degree of similarity. However, cluster validity was evaluated with the Dunn index, and the elbow approach was employed to determine the number of clusters [72]. In order to validate the clustering solutions, the high-dimensional data was then visualised in lower dimensions using an t-SNE map.

3.3.1. Determining the Number of Clusters

The elbow approach, shown in Figure 5, is a popular tool for clustering analysts to use when trying to figure out how many clusters a dataset should have [73]. Finding the exact graph point when cluster differences drastically decrease with increasing cluster numbers is the main aim. The Within-Cluster Sum of Squares (WCSS), the Bayesian Information Criterion (BIC), and the Akaike Information Criterion (AIC) can all be used to accomplish this goal [74]. AIC and BIC are two prevalent statistical criteria employed to evaluate and compare various statistical models, such as clustering models with differing cluster quantities. These criteria assist in selecting the optimal model to accurately determine the most suitable cluster structure for the data.

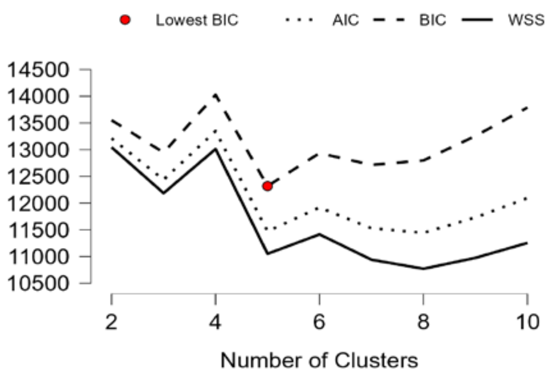

Figure 5. Elbow method to determine the number of clusters

The decision of the five-cluster solution was based on the fact that the first elbow point was at five. In addition, the Fuzzy C-Means Clustering solution's AIC, BIC, and Silhouette metrics are displayed in Table 4. Within the cluster, these metrics measured how consistently data was understood.

The ideal cluster solution was reached by maximizing silhouette scores to their maximum possible value, which may be anything from -1 to 1. Minimizing the BIC and AIC values to their lowest achievable levels was the goal. Table 5 shows other ways to evaluate cluster solutions, such as the entropy, Pearson γ, Calinski-Harabasz index, and Dunn index.

Table 4. AIC, BIC, and Silhouette FCM Clustering

Fuzzy C-Means Clustering					
Clusters	**N**	**R^2**	**AIC**	**BIC**	**Silhouette**
5	417	0.358	12352.830	13199.780	0.100

Note: The model is optimized with respect to the BIC value.

Table 5. Evaluation metrics of FCM Clustering solution

Evaluation Metrics	
	Value
Maximum diameter	18.364
Minimum separation	0.949
Pearson's γ	0.366
Dunn index	0.052
Entropy	1.361
Calinski-Harabasz index	47.812

Note: All metrics are based on the euclidean distance.

This study uses Pearson's measure to find the Pearson correlation for all distances between vectors of ones and zeros. If the value is 0, it means that the cluster categories are the same, and if it is 1, it means that the clusters are different. The ratio of intra-cluster variability to inter-cluster variability is used to find the Calinski-Harabasz index. The Calinski-Harabasz index shows that the best clustering has the most variation between clusters compared to variation within clusters. The clusters are more distinct from each other and more densely packed together when the Calinski-Harabasz index value is higher. The Dunn index is based on two important parts of clustering analysis: The largest diameter and the degree to which two clusters are dissimilar. The goal is to rate the quality of data partitioning [72], [73].

3.3.2. Cluster Validation

The t-SNE method reduces data dimensionality while keeping structure. It represents high-dimensional data in two or three dimensions [73], [75]. The primary objective is to maintain the relative structure by ensuring that data elements that are similar in high-dimensional space remain in close proximity to one another in low-dimensional space.

In order to accomplish this, a probability distribution model is constructed by utilizing the distances between data elements in the original high-dimensional space and those in the lower-dimensional space (where the data will be displayed). t-SNE can find important local structures in very large amounts of data on its own. It can also illustrate global patterns, such as clusters of varying sizes [76]. Figure 6 illustrates the t-SNE plot corresponding to the cluster solution.

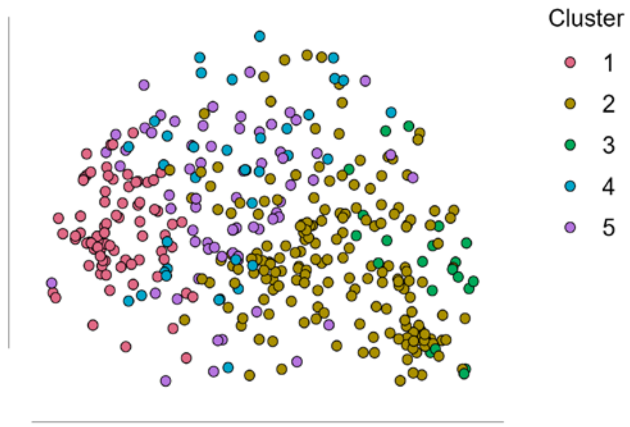

Figure 6. t-SNE cluster plots for cluster solutions

The cluster members, which are depicted in varying shades, are generally located in close proximity to one another. The fact that members with similar or identical traits are grouped together suggests that the clustering solution works. On the plot, data that have similar properties are put together in groups called "clusters." When a clustering solution works well, the distances between members of the same cluster are shorter and the distances between members of different clusters are longer.

The clustering solution's ability to effectively group data based on common traits shows that it is valid and clear. Fuzzy C-Means Clustering Analysis found five groups of students who were cognitively engaged. The results showed that a lot of the skills were similar, which suggests that they depend on each other and affect each other while they are learning. If teachers understand these connections, they might be able to make more effective and targeted learning plans. Fuzzy C-Means Clustering Analysis can find skill patterns, as shown by the elbow method that found the best number of clusters.

4. Discussion

The findings of this study indicate that DEI significantly influences MA but does not affect SLR. This discovery aligns with prior research indicating that the aspiration to initiate a digital enterprise can foster metacognitive awareness. When looking for opportunities, students are more likely to carefully think about and plan their digital actions [30].

The lack of a significant impact of DEI on SLR indicates that mere intention is insufficient for students to autonomously plan their learning without assistance or instructional design that promotes self-regulation [10].

GIL significantly influenced the two mediating variables, MA and SLR. This supports the notion that structured inquiry-based learning facilitates independent thinking and self-directed learning [5]. GIL emphasizing exploration, open-ended inquiries, and scaffolding enhances students' metacognitive awareness and enables them to regulate their behavior to achieve their educational objectives.

Furthermore, MA and SLR significantly enhance CreaTS and CriTS. This outcome supports the notion that metacognitive awareness and self-regulation in learning facilitate the development of advanced cognitive skills. MA assists students in organizing, monitoring, and assessing their cognitive processes with enhanced criticality and creativity [41]. Self-Regulated Learning (SLR) empowers students to independently determine the learning strategies they employ to tackle complex problems in innovative manners [10].

Within the mediation framework, DEI influences CriTS and CreaTS solely through MA, rather than via SLR. This indicates that while digital entrepreneurial intention can enhance awareness of advanced cognitive processes, it does not inherently facilitate improved learning in the absence of instructional methods. Conversely, GIL demonstrates a complete and substantial mediating effect via both MA and SLR. This reinforces the evidence that the inquiry learning approach effectively fosters a learning environment conducive to creative and critical thinking.

This study demonstrates the significance of integrating metacognitive skills and self-regulated learning with effective pedagogical approaches, such as guided inquiry learning, in technical higher education. This is particularly crucial for cultivating advanced cognitive skills that are beneficial in the 21st century.

IPMA indicates that all variables exhibit comparable performance; however, guided inquiry learning is paramount for critical thinking skill and creative thinking skill. Subsequently, SRL and MA will follow. This shows that using questions to teach is the best way to improve the higher-order thinking skills of engineering students in the modern world.

The Fuzzy C-Means Clustering Analysis backs up what the structural model says. It shows that students can be put into five main groups based on how similarly they are engaged in cognitive activities. The cluster has a complicated but logical pattern distribution. The main things that set the clusters apart are guided inquiry learning and self-regulated learning.

The t-SNE visualization data shows how close cluster members are to each other in space, which shows that the clustering model is reliable and consistent.

The study has important implications for both theory and practice. This result shows that guided inquiry learning and other types of inquiry-based learning should be added to the technical curriculum, especially when teaching digital entrepreneurship. This strategy helped students become more self-aware about how they think and increased their ability to control their behavior, which led to better critical and creative thinking.

The idea behind this study adds to what is already known about the dual-mediating model. This model is based on the idea that self-regulated learning and metacognitive awareness are two important cognitive processes that connect wanting to be a digital entrepreneur and having advanced cognitive outcomes. This study shows that DEI does not always lead to more learning independence if itis not paired with the right learning strategy.

This study has several issues, the cross-sectional research design complicates the identification of long-term causal relationships. Second, employing the non-probability method of convenience sampling may hinder the generalization of results to a broader population of engineering students without introducing bias. Third, although the instrument employed has demonstrated efficacy in previous studies, all data were derived from self-reports, which may be influenced by the phrasing of the questions. Future longitudinal studies or quasi-experiments may be conducted to evaluate the efficacy of the Guided Inquiry Learning intervention on cognitive and non-cognitive learning outcomes.

5. Conclusion

MA and SRL serve as critical mediating mechanisms in this investigation, which offers empirical evidence regarding the contributions of DEI and GIL to the cultivation of critical and creative thinking abilities among engineering students. The results indicate that DEI significantly improves students' metacognitive awareness; however, it does not directly promote self-regulated learning. This implies that reflective thinking is stimulated by entrepreneurial intention alone, but it is insufficient to develop autonomous learning behaviours in the absence of suitable instructional support.

In contrast, guided inquiry learning is the most influential pedagogical factor, exerting strong direct effects on both MA and SRL, as well as significant indirect effects on students' critical and creative thinking skills.

These findings underscore the efficacy of inquiry-based instructional designs in the development of higher-order cognitive processes by actively involving students in the planning, monitoring, and evaluation of their learning. The mediation analysis further confirms that MA and SRL play distinct yet complementary roles in translating instructional strategies into advanced cognitive outcomes.

By proposing and validating a dual-mediation model that integrates intention-based and pedagogy-driven mechanisms, this study extends the literature on entrepreneurial cognition and learning sciences from a theoretical perspective. The results demonstrate that DEI primarily contributes to cognitive development through metacognitive processes, whereas GIL enables both reflective and self-regulatory learning pathways. This distinction contributes to the current comprehension of the collaborative influence of cognitive and instructional factors on the higher-order thinking of students in digital entrepreneurship education.

In practical terms, the findings emphasise the significance of incorporating guided inquiry learning into engineering and digital entrepreneurship curricula. Educators and curriculum designers are encouraged to transition from intention-oriented interventions to structured inquiry-based approaches that explicitly promote metacognitive awareness and self-regulated learning. These instructional strategies are especially beneficial in equipping students to navigate the digital economy's complexity, uncertainty, and innovation requirements.

This study has several limitations, despite its contributions. Initially, the cross-sectional research design restricts the capacity to infer causal relationships over time. Second, the generalisability of the findings beyond the sampled population of Indonesian engineering students may be limited by the use of convenience sampling. Third, subjective response tendencies and common method bias may be introduced by relying on self-reported questionnaire data.

In order to investigate the long-term implications of guided inquiry learning on cognitive development, future research is encouraged to implement experimental or longitudinal designs. The robustness of the proposed model would also be improved by comparative studies that span disciplines, institutions, or cultural contexts. Furthermore, in order to obtain more profound insights into the cognitive and self-regulatory processes of students in digital entrepreneurship education, future research could incorporate objective performance measures, learning analytics, or qualitative methodologies.

Acknowledgements

The authors would like to thank Lembaga Penelitian dan Pengabdian Masyarakat Universitas Negeri Padang for funding this work with a contract number: 2091/UN35:15/LT/2025.

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