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Unraveling the cognitive pathway: how critical thinking mediates the impact of anxiety and self-efficacy on informatics achievement in early adolescence

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ABSTRACT

Informatics education in early adolescence demands high-order cognitive skills, yet student performance is frequently impeded by psychological barriers such as anxiety and low self-efficacy. While the direct effects of these factors are known, the specific cognitive mechanisms through which they influence academic achievement remain underexplored. This study investigates the structural pathways connecting anxiety and self-efficacy to informatics learning outcomes, specifically examining the mediating role of critical thinking skills. A predictive correlational design was employed involving 109 seventh-grade students. Data were collected using validated psychological scales and cognitive tests, then analyzed using path analysis to test the mediation hypothesis. The findings demonstrate that anxiety does not merely correlate with lower grades but significantly degrades critical thinking capabilities (cognitive interference). Conversely, self-efficacy acts as a predictor for the activation of these skills (cognitive facilitation). Crucially, critical thinking skills were found to significantly mediate the impact of both psychological factors on learning outcomes. These results suggest that emotional states influence informatics achievement primarily by modulating a student's capacity for algorithmic reasoning. Consequently, effective pedagogy must integrate psychological scaffolding to preserve the cognitive resources required for complex problem-solving.

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Introduction

Success in computer science education extends beyond mastering technical skills like programming; it fundamentally relies on the development of critical thinking and problem-solving abilities (Maesschalck, 2024; Wardani et al., 2024). However, the acquisition of these complex cognitive skills is significantly influenced by students' psychological states, particularly anxiety and self-efficacy, which interact to determine learning outcomes (Herlina et al., 2023; Nurtanto et al., 2025). Anxiety in computer science learning, often triggered by the fear of programming complexity, acts as a critical barrier that can degrade students' cognitive processes and hinder their academic achievement (Azkiya & Ifriza, 2025; Marfuah & Hidayah, 2024).

Literature studies indicate that academic anxiety has complex dimensions, covering test anxiety, fear of negative evaluation, and task anxiety (Cassady & Johnson, 2002; Zeidner & Matthews, 2003). In the context of informatics, this anxiety is often triggered by the perceived difficulty of technical materials such as algorithms and programming, which demand abstract logic (Marfuah & Hidayah, 2024). Cognitive Interference Theory explains that anxiety consumes working memory capacity that should be used for processing tasks, thereby reducing cognitive efficiency (Coy et al., 2011). Conversely, recent studies highlight the importance of positive psychological factors. Research by Navarro et al. (2024) and Rohatgi et al. (2016) found that students' self-confidence and self-efficacy play a crucial role in their success in learning computer science. Meinhardt-Injac & Skowronek (2022) also found that computer anxiety negatively correlates with self-efficacy, implying that students are less prepared to face digital-based tasks when psychological barriers exist.

Although the influence of anxiety and self-efficacy on learning outcomes has been studied, a critical gap remains regarding the internal mechanisms of how these factors work in processing computational information specifically among early adolescents. Previous studies, such as Rahimi & Sevilla-Pavón (2025) and Tapia et al. (2023), have examined mediation models in language learning or medical students, but have not thoroughly examined the role of critical thinking skills as a mediator in the specific context of informatics education for junior high school students. This distinction is vital because informatics requires specific logical structures (computational thinking) that may be disrupted differently by anxiety compared to other subjects.

Based on these theoretical issues, this study aims to investigate the structural relationships between psychological and cognitive factors in computer science learning. Specifically, this study focuses on examining the predictive role of anxiety and self-efficacy on informatics learning outcomes, with critical thinking skills proposed as a key mediating variable. This study is expected to provide new insights into how critical thinking skills function as a cognitive bridge that channels the influence of students' affective factors, thereby providing a basis for the development of more holistic computer science learning strategies.

Method

Research Design

This study employed a quantitative approach with a predictive correlational design (ex-post facto) to investigate the structural relationships between anxiety, self-efficacy, critical thinking skills, and informatics learning outcomes. This design was chosen to examine the extent to which the independent variables predict the dependent variable through the mediator without manipulating the research conditions (Duryadi, 2021).

Population and Sample

The research was conducted at Albanna Junior High School in Denpasar during the 2024/2025 academic year. The population comprised 149 seventh-grade students divided into six classes. A sample of 109 students was established using the Slovin formula to ensure representativeness with a 5% margin of error. The sampling technique employed was Simple Random Sampling, where participants were selected randomly from the population list using a random number generator, ensuring that every student had an equal chance of being selected regardless of their initial academic ability or class placement.

Instruments

Data collection utilized both non-test and test instruments. To ensure the suitability of the instruments for the adolescent age group (12-13 years), strict adaptation and validation procedures were followed academic anxiety questionnaire, self-efficacy questionnaire, critical thinking skills test dan informatics learning outcomes.

Academic anxiety questionnaire, anxiety was measured using a 30-item closed-ended questionnaire. The instrument was adapted from the physiological and behavioral dimensions of the hamilton anxiety rating scale (hamilton, 1959). Crucially, the items were modified and contextualized to reflect academic settings specifically (e.g., trembling when facing a computer error, heart palpitations before a coding test) rather than general clinical anxiety. The adaptation process included forward-backward translation and expert review to ensure the language was age-appropriate.

Self-efficacy questionnaire, assessed using a 35-item questionnaire covering magnitude, strength, and generality dimensions, adapted from the general self-efficacy scale (schwarzer & jerusalem, 2012).

Critical thinking skills test, measured using an essay test comprising 10 items based on facione (2015) indicators: interpretation, analysis, inference, evaluation, explanation, and self-regulation.

Informatics learning outcomes, obtained from teacher documentation, combining cognitive scores (60%) measured by summative tests and psychomotor scores (40%) measured by performance assessments.

Validity and Reliability

To ensure data quality and address the construct validity concerns of adapting clinical scales, all instruments underwent rigorous Content Validity testing using Aiken's V formula involving five experts in educational psychology and informatics. The results showed high validity (Aiken's V > 0.80 for all items), confirming that the adapted anxiety items were relevant for the school context. Construct validity was further tested using Pearson Product Moment correlation (Aiken, 1980; Roebianto et al., 2023). Reliability coefficients were high: Cronbach's Alpha was 0.974 for anxiety and 0.978 for self-efficacy, while the critical thinking test had a reliability coefficient (KR-20) of 0.879.

Data Analysis

Data analysis was performed using Path Analysis to determine direct and indirect effects. Prior to hypothesis testing, classical assumption tests were conducted. Normality was tested using Kolmogorov-Smirnov. Multicollinearity was assessed using the Variance Inflation Factor (VIF), where a VIF value < 5.0 indicates the absence of multicollinearity issues. The significance of the mediating role of critical thinking skills was tested using the Sobel Test. The Sobel Test was selected as it provides a robust and direct method for testing the significance of the indirect effect in single-mediator models with normal distribution, appropriate for the sample size of this study (Duryadi, 2021).

Results and Discussions

Result

The descriptive analysis indicates variability in students' psychological attributes and cognitive performance. As presented in Table 1, the mean score for Anxiety was 38.85 (SD=13.13), indicating a moderate level of anxiety among students. Self-efficacy showed a mean of 69.99 (SD=24.16), while Critical Thinking Skills had a mean of 51.49 (SD=17.24). The Informatics Learning Outcomes averaged 67.70 (SD=8.84).

Table 1. Descriptive Statistics of Research Variables

Variable	N	Mean	Std. Deviation	Min	Max
Anxiety (X1)	109	38.85	13.13	13	65
Self-Efficacy (X2)	109	69.99	24.16	26	114
Critical Thinking (M)	109	51.49	17.24	10	87
Learning Outcomes (Y)	109	67.70	8.84	31	82

Prior to hypothesis testing, classical assumption tests confirmed that the data met the necessary statistical prerequisites. The normality test using the Kolmogorov-Smirnov method indicated normally distributed data ($p > 0.05$). Linearity tests confirmed linear relationships between variables ($p > 0.05$). Multicollinearity was not present, as Variance Inflation Factor (VIF) values for all predictors were below 5.0 (Anxiety=1.31, Self-Efficacy=1.42, Critical Thinking=1.71). Additionally, the Breusch-Pagan test confirmed the homoscedasticity of the residuals ($p > 0.05$).

The Path Analysis results (Table 2) reveal significant direct effects. Anxiety (X1) significantly negatively influenced Critical Thinking Skills ($\beta = -0.487$, $p < 0.001$) and Learning Outcomes ($\beta = -0.515$, $p < 0.001$). Conversely, Self-Efficacy (X2) positively influenced Critical Thinking Skills ($\beta = 0.543$, $p < 0.001$) and Learning Outcomes ($\beta = 0.523$, $p < 0.001$). Critical Thinking Skills (M) emerged as the strongest predictor of Learning Outcomes ($\beta = 0.612$, $p < 0.001$).

Table 2. Summary of Path Analysis and Hypothesis Testing

Path Relationship	Path Coeff. (β)	t-value	p-value	Conclusion
Anxiety → Critical Thinking	-0.487	-5.766	< 0.001	Significant
Self-Efficacy → Critical Thinking	0.543	6.696	< 0.001	Significant
Anxiety → Learning Outcomes	-0.515	-6.212	< 0.001	Significant
Self-Efficacy → Learning Outcomes	0.523	6.351	< 0.001	Significant
Critical Thinking → Learning Outcomes	0.612	8.009	< 0.001	Significant

Regarding the mediation hypothesis, the Sobel Test confirmed significant indirect effects (Table 3). Critical Thinking significantly mediated the relationship between Anxiety and Learning Outcomes ($Z = -2.984$, $p = 0.003$) and between Self-Efficacy and Learning Outcomes ($Z = 3.221$, $p = 0.001$).

Table 3 Summary of Indirect Effects (Mediation Analysis)

Indirect Path	Sobel Z-value	p-value	Mediation Type
Anxiety → Critical Thinking → Learning Outcomes	-2.984	0.003	Partial Mediation
Self-Efficacy → Critical Thinking → Learning Outcomes	3.221	0.001	Partial Mediation

Discussion

This study aimed to elucidate the structural mechanisms connecting psychological factors to informatics achievement among early adolescents. The findings provide empirical support for a mediation model where critical thinking skills act as a pivotal cognitive processor that regulates the impact of anxiety and self-efficacy on learning outcomes.

The significant negative effect of anxiety on critical thinking (-0.487) strongly aligns with the Attentional Control Theory, which posits that anxiety impairs the efficiency of the central executive functions, specifically inhibition and shifting (Eysenck et al., 2007; Putra & Hajar, 2025). In the specific context of informatics, which demands high working memory capacity for abstraction and algorithmic logic, anxiety functions as an "extraneous cognitive load" (Trilisiana et al., 2023). Recent studies confirm that high levels of computer anxiety consume the limited cognitive resources required for complex tasks such as code analysis and debugging (Azkiya & Ifriza, 2025; Vakilifard & Khosro, 2025) When students experience anxiety (manifested as fear of syntax errors or nervousness during compilation) their "mental bandwidth" is diverted to managing emotional distress. This leaves insufficient capacity for the deep reasoning required in critical thinking processes, a phenomenon Katsarou (2021) describes as a barrier to digital competence. Consequently, students fail to perform high-order thinking not due to a lack of innate competence, but due to anxiety-induced cognitive interference (Marfuah & Hidayah, 2024).

In contrast, self-efficacy demonstrated a strong positive influence on critical thinking (0.543), acting as a cognitive facilitator. This finding supports Bandura's Social Cognitive Theory and is consistent with recent empirical work by Kuo & Kuo (2025), who found that self-efficacy is a primary predictor of computational thinking capabilities. Students with high self-efficacy view complex programming tasks as challenges to be mastered rather than threats. This psychological safety allows them to deploy metacognitive strategies such as self-regulation and evaluation without the interference of self-doubt (Bachtiar et al., 2025; Navarro et al., 2024). Furthermore, Franks et al. (2025) note that self-efficacy fosters "cognitive resilience," enabling students to persist through the trial-and-error process essential for developing critical thinking skills. Thus, self-efficacy does not merely motivate; it actively "unlocks" the cognitive machinery required for analysis and inference, allowing students to navigate the complexities of informatics with greater strategic flexibility.

The most significant contribution of this study is the confirmation of critical thinking as a mediator. The partial mediation results imply that psychological factors (anxiety and self-efficacy) do not solely impact grades directly; a significant portion of their influence is channeled through the student's ability to think critically. This supports the "cognitive pathway" model proposed by Tapia et al. (2023) and Rahimi & Sevilla-Pavón (2025), which argues that emotional states must first be processed cognitively to impact academic performance. As noted by (Manousou, 2025), critical thinking is essential for autonomous decision-making in digital environments. Anxiety lowers achievement because it degrades the student's capacity to reason logically (decomposition and pattern recognition), whereas self-efficacy boosts achievement by sharpening these reasoning capabilities (Wardani et al., 2024). This finding is crucial for informatics pedagogy, suggesting that interventions focusing solely on "making students feel confident" (affective support) without explicitly training critical thinking skills (cognitive support) may be insufficient for optimal performance (Nurtanto et al., 2025).

The results of this study are particularly significant given the developmental stage of the participants (7th-grade students, approx. 12-13 years old). According to Piagetian theory, this age marks the transition from concrete operational to formal operational thought, where students begin to grasp abstract concepts—a core requirement for informatics and computational thinking (Barrouillet, 2015). However, this developmental window is also characterized by heightened emotional sensitivity. The strong negative path from anxiety to critical thinking found in this study suggests that for early adolescents, emotional regulation is a prerequisite for cognitive maturation. Unlike older students who may have developed coping mechanisms, 7th graders are uniquely vulnerable; high anxiety doesn't just lower their grades, it arrests their development of abstract reasoning skills (McCurdy et al., 2023). This provides empirical evidence against the "skill-deficit model" (which assumes students fail simply because they lack coding knowledge) and supports a "psychological-interference model" where emotional barriers prevent the application of latent cognitive potential (Lagun, 2025). Thus, fostering self-efficacy in this specific age group is not merely an affective goal, but a cognitive imperative to ensure the successful transition to higher-order thinking in the digital domain.

Furthermore, the findings highlight the unique susceptibility of informatics learning to psychological disruption due to the nature of computational thinking. Unlike subjects that may rely more on rote memorization, informatics requires continuous iterative cycles of decomposition, pattern recognition, and algorithm design (Adorni et al., 2024). This iterative process is inherently fraught with failure (e.g., bugs, syntax errors). For a student with low self-efficacy or high anxiety, these routine failures are not seen as part of the debugging process but as confirmation of incompetence. The strong mediation path identified in this study confirms that critical thinking is the essential tool that converts these technical failures into learning opportunities. Without the regulatory function of critical thinking (specifically the sub-skill of evaluation) students cannot objectively analyze an error message; instead, they react emotionally, leading to the cessation of effort (Abrami et al., 2015).

Finally, the interplay between these variables has profound implications for the formation of students' "STEM identity" during this critical developmental period. Research by Navarro et al. (2024) suggests that early experiences with computer science play a determinative role in future career choices (Wu et al., 2025). The "psychological-interference model" validated in this study implies that students who experience high anxiety are effectively being "pushed out" of the STEM pipeline not because they lack the intellectual capacity, but because their cognitive processing is being hijacked by emotional distress. By mediating this relationship, critical thinking skills offer a protective mechanism. Students who learn to think critically about their own psychological states (metacognition) and the technical problems they face are more likely to develop a resilient STEM identity, viewing computer science as a manageable discipline rather than an insurmountable obstacle (Cabasa & Pañares, 2025).

These findings suggest that educators should adopt a dual-approach strategy. To mitigate the negative path of anxiety, teachers should implement "low-stakes" coding environments and scaffolded problem-solving to reduce extraneous cognitive load (Trilisiana et al., 2023). Simultaneously, to leverage the positive path of self-efficacy, instruction should explicitly model critical thinking strategies (e.g., how to decompose a problem) rather than just teaching syntax, thereby building students' confidence in their reasoning abilities.

Despite its contributions, this study has limitations. First, the cross-sectional design restricts the ability to draw definitive causal conclusions; the relationships observed are structural/predictive rather than strictly causal. Future research should employ longitudinal designs to track how changes in anxiety levels over time affect the development of critical thinking. Second, the reliance on self-report measures for anxiety and self-efficacy may introduce social desirability bias. Finally, the study was conducted in a single private junior high school, which may limit the generalizability of the findings to public schools with different demographic characteristics and infrastructure readiness.

Conclusions

This study elucidates the complex structural pathways between psychological factors and informatics achievement in early adolescence. The core finding is that critical thinking skills function as a partial mediator, serving as the cognitive processor that translates students' emotional states into academic performance. Specifically, the data indicates that anxiety does not merely correlate with lower grades but significantly predicts a degradation in critical thinking capabilities, suggesting that emotional distress creates a cognitive bottleneck that hinders algorithmic reasoning. Conversely, self-efficacy acts as a predictor for the activation of these high-order thinking skills, validating the premise that confidence in this domain is a cognitive enabler rather than just an affective outcome. The theoretical implication of this research is substantial: it challenges the traditional "skill-deficit" perspective in computer science education, which often attributes student failure solely to a lack of technical understanding. Instead, this study supports a "psychological-interference" model, where students possess the latent potential for logic and abstraction but are prevented from utilizing it by anxiety-induced executive dysfunction. For 7th-grade students transitioning to formal operational thought, the ability to regulate anxiety and sustain self-efficacy is revealed to be a prerequisite for mastering the iterative failure inherent in computational thinking. Practically, these findings necessitate a shift in informatics pedagogy. For educators, the recommendation is to decouple the initial learning of logic from high-stakes syntax evaluation. By fostering a "psychologically safe" debugging environment (where errors are framed as data rather than failure) teachers can preserve the working memory resources students need for critical thinking. For curriculum developers, integrating explicit instruction on metacognitive strategies (how to think about thinking) alongside technical skills is essential to build the "cognitive resilience" identified in this study. Future research should address the limitations of this cross-sectional design by employing longitudinal methods to examine whether the negative impact of anxiety on critical thinking diminishes as students gain technical expertise over time. Additionally, experimental studies testing specific interventions (e.g., mindfulness training before coding sessions) would be valuable to establish definitive causal links. Replicating this model in diverse educational settings, including public schools with varying technological infrastructures, is also recommended to verify the generalizability of these structural relationships.

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