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Unraveling the connections: Learning styles, critical thinking skills and mathematics performance among industrial technology students

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Abstract: This study examines the relationships between learning styles, critical thinking skills (CTS), and mathematics performance among Industrial Technology students using a descriptive-quantitative approach. The researchers utilized mean, standard deviation, Spearman rank order coefficient correlation, and regression analysis as statistical treatments. Findings show significant correlations between CTS and math performance, with visual and kinesthetic learning styles positively influencing outcomes. The study underscores the importance of fostering analytical reasoning and adaptive teaching methods aided by a self-learning module developed in technical education. Predicting the students' academic performance can be computed through this model: $y = 1.051\ X1 - 0.762\ X2 - 1.055\ X3 + 0.964\ X4 + 0.495\ X5 - 0.406\ X6 + 0.374\ X7 + 0.700\ X8 - 0.806\ X9 + 0.655\ X10 + 76.965$. The regression model provides valuable insights into the relationship between learning styles, CTS, and academic performance, explaining 19.1% of the variance in the dependent variable. While the explanatory power is modest, the findings highlight key predictors significantly impacting learning outcomes. These results highlight the need for teaching strategies that foster critical thinking and align with diverse learning styles. Future research should include factors such as teachers' motivation and instructional methods to enhance predictive accuracy and intervention design.

Keywords: *Critical thinking skills, Learning styles, Mathematics performance.*

1. Introduction

The insurance of quality education (SDG4), the educational system, and the learning environment should meet specific standards and provide students with the knowledge, skills, and opportunities needed to reach their full potential. It goes beyond mere access to education and focuses on delivering practical, inclusive, and holistic learning experiences [1].

Moreover, Quality education places the learner at the center of the educational process. It recognizes students' diverse needs, interests, and abilities and strives to personalize learning experiences accordingly. This notion includes adopting student-centered pedagogical approaches, differentiated instruction, and individualized support [2].

Mathematics education faces several global issues that impact the quality of teaching and learning in this critical subject. These issues require attention and concerted efforts to improve mathematics education worldwide. Many countries struggle with low mathematics achievement levels, as evidenced by international assessments like the Program for International Student Assessment (PISA). Closing the achievement gap and raising mathematical proficiency levels among students is a significant challenge [3].

Addressing these global issues requires a multifaceted approach involving collaboration among governments, education systems, teacher training institutions, curriculum developers, and other stakeholders. By prioritizing these issues and implementing evidence-based strategies, we can work

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towards improving mathematics education and equipping students with the critical thinking skills (CTS) and mathematical skills needed for success in an increasingly quantitative world [4].

National and international assessments consistently indicate low mathematics achievement among Filipino students. These results include the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA). Many students struggle with fundamental mathematical concepts and lack critical thinking and problem-solving skills Bernardo, et al. [5].

Saleem, et al. [6] revealed in their study that negative attitudes and mindsets towards mathematics among students, parents, and even some teachers can hinder progress in mathematics education. Overcoming math anxiety, promoting a growth mindset, and fostering positive attitudes are key to enhancing students' critical thinking, engagement, and achievement. In the Philippines, students and parents often view math as difficult and unappealing. This perception can discourage students from pursuing advanced mathematics courses and careers in STEM fields. Promoting the value and relevance of mathematics, as well as showcasing its practical applications, can help change public perceptions and encourage greater interest in the subject [7].

Understanding and considering learners' preferences, such as learning styles, can be valuable in designing instructional strategies and materials [8]. Mathematics education issues are complex and multifaceted, involving curriculum design, teacher training, pedagogical approaches, resources, and more. However, incorporating varied instructional methods and materials that align with learners' preferences can create a more engaging and inclusive learning environment.

Mahmood, et al. [9] stated that integrating multiple instruction modes and materials can allow learners to engage with mathematics differently. For instance, combining visual representations, oral explanations, written activities, and hands-on experiences can accommodate a range of learning preferences and enhance understanding. It is essential to consider that learning styles are just one aspect of effective mathematics education.

As part of the institutional research agenda, which focuses on good governance and high-quality education, one of the goals is to improve the University's mechanisms for delivering instruction. By providing educational materials that suit students' preferences, this study will help address students' learning demands. This study examined how the VARK learning styles and level of critical thinking skills (CTS) may impact students' success in Mathematics.

Exploring students' learning styles and critical thinking levels offers valuable insights into their learning preferences, helping to enhance both critical thinking and math performance. Understanding these factors guides the selection of instructional materials that align with students' needs. With Comprehensive Mathematics introduced under the new Industrial Technology (BIndTech) curriculum, this study aims to support effective teaching strategies tailored to student's learning styles and foster improved critical thinking and academic outcomes.

With the above context, this study aimed to determine the VARK Learning Styles, Level of Critical Thinking Skills (CTS), and Mathematics Performance of the first-year Bachelor of Industrial Technology (BIndTech) students at one of the state universities in Negros Occidental Philippines. Specifically, this study sought to answer the following questions:

1. What are the students' preferred VARK learning styles?
2. What is the level of students' Critical Thinking Skills?
3. What is the level of students' Mathematics Performance?
4. Is there a significant correlation between students' VARK Learning Styles, critical thinking skills, and mathematic performance?
5. Can VARK and Critical Thinking Skills predict students' mathematics performance?

1.1. Framework

This research's theoretical body of knowledge is anchored on the VARK Learning Styles of Farman, et al. [10] and Facione Core Critical Thinking Skills in 2015 [11].

Facione's framework emphasizes developing these skills to improve reasoning and make sound decisions. These skills are applicable across various domains and professions, enhancing critical thinking skills, problem-solving, and decision-making capabilities [11].

Understanding the students' preferred learning styles and level of critical thinking skills can help teachers tailor their techniques and seek out learning resources that align with the student's strengths. Still, it's also beneficial to explore and experiment with different approaches to enhance the learning experience.

The VARK learning styles framework aligns with research on learning practices and aims to cultivate students' deep understanding, critical thinking skills, and intellectual dispositions. It provides a framework for teachers to design instruction and find value in considering different learning preferences and incorporating varied instructional approaches to create a well-rounded learning experience [12].

1.2. Scope and Limitations

This study focused on determining the VARK Learning Styles, Level of Critical Thinking Skills (CTS), and Mathematics Performance of the first-year Bachelor of Industrial Technology (BindTech) students at one of the State Universities in the Philippines in the academic year 2024-2025.

The instrument in this study was the researcher-made questionnaire to determine the student's learning style preferences anchored in VARK, Visuals, Auditory, Reading/Writing, and Kinesthetics and the student's level of critical thinking skills adapted from Fleming and Facione, respectively, subjected from validity and reliability tests. The indicator of the variable mathematics performance is the respondents' midterm grades in Mathematics in the Modern World.

The researcher employed [13]. Content Validity Ratio (CVR) to validate the instrument. A panel of five mathematics education experts rated each item as "essential," "useful but not essential," or "not necessary." Only items "essential" met the CVR threshold and were retained [14]. The content validity index of the instruments is 1.0, showing that the items indicator for VARK, Critical Thinking Skills, and Mathematics Performance were essential. To establish the instrument's reliability, the researcher administered the questionnaire to 30 respondents; thus, these students have characteristics similar to those of the respondents for the actual research study. The result of the test is analyzed using Cronbach's Alpha. Cronbach's Alpha measures the internal consistency or reliability between several items, measurements, or ratings. In other words, it estimates how reliable the responses in the questionnaire, instrumentation, or rating evaluated by subjects will indicate the stability of the tools [15]. The computed Cronbach's Alpha generated an alpha of 0.978. According to Inoue, et al. [16] a coefficient of 0.90 and above indicates excellent reliability. The research instrument is reliable and shows excellent internal consistency.

This study is limited only to the scope mentioned above, and the results may be valid for the respondents, but others may not be due to other factors that this study will not cover.

2. Review of Related Literature

2.1. Critical Thinking Skills

Critical thinking Skills (CTS) are pivotal in education, decision-making, and problem-solving across various disciplines. CTS involves analyzing information objectively, evaluating arguments, identifying biases, and making reasoned judgments. CTS is not synonymous with good thinking, but it is a ubiquitous, self-correcting human phenomenon Anggraeni, et al. [17].

Pandey [18] states that critical thinking is "reasonable reflective thinking focused on deciding what to believe or do." It involves cognitive skills such as interpretation, analysis, evaluation, inference, explanation, and self-regulation—abilities vital in academics, daily life, and professional environments. Critical thinking enables individuals to reason logically and apply those skills to real-world, context-specific problems. It fosters deeper self-awareness, encourages objectivity and open-mindedness, and helps individuals better appreciate differing perspectives. By thinking critically, we gain the confidence to offer original insights and new ways of understanding.

Several studies emphasize the importance of critical thinking in academic success. Plummer, et al. [19] highlighted that student with well-developed critical thinking skills tend to perform better in tasks requiring higher-order cognitive functions, such as problem-solving and decision-making. Moreover, Bhardwaj, et al. [20] argue that fostering a culture of critical inquiry in the classroom can significantly improve students' ability to think independently and constructively about complex issues.

In their meta-analysis, Liu and Pásztor [21] found that instructional interventions focused on developing critical thinking (CT) skills significantly enhance student outcomes. However, traditional education systems often overlook the value of CT despite its importance. Okolie, et al. [22] note that educators must intentionally incorporate questioning techniques, case studies, debates, and problem-solving to promote critical engagement. Likewise, integrating interdisciplinary learning has fostered more comprehensive critical thinking, encouraging learners to evaluate information from multiple perspectives [23].

2.2. Learning Styles

Learning styles refer to how individuals absorb, process, and retain information [24]. Over the years, several theories and models have emerged to explain how learners differ in their approach to learning. Understanding learning styles is crucial in designing effective teaching strategies and improving academic performance.

One of the most widely known models is the VARK model developed by Subagja and Rubini [25] which classifies learners into four types: Visual, Auditory, Reading/Writing, and Kinesthetic. According to this model, tailoring instruction to match a student's preferred learning modality can enhance engagement and retention.

However, learning styles remain a topic of debate regarding the effectiveness of teaching students. Deng, et al. [26] conducted a comprehensive review and found insufficient evidence to support the idea that matching instructional style with learning style improves learning outcomes. They argue for evidence-based teaching strategies that benefit all students regardless of learning style preference.

The integration of different learning styles in educational settings persists despite criticism. According to Daniel, et al. [27] recognizing students' preferred learning styles can boost motivation, improve classroom behavior, and enhance academic success.

In more recent studies, Hu, et al. [28] investigated learning styles among university students and emphasized the need for flexible teaching methods that accommodate a variety of learning preferences. Similarly, Alqahtani and Al-Enezi [29] found that aligning instructional design with learning preferences can positively influence student satisfaction and engagement, particularly in online learning environments.

2.3. Mathematics Performance

Mathematics performance is a crucial indicator of academic success and cognitive development, as it reflects students' ability to reason logically, solve problems, and apply quantitative skills in various contexts [30]. Numerous studies have explored the factors influencing mathematics achievement, ranging from cognitive and affective variables to instructional and environmental factors.

In a study by Hebebci and Usta [31] integrating critical thinking into science and math classes significantly improved students' academic performance and problem-solving abilities. Similarly, Wang and Abdullah [32] reported that deliberately teaching CT strategies improved mathematical reasoning among university students. These findings indicate that critical thinking may be linked to and play a causal role in improving math performance.

Moreover, research suggests that aligning instructional methods with students' learning styles can improve math outcomes. Wakhata, et al. [33] found that students whose learning preferences matched teaching methods performed better in math problem-solving tasks. Similarly, Khoo, et al. [34] reported a significant correlation between preferred learning styles and achievement in mathematics among secondary school students in Malaysia.

Tobe [35] observed that students who learned in ways consistent with their preferred styles showed increased motivation and confidence in mathematics, improving performance. The results suggest that learning styles may indirectly impact achievement through affective factors.

Effective teaching in mathematics may involve a multimodal approach, incorporating various teaching strategies to accommodate diverse learning preferences. Vale and Barbosa [36] suggest that combining visual aids, active learning, discussions, and written exercises can help reach a broader range of learners, ultimately supporting better performance in math.

2.4. Synthesis

Mathematics performance is optimized when instruction fosters critical thinking and accommodates diverse learning preferences. While critical thinking enhances students' ability to approach and solve unfamiliar mathematical problems, learning styles influence the effectiveness of instructional delivery. Therefore, educators are encouraged to adopt multimodal teaching strategies that engage students across various learning modalities while developing their critical thinking abilities. This holistic approach can improve understanding, retention, and performance in mathematics.

3. Materials and Methods

3.1. Research Design

This study aims to gather data and statistically analyze students' VARK Learning Styles, Level of Critical Thinking Skills (CTS), and Mathematics Performance. The researcher used the descriptive-quantitative method of research.

The study employed a descriptive-quantitative method combining descriptive research with quantitative analysis to systematically investigate phenomena by collecting numerical data and applying statistical techniques. This method aims to describe characteristics, identify patterns, and quantify variables to provide a detailed and accurate portrayal of the subject under study [37].

Furthermore, quantitative research is a systematic empirical approach to gathering and analyzing numerical data to answer research questions or test hypotheses. It involves collecting and interpreting data in numerical form subjected to statistical analysis. It also aims to be objective and unbiased, focusing on measurable and observable phenomena. It uses structured data collection methods to ensure consistency and reliability [38].

3.2. Participants

This study used a stratified random sample technique on a selected group of first-year Bachelor of Industrial Technology (BIndTech) students who enrolled in the first semester of 2024–2025. Since this is a new curriculum for industrial technology students, they were the perfect choice to address the lack of studies evaluating the students' VARK learning styles, critical thinking abilities, and mathematical performance as the foundation for creating a module for comprehensive mathematics.

3.3. Instrument/s

This study used two (2) researcher-made questionnaires to answer the research questions. The first questionnaire will comprise two parts, the first of which will answer the participants' demographic profile. The second part will answer the students' learning style preferences through the VARK learning styles model.

The second questionnaire evaluated students' critical thinking skills.

The questions were researcher-made questionnaires adapted from VARK Learning Styles of Farman, et al. [10] and Facione Core Critical Thinking Skills in 2015 [11]. Subjected to validity and reliability tests.

3.4. Data Gathering Procedure

The researcher sought and obtained approval to conduct the study from the state university's President through the Dean of the College of Arts and Sciences (CAS), with endorsement from the CAS Research Coordinator.

After receiving approval, data collection commenced. Before administering the research instrument, participants attended an orientation outlining the study's purpose, objectives, procedures, and the researcher's expectations. Those who agreed to participate signed an informed consent form before completing the instrument.

Moreover, the researcher retrieved research instruments with the utmost confidentiality. Data was collected, organized, and analyzed through different statistical tools, and the results were presented to the respondents first.

3.5. Data Analyses

The data in this study were analyzed using quantitative methods.

Mean and Standard deviation to answer problems 1, 2, and 3. Spearman Rank Order Coefficient Correlation for the statement of the problem 4. Regression Analysis to answer problem 5.

The study made use of available statistical software for data analysis.

3.6. Ethical Considerations

In this investigation, the researcher complies with several ethical guidelines. First, the researchers requested authorization from the University President to carry out the study. The participants had given a clear explanation of the researchers' intentions. Emphasizing voluntary involvement, those who consented signed a written consent form. The researchers promised that all information gathered would be kept and used in a way that would always protect the participants' privacy, dignity, anonymity, and data confidentiality. The researcher presented the results to the participants before publishing them or reporting them to the relevant organizations in each research field for approval. After the study, the researcher tore and disposed of all instruments used in data gathering properly.

4. Results and Discussions

This study's Results and Discussion section examines the intricate relationships between critical thinking skills, learning styles, and mathematics performance among Industrial Technology students. This section analyzes the data and how learning styles influence Critical Thinking Skills (CTS) and mathematical achievement. The findings are interpreted in the context of existing research, offering insights into the role of cognitive preferences in academic success. Furthermore, this section explores the implications of these connections for teaching strategies, curriculum development, and student learning outcomes while also addressing study limitations and potential directions for future research.

Table 1.
The Students' Preferred VARK Learning Styles.

Variable	n	Mean	SD	Interpretation
Visuals	251	3.82	0. 511	More Preferred
Auditory	251	3.49	0. 490	Preferred
Reading/Writing	251	3.53	0. 532	More Preferred
Kinesthetics	251	3.45	0. 538	Preferred

Note: 4.50 - 5.00 (Most Preferred); 3.50 - 4.49 (More Preferred); 2.50 - 3.49 (Preferred); 1.50 - 2.49 (Less Preferred); 1.00 - 1.49 (Least Preferred).

The results indicate that the visual learning style is ranked first in the "More Preferred" among the four learning modalities, with a mean score of 3.82 (SD = 0.511). The result shows that learners tend to favor visual aids such as images, diagrams, and charts when processing information, which aligns with research suggesting that visual representations enhance comprehension and retention of knowledge

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[39]. The reading/writing modality follows closely with a mean score of 3.53 (SD = 0.532), also interpreted as "More Preferred," indicating that many learners benefit from textual materials such as notes, lists, and written explanations. Studies have shown that reading and writing help reinforce information retention by engaging cognitive processes that involve encoding and retrieval [40].

Meanwhile, the auditory learning style, with a mean of 3.49 (SD = 0.490), and the kinesthetic learning style, with a mean of 3.45 (SD = 0.538), are both classified as "Preferred." This outcome shows that while these modalities are still valued, they are slightly less favored than visual and reading/writing approaches. Auditory learners process information effectively through listening, discussions, and lectures [13] whereas kinesthetic learners engage more deeply with hands-on activities and movement-based learning [41]. Although these modalities are not the most preferred in the given dataset, they remain essential components of multimodal learning strategies, which research has shown to enhance overall academic performance [42].

Therefore, the data highlights a general preference for learning strategies that involve visual and textual elements over auditory or hands-on experiences. However, all modalities remain relevant in the learning process, as a multimodal approach was the most effective for accommodating diverse learning needs and improving knowledge retention [43].

Table 2.
The Students' Level of Critical Thinking Skills.

Variable	n	Mean	SD	Interpretation
Interpretation	251	3.81	0.863	Practicing Thinkers
Analysis	251	3.88	0.944	Practicing Thinkers
Evaluation	251	3.93	1.009	Practicing Thinkers
Inference	251	3.86	0.792	Practicing Thinkers
Explanation	251	3.64	0.849	Practicing Thinkers
Self – regulation	251	3.96	0.960	Practicing Thinkers

Note: 5.50 - 6.00 (Master Thinkers); 4.50 - 5.49 (Advanced Thinkers); 3.50 – 4.49 (Practicing Thinkers); 2.50 – 3.49 (Beginning Thinkers); 1.50 – 2.49 (Challenged Thinkers); 1.00 – 1.49 (Unreflective Thinkers).

Table 2 indicates that across various cognitive skills—interpretation, analysis, evaluation, inference, explanation, and self-regulation—participants consistently fall into the category of "Practicing Thinkers." This classification suggests that while they demonstrate a developing ability to engage in critical thinking processes, they may still be refining these skills.

Among the cognitive domains assessed, self-regulation received the highest mean score of 3.96 (SD = 0.960), indicating that participants actively monitor and adjust their thinking processes. This crucial metacognitive skill supports independent learning and problem-solving [44]. Evaluation, with a mean score of 3.93 (SD = 1.009), is also highly rated, suggesting that participants can make reasoned judgments and assess the credibility of information [45].

Analysis (M = 3.88, SD = 0.944) and Inference (M = 3.86, SD = 0.792) scores suggest that participants can break down information into components and draw logical conclusions, skills that are essential for problem-solving and decision-making [17]. Interpretation (M = 3.81, SD = 0.863) reflects the ability to comprehend and clarify meaning, which is fundamental in understanding complex ideas.

The lowest mean score is observed in Explanation (M = 3.64, SD = 0.849), indicating that participants may face challenges articulating their reasoning clearly while they can understand and analyze information. These results suggest further development in effectively communicating their thought processes, a skill crucial for academic and professional success [46].

Generally, the results show that participants practice and refine their critical thinking abilities, with particular strengths in self-regulation and evaluation. Continued exposure to analytical discussions, problem-solving exercises, and reflection-based learning strategies can help them advance toward more sophisticated levels of critical thinking.

Hence, the students' mathematics performance is fair, with a mean grade of 82.048 and a standard deviation of 2.742. The result shows that, on average, students are achieving satisfactory results, though there is room for improvement. The standard deviation indicates that most students' grades are relatively close to the mean, reflecting moderate consistency in their performance.

A fair level of performance implies that while students demonstrate a foundational understanding of mathematical concepts, they may struggle with more complex problem-solving tasks or higher-order thinking skills [47]. Various factors could contribute to this level of performance, including teaching methods, student engagement, study habits, and the availability of academic support [48].

The relatively low standard deviation suggests that the variation in student scores is minimal, meaning that most students have similar levels of mathematical proficiency. This end could indicate a uniform instructional approach, where most students receive comparable support and challenges in their learning environment. However, it also suggests that there may be limited differentiation in instruction, which could be a concern if some students require additional support to excel [49].

Educators may consider implementing targeted interventions such as differentiated instruction, problem-based learning, and additional practice opportunities to enhance mathematics performance. Encouraging students to engage in active problem-solving, applying mathematical concepts to real-world scenarios, and fostering a growth mindset can also help improve their overall understanding and performance [50].

Moreover, the findings in Table 3 suggest that visual and kinesthetic learning styles positively correlate with students' Academic Performance. In contrast, auditory and reading/writing learning styles do not significantly correlate. The moderate correlation between visual learning and academic performance ($\rho = 0.254$, $p < 0.001$) aligns with prior research indicating that students who rely on visual aids, such as diagrams, charts, and images, tend to retain and process information more effectively [40]. Similarly, the positive correlation between kinesthetic learning and academic performance ($\rho = 0.2054$, $p = 0.001$) supports findings by Insorio [50] which emphasize the importance of hands-on and experiential learning in improving student engagement and academic outcomes. In contrast, Auditory ($\rho = 0.014$, $p = 0.825$) and reading/writing learning styles ($\rho = 0.090$, $p = 0.156$) did not significantly correlate with academic performance, suggesting that these traditional study approaches may not be as operative for academic success in this context. This outcome aligns with research by Bhardwaj, et al. [20] who noted that learning preferences vary in their impact depending on the nature of the subject and assessment format.

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Table 3.
Correlations Among the Selected Components of Students Academic Performance.

Variable		Visuals	Auditoy	Reading/ Writing	Kinesthetic	Interpretation	Analysis	Evaluation	Inference	Explanation	Self-Regulations	MTG
Visuals	Spearman's rho	—										
	p-value	—										
Auditoy	Spearman's rho	0.452***	—									
	p-value	< 0.001	—									
Reading/ Writing	Spearman's rho	0.603***	0.492***	—								
	p-value	< 0.001	< 0.001	—								
Kinesthetic	Spearman's rho	0.454***	0.451***	0.543***	—							
	p-value	< 0.001	< 0.001	< 0.001	—							
Interpretation	Spearman's rho	0.253***	0.257***	0.282***	0.208***	—						
	p-value	< 0.001	< .001	< .001	< 0.001	—						
Analysis	Spearman's rho	0.277***	0.155*	0.309***	0.231***	0.435***	—					
	p-value	< 0.001	0.014	< 0.001	< 0.001	< 0.001	—					
Evaluation	Spearman's rho	0.281***	0.134*	0.300***	0.207***	0.102	0.192**	—				
	p-value	< 0.001	0.033	< 0.001	< 0.001	0.108	0.002	—				
Inference	Spearman's rho	0.377***	0.332***	0.412***	0.311***	0.472***	0.470***	0.159*	—			
	p-value	< 0.001	< .001	< .001	< .001	< 0.001	< .001	0 .012	—			
Explanation	Spearman's rho	0.353***	0.387***	0.409***	0.330***	0.433***	0.370***	0.216***	0.743***	—		
	p-value	< 0.001	< 0.001	< .001	< .001	< 0.001	< 0.001	< 0.001	< 0.001	—		
Self-Regulations	Spearman's rho	0.490***	0.330***	0.497***	0.376***	0.380***	0.450***	0.305***	0.624***	0.590***	—	
	p-value	< 0.001	< 0.001	< .001	< 0.001	< 0.001	< .001	< .001	< 0.001	< 0.001	—	
MTG	Spearman's rho	0.254***	0.014	0.090	0.205**	0.146*	0.125*	0.179**	0.171**	0.105	0.292***	—
	p-value	< 0.001	0.825	0.156	0.001	0.021	0.048	0 .004	< 0.006	0.097	< 0.001	—

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Regarding students critical thinking skills, self-regulation (ρ = 0.292, $p < 0.001$) demonstrated the strongest correlation with academic performance, emphasizing the role of metacognitive awareness and learning strategies in educational achievement [44]. Self-regulated learners actively monitor their understanding, set goals, and adjust their approach to optimize performance, leading to better academic outcomes [48]. Additionally, other critical thinking skills, such as interpretation (ρ = 0.146, p = 0.021), analysis (ρ = 0.125, p = 0.048), evaluation (ρ = 0.179, p = 0.004), and inference (ρ = 0.171, p = 0.006), were also significantly correlated with academic performance, albeit with weaker associations. These findings align with Facione [45] conceptualization of critical thinking, which suggests that students who can interpret, analyze, and infer information effectively are better equipped to succeed academically. However, the explanation (ρ = 0.105, p = 0.097) was not significantly correlated with academic performance, suggesting that while the ability to articulate reasoning is essential, it may not directly impact mathematics performance.

These results reinforce the importance of visual and kinesthetic learning strategies in enhancing academic performance while highlighting students' critical thinking skills as a key determinant of success. Educators should consider incorporating more visual aids, hands-on activities, and critical thinking strategies into instructional methods to optimize student learning outcomes. Future research may further explore how these factors interact across different disciplines and assessment types to refine teaching and learning approaches.

Table 4.
Significant Variables for Students' Mathematics Performance.

Model	R^2	R^2 Adjusted	Variables	Beta Coefficients	t	Sig
M_1	0.191	0.158	Constant	76.965	50.334**	< 0.001
			Visuals (x_1)	1.051	2.496*	0.013
			Auditory (x_2)	-0.762	-1.966*	0.050
			Reading/writing (x_3)	-1.055	-2.462*	0.015
			Kinesthetic (x_4)	0.964	2.599*	0.010
			Interpretation (x_5)	0.495	2.271*	0.024
			Analysis (x_6)	-0.406	-2.008*	0.046
			Evaluation (x_7)	0.374	2.207*	0.028
			Inference (x_8)	0.700	2.111*	0.036
			Explanation (x_9)	-0.806	-2.707*	0.007
			Self-Regulations (x_{10})	0.655	2.705*	0.007

Note: ** Highly Significant at p-value < 0.01* Significant at p-value < 0.05

The regression model (M_1) presented in Table 4 demonstrates a modest but significant relationship between the independent and dependent variables, with an R^2 value of 0.191 and an adjusted R^2 of 0.158. The result suggests that the predictors can elucidate approximately 19.1% of the variance in the dependent variable. At the same time, the adjusted R^2 indicates a slightly reduced explanatory power after accounting for the number of predictors. Despite the relatively low R^2, several independent variables show significant relationships with the outcome, emphasizing the importance of learning styles and cognitive skills in predicting performance [51].

Among the learning styles, Visual (β = 1.051, p = 0.013) and Kinesthetic (β = 0.964, p = 0.010) approaches are positively associated with the dependent variable, indicating that learners who rely on these modalities tend to perform better. These results align with previous research suggesting that visual and kinesthetic learning styles enhance engagement and information retention [52]. In contrast, Auditory (β = -0.762, p = 0.050) and Reading/Writing (β = -1.055, p = 0.015) learning styles negatively impact performance, suggesting that students who predominantly rely on these methods may face challenges in specific educational contexts. This finding resonates with studies indicating that traditional lecture-based auditory learning is less effective for comprehension and recall than visual and interactive learning strategies [53].

Regarding cognitive skills, Interpretation (β = 0.495, p = 0.024), Evaluation (β = 0.374, p = 0.028), inference (β = 0.700, p = 0.036), and Self-Regulation (β = 0.655, p = 0.007) positively influence the dependent variable. These results suggest that higher-order cognitive abilities, particularly self-regulation and inference, enhance learning outcomes [54]. Conversely, analysis (β = -0.406, p = 0.046) and explanation (β = -0.806, p = 0.007) show significant negative relationships, implying that excessive focus on dissecting information or explaining concepts may not always lead to better performance. This outcome is consistent with research indicating that overemphasizing analytical processing without application can sometimes hinder learning efficiency [55].

Although the model does not explain a high percentage of the variance, its findings align with educational psychology literature emphasizing the importance of multimodal learning strategies and cognitive engagement in academic performance. Future research should explore additional variables, such as motivation, prior knowledge, and instructional methods, to better understand the complexities of learning processes [56].

Predicting the students' academic performance can be computed through this model: $\mathbf{y} = 1.051X_1 - 0.762\ X_2 - 1.\ 055\ X_3 + 0.964\ X_4 + 0.495\ X_5 - 0.406\ X_6 + 0.374\ X_7 + 0.700\ X_8 - 0.806\ X_9 + 0.655\ X_{10} + 76.965$.

5. Conclusions and Recommendations

The findings indicate a clear preference for the visual learning style, followed closely by the reading/writing modality. Learners favor information presented through images, diagrams, and textual materials. While auditory and kinesthetic learning styles are slightly less preferred, they remain valuable in facilitating comprehension and engagement. These results support the growing body of research emphasizing the benefits of multimodal learning approaches, which integrate various modalities to accommodate diverse learning preferences and enhance knowledge retention. Ultimately, while visual and textual elements may be the most favored, an inclusive and adaptable learning environment that incorporates all modalities remains essential for maximizing educational effectiveness.

The findings highlight the crucial role of critical thinking skills and learning preferences in shaping students' academic performance. While students categorized as "Practicing Thinkers" indicate a developing ability in critical thinking, their strengths in self-regulation and evaluation suggest a strong foundation for independent learning and reasoned judgment. However, the lower scores in "Explanation" indicate a need for effective improvement in articulating thought processes.

Regarding learning preferences, visual and kinesthetic learning styles positively correlate with academic performance, reinforcing the effectiveness of diagrams, charts, and hands-on experiences in enhancing comprehension. Conversely, auditory and reading/Writing styles do not significantly correlate with performance, suggesting that traditional study methods may not be as impactful in this context.

Additionally, students' mathematics performance is fair, with minimal variability in scores, indicating a relatively uniform level of proficiency. This consistency may reflect a standardized instructional approach but raises concerns about differentiated learning opportunities.

Educators should implement multimodal teaching strategies to improve academic outcomes, emphasizing visual and kinesthetic methods while integrating critical thinking exercises such as problem-solving and self-regulated learning activities. Future research should explore how these factors interact across different subjects and assessment types to refine instructional approaches and better support diverse learning needs.

The regression model provides valuable insights into the relationship between learning styles, cognitive skills, and academic performance, explaining 19.1% of the variance in the dependent variable. While the explanatory power is modest, the findings highlight key predictors significantly impacting learning outcomes. Visual and kinesthetic learning styles positively influence performance, reinforcing the effectiveness of imagery and hands-on experiences in knowledge retention. Conversely, auditory and reading/writing styles negatively impact performance, suggesting that traditional lecture-based and text-heavy approaches may not be as practical for academic success in this context.

Although the model may not capture the full complexity of academic performance, it underscores the significance of multimodal learning strategies and higher-order cognitive skills. Future research should explore additional factors such as motivation, instructional methods, and prior knowledge to refine predictive models and develop more effective learning interventions. The derived regression equation offers a practical tool for predicting student performance, guiding educators in tailoring instructional approaches to optimize learning outcomes.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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