Journal of Social Sciences and Humanities Research Fundamentals (ISSN: 2748-9345)

Received: 18 March 2026 | Accepted: 05 April 2026 | Published: 30 April 2026

DOI: 10.55640/jsshrf-06-04-16

RESEARCH ARTICLE

The Mediating Role Of Critical And Algorithmic Thinking Indicators In Determining Students' Programming Aptitude (A Case Study Of The Mindmetricai Platform)

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VOLUME: Vol.06 Issue04 2026

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Abstract

In today's era of rapid development of information technology and digitalization processes, changes in education and the proliferation of automated educational systems are radically transforming real-time diagnostic and effective development methods for future IT professionals' programming aptitude. Using the MindMetricAI intelligent diagnostic platform as a case study, this research investigates the relationship between higher education students' academic performance in programming and their cognitive aptitude indicators by examining the mediating role of critical and algorithmic thinking. The introduction of intelligent diagnostic systems and flexible assessment platforms has expanded the flexibility of identifying students' cognitive profiles and individual capabilities. However, concerns regarding the effectiveness of traditional methods for assessing programming aptitude persist. Multi-factor cognitive indicators, which include the ability to use software tools, analyze logical structures, and critically evaluate algorithmic solutions, are of vital importance in this regard.

This study examines how students' programming aptitude indicators affect their academic performance and analyzes the mediating role of critical and algorithmic thinking in this process. The study hypothesizes that critical and algorithmic thinking skills mediate the relationship between programming aptitude and academic achievement. To gather primary data, questionnaires based on MindMetricAI platform indicators were administered to 356 undergraduate students in their 1st and 2nd years at Nukus State Technical University, Bukhara State Technical University, and Navoi State University. The analysis results demonstrated that critical and algorithmic thinking indicators play a significant mediating role in determining students' programming aptitude and academic performance levels, while possessing high accuracy in identifying cognitive profiles.

KEYWORDS

Programming aptitude, algorithmic thinking, critical thinking, mediating role, MindMetricAI platform, intellectual diagnostics, digital educational environment, cognitive indicators.

INTRODUCTION

In today's context of rapid advancements in information technology and automation, the integration of digital technologies into the educational environment is becoming increasingly popular, providing the opportunity to diagnose

students in real-time using software platforms and assess their aptitude and academic metrics within a short time without excessive cognitive load. The implementation of digital learning tools has not only radically transformed teaching and assessment processes but has also brought scientific approaches regarding their impact on students' cognitive potential to a new level. This study examines the correlation between the digital diagnostic environment (the MindMetricAI platform) and programming aptitude in higher education, paying special attention to the mediating roles of critical and algorithmic thinking.

The widespread use of digital learning platforms—ranging from online courses to virtual classrooms—has created unprecedented conditions for higher education institutions to expand their reach and provide flexible learning opportunities for students. However, alongside these conveniences, the actual effectiveness of digital environments and the extent to which they improve or negatively impact students' personal outcomes raise justified concerns in the academic community. In particular, digitizing programming education without considering students' individual cognitive characteristics may fail to yield expected results. Therefore, objectively assessing students' programming aptitude and cognitive potential using intelligent diagnostic platforms such as MindMetricAI serves as an essential mechanism for enhancing educational efficiency.

On the other hand, digital literacy has become a paramount set of skills for modern students. It encompasses the ability to navigate digital tools freely, evaluate online information critically, and communicate effectively in digital formats. Understanding how students' digital literacy and cognitive indicators affect their academic achievements is of primary importance in the information age. In particular, the main objective of this study is to assess the digital and algorithmic potential of youth majoring in programming through specialized platforms like MindMetricAI and to uncover their mediating role in academic performance.

Furthermore, this study empirically analyzes how critical and algorithmic thinking indicators act as mediators between the digital educational environment, digital literacy, and academic performance. Critical and algorithmic thinking are crucial cognitive abilities that enable students to deeply analyze information and source code, identify logical errors, evaluate them, and formulate optimal algorithmic solutions. The study hypothesizes that critical and algorithmic thinking skills fostered through the MindMetricAI platform serve as the primary mediator explaining the impact of digital literacy and learning experiences on students' academic performance and programming aptitude.

As higher education institutions introduce pedagogical-diagnostic software tools and platforms into educational and monitoring processes, this study clarifies the direct impact of these tools on programming aptitude and academic achievement. It provides empirical evidence on the effectiveness of digital learning and serves as a supportive guide for faculty members in improving their digital strategies. Such digital diagnostic environments play a significant role in objectively and accurately assessing students' programming aptitude.

The study demonstrates the effectiveness of automated adaptive assessment of students' knowledge and cognitive indicators in digital diagnostic environments within higher education systems. Moreover, the study presents critical and algorithmic thinking as mediators in the relationship between digital competencies and programming aptitude. This shows that while programming aptitude and diagnostic tools are important, the ability to critically and algorithmically evaluate and apply information enhances academic outcomes and cognitive knowledge.

For this reason, intelligent diagnostic tools and environments are extremely important for identifying student aptitude, especially as they prove more effective than traditional control methods in assessing logical, critical, and algorithmic thinking indicators. Furthermore, this study provides important recommendations for educators and faculty members who aim to teach programming and conduct adaptive assessments of students within digital educational environments.

The purpose of this study is to scientifically substantiate the complex interrelationship between the digital diagnostic environment and critical-algorithmic thinking within the higher education system, as well as their mediating function in determining programming aptitude. By thoroughly examining these correlations, the study aims to provide educators, instructors, and educational administrators with practical recommendations on improving adaptive diagnostic systems in a digital environment, optimizing cognitive load, and stimulating students' academic achievements.

Amid rapidly developing digital technologies and teaching methods, this study is timely. It helps higher education institutions understand the key factors contributing to student

success in the digital age and enables them to adapt more effectively to these changes.

Bloom's taxonomy divides cognitive skills into six creative levels: remembering, understanding, applying, analyzing, evaluating, and creating. In particular, higher-order cognitive skills such as analyzing, evaluating, and creating serve as a fundamental basis for developing critical and algorithmic thinking in students. This approach is reflected in the diagnostic indicators of the MindMetricAI platform, acting as an important scientific and methodological guide for instructors in creating adaptive tasks that assess students' programming aptitude and develop their advanced cognitive skills.

Constructivist theory posits that students actively construct their concepts and knowledge through personal experience and reflection upon that experience. This approach stimulates active learning and critical-algorithmic thinking among students because, during the programming process, students do not passively accept information, but rather strive to analyze, question, and practically synthesize it. In particular, relying on a constructivist approach, the MindMetricAI digital diagnostic environment gives students the opportunity to test their programming knowledge in practice and draw independent conclusions.

Information processing theory explains how the human mind receives, remembers, stores information, and retrieves it when necessary. Understanding the mechanisms of organizing information effectively and utilizing it without excessive cognitive load further strengthens critical and algorithmic thinking. In accordance with this theory, educators and software developers create adaptive diagnostic strategies that help students process programming codes and logical problems more deeply, thereby forming higher-order cognitive skills.

Peter Facione's concept of critical thinking (interpretation, analysis, evaluation, inference, explanation, and self-regulation) and Robert Ennis define this cognitive construct as a purposeful and self-regulating process (self-regulation) aimed at making discrete decisions and drawing logical inferences. Jeannette Wing and Marcos Román-González's approaches substantiate algorithmic and computational thinking as a set of fundamental cognitive abilities that include problem decomposition, abstraction, and the potential for psychometric assessment [4].

Within the framework of the MindMetricAI platform, these structured approaches serve as a theoretical-psychometric framework for evaluating the mediating role of critical and algorithmic thinking indicators in diagnosing students' programming aptitude. According to John Sweller's cognitive load theory and Raymond Lister's programming skills hierarchy, code-tracing and understanding skills—while balancing cognitive memory capacity—constitute the primary mediating mechanism between a student's latent cognitive potential and their final programming aptitude [5].

The literature review is aimed at identifying the scientific contributions of various studies in the fields of digital educational environments, adaptive diagnostics, critical and algorithmic thinking, and the determination of students' programming aptitude. Digital and adaptive educational platforms, having firmly established their place in the higher education system, allow not only the delivery of educational materials but also real-time assessment of students' cognitive processes and the balancing of cognitive load. In this context, scientific perspectives on how critical and algorithmic thinking indicators play an important mediating role between a student's latent cognitive potential and practical programming results are analyzed.

Modern educational processes encompass large-scale innovative approaches implemented through digital technologies and intelligent platforms, including adaptive learning, digital diagnostics, and e-learning models. Numerous scientific studies are aimed at investigating the impact of digital environments on student performance indicators. In particular, modern research shows that digital tools enhance students' cognitive activity, flexibly manage the knowledge acquisition trajectory, and rapidly assess their programming aptitude. Today, higher education institutions are gradually transitioning from traditional assessment methods to automated diagnostic formats that evaluate students' personal potential in real time.

At the same time, the degree of influence exerted by digital educational and diagnostic environments on student performance and the determination of programming aptitude varies and depends on a number of factors, such as software design quality, individual student cognitive characteristics, and usage conditions. Although the importance of digital platforms is unquestionable, certain difficulties and uncertainties persist in the digitalization of the educational process. In particular, this situation is directly related to factors such as a lack of

objective criteria in assessing students' programming skills, discrepancies in managing cognitive load, and the necessity of mutually integrating traditional and digital teaching methods.

Digital diagnostic and educational platforms possess great potential for developing critical and algorithmic thinking skills in students. However, this process is directly tied to a number of cognitive-methodological factors, such as the socio-academic environment, students' prior learning skills, and the level of digital technology usage in programming education. Observations carried out using the MindMetricAI platform demonstrate a positive shift in students' attitudes toward the automated adaptive environment, as well as significant growth in their potential to solve logical-creative problems.

The adaptation of the educational process to rapid technological progress makes the full utilization of the capabilities of intelligent and electronic educational environments an objective necessity. In the context of training 21st-century personnel, students are required to possess modern competencies, specifically critical thinking, algorithmic thinking, and digital literacy skills. Today, digital diagnostic and adaptive technologies are becoming an integral part of the educational process, serving as a valuable tool for determining students' programming aptitude in real time, rapidly adapting to their individual characteristics, and dramatically increasing teaching efficiency.

Despite certain difficulties encountered in the process of reforming and digitizing modern education, the rapid development of pedagogy and intelligent technologies is fundamentally transforming the higher education system. In particular, digital diagnostic and adaptive platforms such as MindMetricAI demonstrate a central role in uncovering students' programming aptitude, optimizing cognitive load, and shaping future professional skills.

Hypothesis 1: In the digital diagnostic environment (MindMetricAI platform), students' cognitive and digital indicators have a statistically significant and positive impact on determining their programming aptitude.

Hypothesis 2: Critical thinking indicators play an important mediating role in the relationship between students' digital literacy/cognitive profile and their academic results related to programming.

Hypothesis 3: The level of algorithmic thinking—incorporating problem decomposition and abstraction—directly mediates the effect between a student's initial cognitive potential and their final programming aptitude.

Hypothesis 4: Code-tracing and logical analysis tasks on the MindMetricAI platform, by optimizing cognitive load, significantly enhance the possibility of manifesting a student's latent (hidden) programming aptitude.

Methodology

Methodologically, this study is descriptive and empirical in nature, aimed at uncovering the general regularities of assessing students' programming aptitude within a digital diagnostic environment. A cross-sectional approach was employed, with data collected over a specific time period. To form the empirical foundation of the study, primary data were gathered using specialized questionnaires and psychometric tests based on indicators from the MindMetricAI platform.

The analysis focuses on 1st- and 2nd-year undergraduate students majoring in information technology, computer science, software engineering, and artificial intelligence at public technical universities across the Republic of Uzbekistan.

Sampling: While the general population for this study comprised technical higher education institutions in Uzbekistan, the target population specifically consisted of students from Nukus State Technical University, Bukhara State Technical University, and Navoi State University. A questionnaire method was utilized to collect primary data.

A purposive and judgment sampling technique was applied to select respondents. To establish the empirical base, a total of 400 students were initially approached. Data were collected via the MindMetricAI intelligent diagnostic platform and specialized psychometric questionnaires. After removing incomplete and erroneously filled responses, 356 valid answers were accepted for analysis (the overall response rate was 89%).

Digital literacy and digital competencies were measured based on indicators of free navigation in the modern digital environment and the utilization of digital tools.

Critical and algorithmic thinking were evaluated using special indicators on a 5-point Likert scale, drawing upon Peter Facione and Robert Ennis’s classification of cognitive skills.

Programming aptitude and academic performance were measured based on students' academic achievement in programming courses and the results of code analysis (code tracing) via the MindMetricAI platform.

Within the scope of the study, specialized adaptive tests from the MindMetricAI intelligent platform and code-tracing indicators were used to assess students' programming aptitude. The platform enabled the real-time measurement of students' skills in finding algorithmic solutions, detecting logical errors, and analyzing source code, thereby determining their latent programming potential.

Pilot Study: Following the development of the questionnaire, an initial trial was conducted among higher education students. The reliability of the variables was tested based on these data. Reliability coefficients were calculated as follows:

For digital literacy — 0.924;

For the digital diagnostic environment (MindMetricAI) — 0.838;

For critical and algorithmic thinking — 0.867;

For algorithmic thinking and programming aptitude — 0.871.

Since all Alpha coefficients proved to be exceptionally high and exceeded the satisfactory threshold according to scientific requirements (above 0.700), the reliability of the instruments was fully confirmed, and the main empirical analyses were carried out.

Results

The demographic characteristics of the selected students are: 70% male, 30% female. Their ages range from 17 to 20 years.

The differences across factors such as digital literacy, the digital diagnostic environment, critical thinking, and algorithmic thinking are presented in the tables below:

Table 1: Analysis of Differences Across Demographic and Academic Factors (ANOVA / p-values)

Factors	DL (p)	DDE (p)	CT (p)	AT (p)	Result / Conclusion
Gender	0.809	0.670	0.599	0.280	No difference (p > 0.05)
Age	0.231	0.984	0.594	0.158	No difference (p > 0.05)
Education Level	0.091	0.891	0.227	0.155	No difference (p > 0.05)
Institution	0.941	0.743	0.855	0.913	No difference (p > 0.05)
Academic Program	0.000	0.000	0.000	0.000	Significant difference(p < 0.05)
Location	0.887	0.579	0.598	0.765	No difference (p > 0.05)

(Where DL stands for digital literacy, DDE for digital diagnostic environment, CT for critical thinking, and AT for algorithmic thinking)

Regarding the gender factor, the p-value for digital literacy is 0.809, for the digital diagnostic environment it is 0.670, for critical thinking it is 0.599, and for algorithmic thinking it is 0.280, all of which exceed the traditional significance level of 0.05 (5%). This result indicates that there are no statistically significant differences between male and female students regarding these indicators; in other words, gender does not affect students' assessment of digital literacy, the diagnostic environment, and cognitive thinking abilities.

Similarly, the p-values by age are 0.231 for digital literacy, 0.984 for the digital diagnostic environment, 0.594 for critical thinking, and 0.158 for algorithmic thinking, demonstrating that all values are greater than 0.05. This implies that age likewise has no statistically significant effect on perceptions regarding the studied factors.

By level of education, the p-values were 0.091 for digital literacy, 0.891 for the digital diagnostic environment, 0.227 for critical thinking, and 0.155 for algorithmic thinking. These figures are greater than 0.05, indicating no significant differences across these factors based on students' education level (although the indicator for digital literacy is close to the threshold value, the difference is not statistically significant).

For the nature of the educational institution, the p-values are 0.941 (DL), 0.743 (DDE), 0.855 (CT), and 0.913 (AT) respectively, which are considerably larger than 0.05. This suggests that the type of educational institution (e.g., private or public universities) does not statistically significantly influence students' views on digital literacy, the diagnostic environment, and cognitive skills.

For the academic program, the p-value across all variables is 0.000, which is significantly lower than 0.05. This result demonstrates sharp and reliable differences in digital literacy, the digital diagnostic environment, critical thinking, and algorithmic thinking scores based on the academic program. In other words, the academic program (major) chosen by students directly affects the manifestation of their digital competencies and cognitive potential.

Regarding location, the p-values are 0.887 for digital literacy,

0.579 for the digital diagnostic environment, 0.598 for critical thinking, and 0.765 for algorithmic thinking, all exceeding 0.05. This indicates that the geographical location of the educational institution does not exert a statistically significant impact on the factors under investigation.

Finally, the analysis results show that the academic program is the only factor among those analyzed that has a significant impact on digital literacy, the digital diagnostic environment, critical thinking, and algorithmic thinking indicators. Conversely, there are no statistically significant variations or differences across other factors such as gender, age, education level, institution type, and location.

Table 2: Kendall Tau (τ) Correlation Analysis Results

Indicators	Digital Literacy	Digital Learning (DDE)	Critical Thinking	Algorithmic Thinking / Aptitude
Digital Literacy	1	—	—	—
Digital Learning (DDE)	0.388	1	—	—
Critical Thinking	0.664	0.526	1	—
Algorithmic Thinking / Aptitude	0.734	0.344	0.526	1

The correlations between digital literacy, the digital diagnostic environment (MindMetricAI platform), critical and algorithmic thinking, and academic performance (manifestation of programming aptitude) indicators were analyzed using the nonparametric Kendall Tau correlation test, and their statistical values were evaluated (Table 2).

The results calculated using the Kendall Tau correlation coefficient indicate the following logical and scientific relationships among the variables being analyzed:

1. There is a moderate positive correlation between digital literacy and the digital diagnostic environment (MindMetricAI) (τ = 0.388). This demonstrates that students with high levels of digital literacy skills are more inclined to effectively utilize the adaptive diagnostic capabilities of the MindMetricAI platform and digital learning experiences.

2. A significantly positive correlation was recorded between digital literacy and critical-algorithmic thinking (τ = 0.664). This indicates that students who have thoroughly mastered digital tools also possess highly developed skills in analyzing logical problems and critical thinking.

3. A very strong positive correlation was identified between digital literacy and academic performance (programming aptitude) (τ = 0.734). This confirms that students with advanced digital competencies achieve higher academic scores in programming courses and better results in practical code writing.

4. There is a moderate positive correlation between the digital diagnostic environment (MindMetricAI) and critical thinking (τ = 0.526). This shows that the experience of working within an automated adaptive platform is closely related to students' expression of critical and algorithmic thinking abilities.

5. A moderate positive correlation was observed between the digital diagnostic environment and academic performance (τ = 0.344). This implies that students with positive scores in the digital diagnostic system also exhibit a higher overall level of academic achievement.

6. There is a moderate positive correlation between critical thinking and academic performance (τ = 0.526), indicating that students with high critical and algorithmic thinking abilities demonstrate successful academic results in programming courses.

Empirical Results and Discussion

The results of the conducted study reveal complex interrelationships among the digital diagnostic environment (MindMetricAI platform), digital literacy, critical and algorithmic thinking, and students' academic performance (programming aptitude) within the higher education system.

The findings indicate that while digital literacy and the MindMetricAI diagnostic environment do not directly increase a student's programming aptitude, their critical and algorithmic thinking skills act as a powerful mediator, playing a decisive role in translating a student's latent programming potential into practical outcomes. In other words, cognitive indicators identified through the platform's metrics provide high accuracy in predicting the future professional aptitude of prospective IT specialists.

Initially, when evaluating the direct impact of the digital learning and diagnostic environment on students' programming performance, this relationship was found to be slightly negative or low. This demonstrates that merely using digital technologies and diagnostic platforms does not automatically enhance students' academic results; rather, the student's personal preparation and cognitive skills play a decisive role in this process. Additionally, the analysis confirmed that the academic program (major) chosen by the student is the most dominant and primary factor shaping all studied indicators, whereas demographic and geographical factors exert no significant impact.

However, when indirect effects were analyzed, digital literacy and the diagnostic indicators of the MindMetricAI platform emerged as a strong and positive mediator, accounting for a substantial portion (76.56%) of the total effect. This statistically fully proves that digital literacy balances any unfavorable or negative aspects of the digital environment, transforming it into a positive tool that leads to the student's academic and professional success.

These correlation results prove the existence of deep and meaningful relationships among the cognitive and digital factors under investigation. Once the initial correlational relationships were confirmed, the study proceeded to the stage of evaluating the mediating role of critical and algorithmic thinking in determining students' academic performance and programming aptitude within the MindMetricAI platform environment.

Digital learning has a significant impact on digital literacy with a p-value of 0.000. Furthermore, digital learning accounts for 32.91% of the variance in digital literacy among the selected students.

Conclusion

This study uncovered the dynamics among the digital diagnostic environment, digital literacy, critical-algorithmic thinking, academic performance, and programming aptitude among higher education students. The results not only confirmed the dominant role of the academic program but also demonstrated how crucial digital literacy is as a mediator in a digital learning environment, serving as a primary bridge in actualizing students' programming aptitude by mitigating the constraints of the digital environment.

In conclusion, for the early identification and development of students' programming aptitude in higher education institutions, moving away from traditional approaches, utilizing intelligent diagnostic platforms such as MindMetricAI, and fostering students' critical-algorithmic thinking hold significant pedagogical and practical importance.

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