ISBN: 978-628-96613-3-0. ISSN: 2414-6390. Digital Object Identifier: https://dx.doi.org/10.18687/LACCEI2026.1.1.1852

Thinking Shapes Learning: The Predictive Power of Cognitive Abilities in the First Year of Engineering

Valentina Ramos[1]; Antonio Franco-Crespo[2]; Iván Carrera[3]
[1,2, 3] Escuela Politécnica Nacional, Ecuador, *valentina.ramos@epn.edu.ec, antonio.franco@epn.edu.ec, ivan.carrera@epn.edu.ec*

Abstract*– This study examines the predictive relationship between cognitive abilities assessed during the university admission process—specifically mathematical, spatial, and verbal reasoning—and academic performance after the first semester of engineering education. The aim is to identify which cognitive components best forecast students' early success in STEM-related diagnostic evaluations. A correlational, ex post facto, longitudinal design was applied using institutional data from a higher education institution based in Ecuador. The dataset included 4,813 applicants who completed the Admission Aptitude Test and 248 students who later undertook disciplinary diagnostic tests in Mathematics, Physics, Chemistry, and Language after a leveling semester. Correlation and multiple regression analyses were conducted to examine associations and predictive effects. Mathematical aptitude was the strongest and most consistent predictor of diagnostic performance, particularly in Mathematics and Chemistry. Spatial aptitude showed moderate predictive power in Physics and Chemistry, whereas verbal aptitude exhibited weak or nonsignificant relationships, especially in Language. These results confirm the central role of quantitative reasoning in early engineering achievement. The study is limited to one institution and one admission cycle, restricting generalizability. Future research should explore longitudinal effects and integrate non-cognitive variables such as motivation and self-efficacy to construct more comprehensive predictive models. Findings support incorporating validated aptitude assessments into admission processes and strengthening mathematical and spatial reasoning through preparatory or remedial programs.

Keywords*-- cognitive abilities, mathematical reasoning, spatial aptitude, verbal aptitude, STEM education, engineering students, admission test, academic performance.

I. Introduction

University admission processes form part of the traditional methodology used to ensure that prospective students possess the necessary abilities—usually developed during secondary education—to successfully enter higher education. These processes may rely on the measurement of knowledge as a prerequisite for mastering more complex concepts, or on the assessment of abilities and competencies that predispose individuals to acquire new knowledge and skills [1]. In many cases, admission processes combine both elements: knowledge and aptitude.

Several authors argue that abilities are even more important than prior knowledge itself, as learning success depends on the disposition to learn. Without such predisposition, acquiring new knowledge becomes unlikely, particularly given the disparities in the quality of secondary education between public and private institutions ([2]. Among these abilities, cognitive capacities play a central role.

Cognitive Foundations of Learning in Engineering Education

Learning constitutes a key element in university education and, consequently, in the training of engineering students. In STEM disciplines, professionals are expected to visualize, manipulate, and understand artifacts [3], requiring cognitive skills that differ from those demanded by other fields. For learning to occur, it is essential to understand how cognitive elements associated with thinking—such as the ability to receive, interpret, reproduce, and coherently express information—operate.

Cognitive processes are therefore closely linked to problem-solving [4] a particularly relevant aspect of engineering education. According to [5], cognitive capacities are limited, and their characteristics directly influence individual learning processes. These capacities differ among students prior to entering university, depending on their previous preparation and the quality of secondary education received.

Some authors emphasize the importance of adequate pre-university preparation. In contrast, others argue that a solid foundation is not strictly necessary if admission measures can ensure that students possess the cognitive predisposition required for success. This aptitude can be further strengthened through remedial or leveling courses [6]. Likewise, several studies have demonstrated the importance of admission tests that assess abilities even before students enroll in preparatory programs [7], [8].

A) Predictive Relationships Between Cognitive Skills and Academic Performance

[9] explored the impact of personality traits on student performance in higher education, highlighting how factors such as motivation and self-awareness help students seek strategies to improve their academic outcomes. Among the foundational components of personality are cognitive traits, which are commonly measured through aptitude tests integrated into university admission processes [2].

There is strong evidence of the impact of cognitive skills on student performance, particularly among individuals who faced learning difficulties in secondary education and who lack comparable support structures in higher education [10]. These students often struggle to adapt to new academic demands. Moreover, cognitive differences linked to sociocultural background have been shown to influence performance in STEM programs [11].

[12] investigated the impact of mathematical and linguistic reasoning as cognitive predictors of university performance and found that verbal skills had a greater effect than mathematical ones. Similarly, [1] demonstrated that both numerical and verbal abilities significantly influence academic achievement and emphasized the need for stronger preparation in these areas during secondary education [1], [13]. [14] also concluded that mathematical and verbal skills are complementary predictors of university performance.

B) Cognitive Profiling and Educational Implications for STEM Education

University admission processes are not standardized, which complicates preparation during secondary school—especially for students from public education systems. This challenge also extends to STEM programs, including engineering [15]. Prior studies have shown the importance of a solid foundation in mathematics and science for academic success in engineering [11], [15].

[16] further identified spatial reasoning as a key component of STEM competence. Spatial thinking and training in spatial skills have a measurable impact on mathematical reasoning [16], [17], [18], [19]. Mathematics also contributes to the development of other essential abilities such as drawing, design, and problem-solving, all fundamental to engineering and STEM learning [20].

Consequently, mathematical reasoning—linked to both spatial and verbal reasoning—should be considered a critical element in university admission processes, particularly for engineering programs, as it provides a reliable indicator of future academic success.

C) Purpose of the Present Study

Existing cognitive abilities, as assessed during the university admission process, play a significant role in shaping students' subsequent academic development in higher education. Understanding these relationships is essential for informing the design of preparatory and remedial programs aimed at strengthening learning strategies and cognitive skills that support academic success. This is particularly relevant in engineering education, where the development of specific cognitive competencies underpins students' ability to engage with complex and abstract disciplinary content.

While prior research has established the importance of cognitive abilities as predictors of academic performance, the present study extends this body of knowledge by examining these relationships within a structured transition from admission to early university education. Specifically, it links admission test outcomes with post-leveling diagnostic performance, providing empirical evidence of how cognitive aptitudes are manifested following an institutional intervention designed to align and reinforce students' prior knowledge. This perspective offers a more nuanced understanding of the continuity between cognitive potential and early academic achievement in engineering education, particularly within the context of leveling programs.

Accordingly, the objective of this study is to examine the relationship between cognitive abilities—specifically mathematical, spatial, and verbal reasoning—and the academic performance of engineering students during their first year of study.

II. Method

A) Sample

The study included first-year engineering students enrolled in the leveling courses of a higher education institution based I Ecuador. The institution is a public university that offers programs in science, technology, and engineering, organized into eight faculties and twenty-three undergraduate engineering programs. Data were drawn from institutional admission records and diagnostic evaluations applied at the beginning of the first academic semester.

The admission database comprised 4,813 applicants who completed the standardized cognitive assessment used in the university admission process. This assessment evaluated three key components: mathematical reasoning, spatial reasoning, and verbal reasoning. During the first academic semester, students participated in diagnostic evaluations in four foundational subjects: Chemistry, Physics, Mathematics, and Language. Specifically, 829 students completed the Chemistry diagnostic, 836 the Physics diagnostic, 779 the Mathematics diagnostic, and 792 the Language diagnostic.

After merging all datasets and excluding incomplete cases, the final analytical sample consisted of 248 students with complete data across all variables. This consolidated dataset served as the basis for the correlation and regression analyses exploring the relationship between cognitive abilities and academic performance during the first year of engineering education.

B) Instrument

Two categories of instruments were used in this study: the Admission Aptitude Test and the Disciplinary Diagnostic Tests.

Admission Aptitude Test

The Admission Aptitude Test is the official instrument used in the institution for admission into undergraduate programs in science and engineering. It evaluates three cognitive domains — mathematical reasoning, spatial reasoning, and verbal reasoning — through 75 multiple-choice items administered in approximately 120 minutes. All items were designed and reviewed by subject-matter experts under the supervision of the Center for Continuing Education of the institution, following institutional guidelines approved by the university's Teaching Council. The item development process ensured content and comprehension validity, verifying that each question appropriately represented the intended reasoning domain and was clearly interpretable by applicants from diverse educational backgrounds.

Items were further classified according to difficulty levels (high, medium, and low), allowing the exam to capture a broad spectrum of cognitive performance. This structure aligns with the institution's objective of assessing reasoning potential rather than rote knowledge, serving as a predictive measure of students' learning capacity in engineering education.

Disciplinary Diagnostic Tests

Following admission, students completed disciplinary diagnostic examinations in four core subjects: Mathematics, Physics, Chemistry, and Language. These assessments were collaboratively designed by faculty members teaching first-year courses from the Faculty of Sciences and the Faculty of Chemistry. For the Language diagnostic, the design and validation process involved academic collaboration between the Department of Social Sciences and the Department of Basic Training. Faculty members from these departments contributed to defining the competencies assessed—such as reading comprehension, grammar, writing, and academic communication—ensuring that the instrument reflected the linguistic and communicative demands of university-level education.

Each exam consisted of approximately 30–40 multiple-choice items, administered in sessions lasting between 60 and 90 minutes. The items were developed and validated by academic committees from the corresponding departments, ensuring representativeness of key curricular contents and consistency with institutional learning outcomes. The validation process involved expert review for content and comprehension, guaranteeing that each question accurately reflected essential disciplinary competencies. Items were likewise classified by difficulty level (high, medium, and low), which allowed the diagnostics to provide nuanced information about students' baseline performance and readiness for undergraduate engineering courses.

Together, these instruments ensured both cognitive and curricular coverage, providing reliable measures of students' reasoning abilities and subject-specific foundations at the beginning of their university studies.

C) Design

This study employed a correlational and longitudinal ex post facto design, aimed at analyzing the predictive relationship between students' cognitive abilities assessed during university admission and their academic performance after the first semester of engineering education. The research was conducted within the context of the institutional admission and leveling process that precedes entry into the first year of undergraduate programs. The admission stage constituted the initial point of data collection, during which all applicants completed the Admission Aptitude Test. This standardized examination assessed mathematical, spatial, and verbal reasoning abilities, providing a measure of students' cognitive potential and serving as the official criterion for admission into the university's engineering and science programs.

Following admission, students entered a leveling semester, a preparatory phase designed to consolidate and align the disciplinary knowledge acquired during secondary education. This stage is equivalent to a pre-university or foundation program, emphasizing the reinforcement of fundamental concepts in Mathematics, Physics, Chemistry, and Language. The leveling courses were coordinated by the Vice-Rectorate for Academic Affairs and delivered by faculty members from the Faculties of Sciences, Chemistry and Agroindustry, and Social Sciences, ensuring alignment between high-school preparation and university-level expectations.

At the conclusion of the leveling semester, students participated in a series of diagnostic examinations administered in the same four disciplinary areas. These assessments measured the degree to which students had strengthened their foundational knowledge and disciplinary competencies over the semester. The diagnostic results also provided institutional feedback on students' readiness for the first year of engineering education.

By linking the results of the admission test with those of the diagnostic evaluations, the study established a comprehensive framework for examining the continuity between cognitive aptitude and academic achievement. This design allowed for the assessment of how reasoning abilities identified prior to university entry are reflected in subsequent performance after a structured period of knowledge leveling.

III. Results

A) Performance Associated with Admission and Diagnostic Results

This study is based on the results obtained from the university admission test, which assessed three types of reasoning: mathematical, spatial, and verbal. In addition, the corresponding scores of the same students were calculated for a diagnostic test administered one semester later, after completing the preparatory program prior to entering the degree program. These results, obtained once students finished the leveling period, are presented in Table 1.

TABLE I

Descriptive statistics for admission and diagnostic test scores

	Min	Max	Mean	SD
Admission total score	19	48	38.63	5.130
Mathematical reasoning	5	20	15.46	2.984
Spatial reasoning	5	15	11.80	1.861
Verbal reasoning	4	15	11.37	2.056
Mathematics diagnostic	2	19	10.48	3.462
Physics diagnostic	0	18	6.70	3.411
Chemistry diagnostic	1	12	5.37	2.118
Language diagnostic	3	12	7.52	1.749

Note: Admission test results are weighted on a 50-point scale, with 50 being the maximum possible score.

Descriptive statistics for the admission and diagnostic assessments are presented in Table 1. The results indicate that students who participated in the diagnostic stage performed relatively well on the admission test components, which were scored on a 50-point scale. The overall admission total score showed a high mean value (M = 38.63, SD = 5.13), suggesting that these students were among the strongest performers in the admission process.

Among the cognitive domains, mathematical reasoning displayed the highest mean (M = 15.46, SD = 2.98), followed by spatial reasoning (M = 11.80, SD = 1.86) and verbal reasoning (M = 11.37, SD = 2.06). These results suggest that students who reached the diagnostic phase of the program exhibited powerful quantitative reasoning abilities, consistent with the cognitive profiles typically associated with STEM-oriented disciplines.

For the disciplinary diagnostic examinations administered after the leveling semester, mean scores were lower overall and showed greater variability. Mathematics yielded the highest mean (M = 10.48, SD = 3.46), followed by Language (M = 7.52, SD = 1.75), Chemistry (M = 5.37, SD = 2.12), and Physics (M = 6.70, SD = 3.41). The larger standard deviations observed in Mathematics and Physics suggest a greater dispersion in students' performance across these subjects, reflecting more heterogeneous levels of mastery after the leveling process. In contrast, the smaller variability found in Language and Chemistry indicates more consistent results, possibly due to a narrower range of learning outcomes or to the nature of the assessments, which may have emphasized foundational rather than integrative skills.

These outcomes provide a valuable foundation for examining how students' diagnostic results align with their later academic performance and learning trajectories. The patterns observed in this stage help frame the subsequent analyses that explore the predictive relationships between cognitive aptitudes and disciplinary achievement.

B) Relationships Between Diagnostic and Admission Variables

To explore the connections between students' cognitive profiles and their academic performance after the leveling semester, Pearson correlation analyses were conducted among the admission and diagnostic variables. These correlations aimed to determine the extent to which reasoning abilities assessed during the admission process (mathematical, spatial, and verbal) were associated with subsequent disciplinary performance in Mathematics, Physics, Chemistry, and Language.

The resulting correlation coefficients are displayed in Figure 1, which presents a heatmap summarizing the strength and direction of the relationships among all variables included in the study.

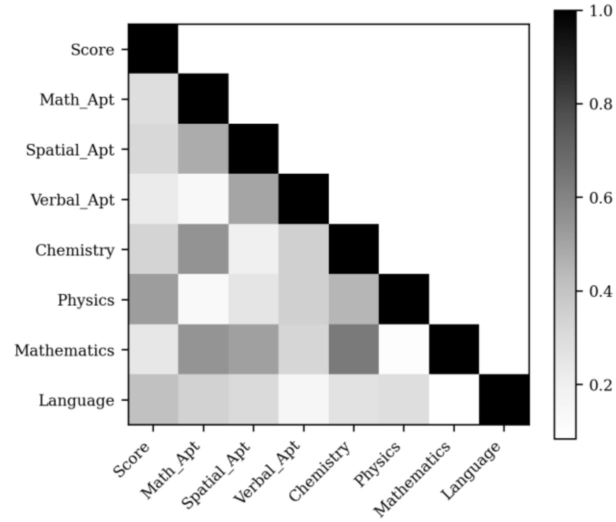

Fig. 1 Heatmap showing the relationship between cognitive components of the admission test and diagnostic performance in core subjects

The correlation analysis revealed several meaningful patterns linking admission test components with students' diagnostic performance after the leveling semester. As expected, mathematical aptitude from the admission test showed moderate to strong correlations with all diagnostic subjects, particularly with Mathematics (r = .49) and Chemistry (r = .40). These relationships indicate that quantitative reasoning skills measured during admission are reliable predictors of students' ability to succeed in disciplines that demand logical and numerical processing.

Similarly, the total admission score exhibited significant correlations with all diagnostic outcomes, with the highest coefficients observed for Mathematics (r = .44) and Chemistry (r = .44). This result reinforces the internal consistency of the admission process and suggests that the overall cognitive performance assessed prior to entry aligns with students' academic achievement after one semester of foundational instruction.

However, a particularly striking finding is the weak correlation between Verbal Aptitude and diagnostic Language performance (r = .11). This low association contrasts with expectations, as both variables would theoretically capture related dimensions of linguistic reasoning and comprehension. One possible explanation is that the verbal section of the admission test primarily evaluates verbal analogies, vocabulary, and logical verbal reasoning. In contrast, the diagnostic Language test emphasizes academic reading, grammar, and written communication. These differences in construct alignment may account for the limited overlap observed.

In contrast, Spatial Aptitude demonstrated moderate but consistent correlations with all diagnostic areas (r ≈ .29–.30), suggesting that spatial reasoning supports cognitive flexibility and problem-solving across STEM disciplines.

C) *Predictive Impact of Admission Test Components on Diagnostic Performance*

To examine the predictive capacity of cognitive abilities assessed during the admission process, multiple linear regressions were conducted using the three admission test components—mathematical, spatial, and verbal aptitude—as independent variables, and the diagnostic test results in Mathematics, Physics, Chemistry, and Language as dependent variables. Table 2 presents the standardized regression coefficients (β) and their corresponding t-values, indicating the extent to which each aptitude dimension contributes to predicting students' academic performance after the leveling semester.

TABLE II
REGRESSION COEFFICIENTS FOR ADMISSION TEST COMPONENTS PREDICTING DIAGNOSTIC PERFORMANCE ACROSS FOUR ACADEMIC AREAS

Predictor (Admission Component)	Dependent Variable	β (Standardized)	t
Mathematical Aptitude	Mathematics diagnostic	0.467	7.354*
	Physics diagnostic	0.255	3.790*
	Chemistry diagnostic	0.293	4.469*
	Language diagnostic	0.153	2.131*
Spatial Aptitude	Mathematics diagnostic	0.036	0.586
	Physics diagnostic	0.175	2.674*
	Chemistry diagnostic	0.143	2.247*
	Language diagnostic	-0.058	-0.831
Verbal Aptitude	Mathematics diagnostic	0.028	0.474
	Physics diagnostic	0.053	0.862
	Chemistry diagnostic	0.145	2.414*
	Language diagnostic	0.076	1.155

Note. Asterisks indicate statistical significance levels: $p < .05$

The regression models reveal that mathematical aptitude is the most consistent and powerful predictor of academic performance across all diagnostic subjects. Its standardized coefficients (β) range from .15 to .47, all statistically significant ($p < .05$), confirming that students with higher quantitative reasoning skills at the time of admission tend to achieve better outcomes after the leveling semester. The strongest predictive relationship was observed for Mathematics ($\beta = .47$, $t = 7.35$, $p < .001$), followed by Chemistry ($\beta = .29$, $t = 4.47$, $p < .001$) and Physics ($\beta = .26$, $t = 3.79$, $p < .001$).

Spatial aptitude also showed a positive and significant contribution to Physics ($\beta = .18$, $t = 2.67$, $p < .01$) and Chemistry ($\beta = .14$, $t = 2.25$, $p < .05$), suggesting that spatial reasoning skills support performance in subjects that involve visual and representational problem-solving. However, its predictive effect on Mathematics and Language was negligible and statistically nonsignificant.

Verbal aptitude, on the other hand, demonstrated weak or nonsignificant associations with diagnostic outcomes. Although modestly significant effects were found in Chemistry ($\beta = .15$, $t = 2.41$, $p < .05$), no meaningful predictive relationship emerged for Language ($\beta = .08$, $t = 1.16$, $p > .05$). This result contrasts with initial expectations, as verbal reasoning would theoretically align with linguistic and communication skills.

IV. DISCUSSION

The results obtained from this study revealed patterns that both align with and diverge from the theoretical framework established in the literature. Several findings confirmed previously reported relationships between cognitive abilities and academic performance in STEM education, particularly regarding the role of mathematical and spatial reasoning. However, other results—such as the unexpectedly weak relationship between verbal aptitude and linguistic performance—introduce new perspectives that invite further examination.

From a theoretical perspective, these findings can be interpreted within frameworks that conceptualize cognitive abilities as foundational components of learning and problem-solving in STEM education. Mathematical reasoning, in particular, may be understood as a domain-general cognitive resource that supports abstract thinking, symbolic manipulation, and logical structuring, all of which are essential for engineering tasks. In contrast, the weaker predictive role of verbal aptitude in early academic performance suggests that different cognitive domains may contribute at distinct stages of learning, with some abilities becoming more relevant as students engage in complex, collaborative, and communication-intensive tasks later in their academic trajectories.

The following sections discuss the main findings derived from the analyses, their theoretical implications, and their relevance for understanding the cognitive factors influencing students' transition from admission to early university success.

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A) *Mathematical Aptitude as the Strongest Predictor of Academic Performance*

One of the main findings of this study lies in the strong correlation and predictive impact of mathematical reasoning, not only in relation to other elements assessed during the admission process but also in connection with the results obtained in the diagnostic test. Mathematical reasoning emerged as the best predictor of success during the first year of engineering studies. Previous research has shown that abilities associated with mathematical reasoning are strong predictors of performance across disciplines, such as physics, as well as of the development of other skills like argumentation and the ability to solve problems in diverse contexts [21]. Similarly, [22] found that individuals with more advanced mathematical thinking are more likely to be drawn to careers in STEM fields.

B) *Limited Predictive Role of Verbal Aptitude*

Although there is evidence of the impact of verbal aptitude and its interrelation with other skills such as mathematical and spatial reasoning [22], our results indicate a limited effect of verbal aptitude on knowledge development within STEM disciplines. In line with our findings, Delaney and Devereux (2020) also reported that mathematical reasoning more strongly predicts academic performance at the university level compared to verbal abilities. However, despite the low predictive value observed in this study, prior research highlights that both mathematical and linguistic abilities contribute to predicting students' performance in higher education courses [14]. Therefore, verbal aptitude should not be excluded from educational models, as it may still play a complementary role in academic success.

However, this finding does not necessarily imply that verbal aptitude lacks relevance in engineering education. Beyond its limited predictive role in early diagnostic performance, verbal aptitude may become increasingly relevant in later stages of engineering education and professional practice. As students progress through their programs, they are expected to develop competencies related to technical writing, scientific communication, teamwork, and interdisciplinary collaboration. These skills are essential for addressing complex, real-world problems and align with the competencies required of the "Global Engineer" in the 21st century, particularly in contexts shaped by digital transformation and artificial intelligence [25], [26]. Therefore, the low predictive effect observed in this study should not be interpreted as a lack of importance, but rather as an indication that the contribution of verbal aptitude may emerge more strongly over time or in contexts that require higher-order communication and collaborative problem-solving skills.

C) *Moderate Contribution of Spatial Aptitude in STEM-Related Diagnostics*

Several studies have reported a close relationship between spatial and mathematical aptitudes [16], [17], [19], [23]. However, our research shows that the relationship between spatial and mathematical reasoning is not substantially stronger than that between verbal and mathematical reasoning. Moreover, the effect of spatial thinking development was not statistically significant as a predictor of diagnostic performance in mathematics. [24] found that the link between spatial and mathematical skills does exist but is weaker than suggested by other authors, and verbal abilities may even mediate it. Likewise, [17] demonstrated that the presence of spatial abilities does not necessarily translate into their practical application, which may explain why the expected predictive effect of spatial reasoning on mathematics diagnostic performance was not observed in this study.

V. Conclusions

This study examined the predictive relationships between cognitive aptitudes assessed in the university admission process and the diagnostic tests applied after the first semester of engineering studies. The findings reveal that mathematical aptitude stands out as the most robust predictor of early academic success, confirming the central role of quantitative reasoning in STEM education. Students with stronger mathematical reasoning skills demonstrated higher performance not only in mathematics but also across related disciplines such as physics and chemistry, supporting the idea that mathematical thinking underpins the development of higher-order problem-solving abilities and cross-disciplinary transfer.

In contrast, verbal aptitude exhibited a limited predictive role, showing weak correlations with diagnostic performance. This suggests that, although linguistic and communicative skills are essential for professional practice, their impact on early academic outcomes in engineering programs may be indirect or mediated by other cognitive domains. Nevertheless, verbal reasoning should not be disregarded in educational models, as its contribution may emerge more strongly in later academic stages or in contexts requiring interpretation and synthesis of complex information.

Spatial aptitude showed moderate but consistent associations with STEM-related diagnostic scores, particularly in chemistry and physics. These results indicate that spatial reasoning contributes to understanding and manipulating abstract representations, yet its predictive power may depend on instructional design, prior exposure, and integration with mathematical reasoning.

The findings highlight that cognitive profiles, especially those emphasizing mathematical reasoning, play a decisive role in students' transition from secondary to higher education in engineering. The results support the inclusion of validated aptitude assessments in admission processes and suggest that preparatory or remedial programs should reinforce quantitative and spatial reasoning to facilitate students' adaptation to university-level STEM learning.

A) *Limitations and Future Research Directions*

Although this study provides relevant insights into the predictive role of cognitive aptitudes in engineering education, several limitations should be acknowledged. First, the analysis was based on a single institutional context, which may limit the generalizability of the findings to other higher education systems with different admission models or curricular structures. The characteristics of the institution, including its selective admission process and emphasis on quantitative disciplines, may have influenced the relative weight of mathematical aptitude as a predictor.

Second, the study relied on data from one admission cycle and one semester of diagnostic evaluation. This temporal restriction prevents examining longitudinal effects or identifying how predictive relationships evolve throughout the degree program. Future studies could adopt a longitudinal design, following students across multiple semesters to better understand how early cognitive indicators relate to persistence, academic performance, and graduation outcomes.

Third, the measures of aptitude and diagnostic performance, while validated and standardized within the institution, were limited to quantitative test data. Although the present study focused on cognitive predictors, the analytical model could be expanded by incorporating additional variables that may influence academic performance. Factors such as motivation, self-efficacy, prior academic achievement, and socio-economic background have been shown to interact with cognitive abilities in shaping student success. The absence of these variables in the current model limits the ability to fully capture the complexity of learning processes in engineering education. Integrating qualitative or mixed-method approaches could therefore offer a more holistic understanding of student success in STEM programs.

Finally, the analysis focused primarily on traditional cognitive domains (mathematical, spatial, and verbal). Future research could explore non-cognitive and metacognitive predictors, such as problem-solving strategies, epistemic beliefs, and self-efficacy, to enrich predictive models of student achievement. Comparative studies across institutions or countries could also reveal whether the relative predictive power of these aptitudes remains consistent across different educational and cultural contexts.

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