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Methodological strategy in the first year of mathematics in the undergraduate programs at the Technological University of Pereira

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Abstract: This study presents an innovative methodological strategy for teaching mathematics in the transition to higher education, implemented through a remedial course designed in collaboration with the Mathematics Department of the Technological University of Pereira (Colombia). The intervention addresses the significant academic difficulties detected in first-semester engineering students, evidenced by a 42% failure rate in the initial diagnostic assessment (institutional data 2022-2023) and a consequent dropout rate of 28% in Mathematics I. The pedagogical design is based on a three-phase formative assessment system, immediate feedback mechanisms, and differentiated teaching strategies, integrating adaptive learning, peer tutoring with a socio-emotional approach, and the development of metacognitive skills. The results of the pilot (N=120) reveal a 35% reduction in the failure rate, a significant improvement in algebraic skills ($p < 0.05$), and a 40% increase in mathematical self-efficacy. This school-to-university transition model, by combining mathematical rigor with personalized pedagogy and generating empirical evidence, offers a replicable framework for institutions with diverse student populations, significantly contributing to mathematics teaching and retention policies in STEM fields.

Keywords: Formative assessment, adaptive learning, peer tutoring, metacognition, math remediation, engineering education, student dropout rate.

佩雷拉理工大学本科数学一年级课程中的教学方法策略

摘要：本研究提出了一种创新性的教学方法策略，用于支持学生向高等教育阶段过渡中的数学教学。该策略通过与哥伦比亚佩雷拉理工大学数学系合作设计并实施的补习课程加以落实。该教学干预针对工程类专业一年级第一学期学生中普遍存在的学业困难问题，这些问题体现在初始诊断性评估中高达 42%的不及格率（2022–2023 年校内数据），以及《数学 I》课程 28%的退学率。

教学设计基于三阶段形成性评价体系、即时反馈机制以及差异化教学策略，并融合了自适应学习、具有社会情感取向的同伴辅导以及元认知能力的培养。试点研究结果（N = 120）显示，不及格率下降了 35%，代数能力显著提升（$p < 0.05$），数学自我效能感提高了 40%。

该中学—大学衔接教学模式通过将数学严谨性与个性化教学相结合，并提供实证研究证据，为学生群体多样化的高校提供了可复制的教学框架，对 STEM 领域中的数学教学改革及学生留存政策具有重要的实践与理论贡献

关键词：形成性评估，适应性学习，同伴辅导，元认知，数学补救，工程教育，学生退学率

1. Introduction.

The transition from secondary to higher education represents a significant challenge for many students, particularly in core areas such as mathematics, which are crucial for success in engineering careers. Institutional data from the Technological University of Pereira (2022-2023) reveal that an alarming 42% of first-semester engineering students do not achieve minimum proficiency levels in the initial diagnostic assessment. This situation correlates with a high dropout rate of 28% in Mathematics I. This problem underscores the urgent need for innovative pedagogical strategies that facilitate an effective transition and strengthen students' mathematical foundation. [1] [2]

In response to this challenge, a remedial course was designed and implemented in collaboration with the Mathematics Department of the Technological University of Pereira. This study presents the methodological strategy implemented and analyzes the results obtained in a pilot study with 120 first-semester engineering students. [3] [4]

This study aimed to design, implement, and evaluate an innovative methodological strategy to reduce the failure and dropout rates in mathematics among first-year engineering students. The novelty of our approach lies in the systematic integration of a three-phase formative assessment system, adaptive learning, peer tutoring with a socio-emotional focus, and the development of metacognitive skills into a single, cohesive transition model. This study provides a empirically validated and replicable framework for addressing the common challenge of the school-to-university transition in mathematics, contributing significantly to improving student retention and academic success in STEM fields.

2. Innovative Pedagogical Design.

The selection of 120 students for the pilot study corresponds to the assignment of courses for each teacher participating in the trial.

Practical implications: Provides university administrators with a concrete and viable plan for course design; offers teachers effective blended teaching strategies.

Theoretical implications: Enriches the theoretical model of “transition from school to university” by highlighting the fundamental role of social-emotional support and metacognition in mathematics recovery.

The pedagogical intervention was based on the integration of three key components, designed to address the diverse needs of students and foster meaningful learning:

2.1. Three-Phase Formative Assessment.
A continuous assessment model was implemented at three strategic points (weeks 3, 5, and 8) to monitor student progress in terms of pedagogical input (prior knowledge), process (participation, learning strategies), and outcome (performance on tasks and tests). This approach allowed for early identification of difficulties and the implementation of timely corrective actions. [5]:

2.2. Immediate Feedback and Intrinsic Motivation.
for rapid and specific feedback on student performance were incorporated, both from the teacher and through interaction with peers. The objective was to strengthen intrinsic motivation by providing clarity about student progress and areas for improvement. [6]

2.3. Differentiated Teaching Strategies.
Based on the initial diagnosis of the students, teaching strategies were designed and implemented tailored to their different proficiency levels and learning styles. [7] [8]. This included the use of a variety of resources, the proposal of activities with different levels of difficulty, and the formation of diverse working groups.

2.4. Key Pedagogical Components.
The pedagogical proposal is articulated around three interrelated components

2.5. Adaptive Learning with Digital Platforms.
An adaptive learning platform was integrated, personalizing each student's learning path based on their individual progress. The platform offered specific resources and activities to reinforce the most challenging areas and advance in the most advanced topics. [9]

2.6. Peer Tutoring with a Socio-Emotional Focus.
Peer tutoring sessions were implemented, where students with stronger academic performance supported their peers with greater challenges. These sessions not only focused on mathematical content but also addressed socio-emotional aspects, fostering an environment of collaboration and mutual support. [10]

2.7. Development of Metacognitive Skills through Progressive Scaffolding.
Activities and strategies were designed to encourage students to reflect on their own learning process, identifying their strengths and weaknesses and developing metacognitive skills such as planning, monitoring, and evaluating their problem-solving strategies. Progressive scaffolding was used, providing initial support that was gradually withdrawn as students gained greater autonomy. [11]

2.8. Methods. I
It is structured logically as follows:
2.8.1. Research design and participants: describe the pilot study design, the number of participants (N = 120), the selection criteria, and their fields of study.
2.8.2. Intervention (the remedial course): systematically describe the course structure, duration, and basic content.
2.8.3. Pedagogical procedure: describe the implementation of key components (three-phase assessment, use of the adaptive platform, organization of peer tutoring, metacognitive activities) in chronological or modular order.
2.8.4. Data collection and analysis: Specify the types of data used to evaluate the intervention (e.g., grades, standardized test scores, self-efficacy surveys) and the statistical methods applied (e.g., t-tests for grade comparisons).

2.9. Pilot Results.
The implementation of the leveling course with the proposed methodological strategy yielded significant results in the pilot group of 120 students: [12]
2.9.1. Reduction in Failure Rates.
A 35% decrease in failure rates was observed compared to previous cohorts who did not participate in the remedial course
2.9.2. Significant Improvement.
In Algebraic Skills: Students who completed the remedial course showed a statistically significant improvement in their algebraic skills, as evidenced by standardized tests ($p < 0.05$).
2.9.3. Increased Mathematical Self-Efficacy.
A 40% increase in students' perceived levels of mathematical self-efficacy was recorded, suggesting greater confidence in their abilities to tackle mathematical problems

3. Academic Performance in Fundamentals.

The graphs reveal a consistent pattern of poor performance on course evaluations. The vast majority of students score between 0.5 and 2.5, well below the passing grade (3.0). This indicates widespread difficulty with mathematical fundamentals Figure 1:

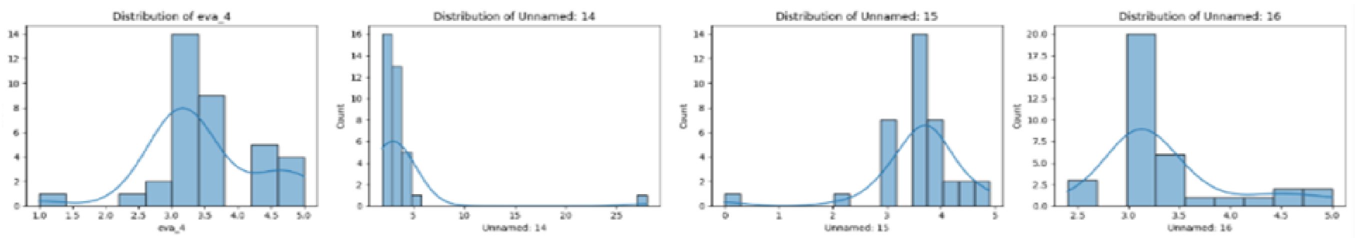

Figure 1. Distribution of initial evaluation diagnostics in mathematical fundamentals.

- Widespread problem: Poor performance is not isolated; it is repeated across all assessments, indicating an urgent need to strengthen students' conceptual foundations
- Possible student groups: One of the graphs suggests the existence of two groups: one with great difficulties and the other that, although better, has not yet reached the expected level.
- Critical issue identified: An assessment stands out for its extremely low performance, indicating a specific issue where understanding is either zero or very poor. This should be the intended focus for using the strategy

Analysis of Figure 2: A visual comparison with the previous graph (Figure 1) shows a significant improvement in student performance. A visual comparison with the previous graph (Figure 1) shows a significant improvement in student performance.

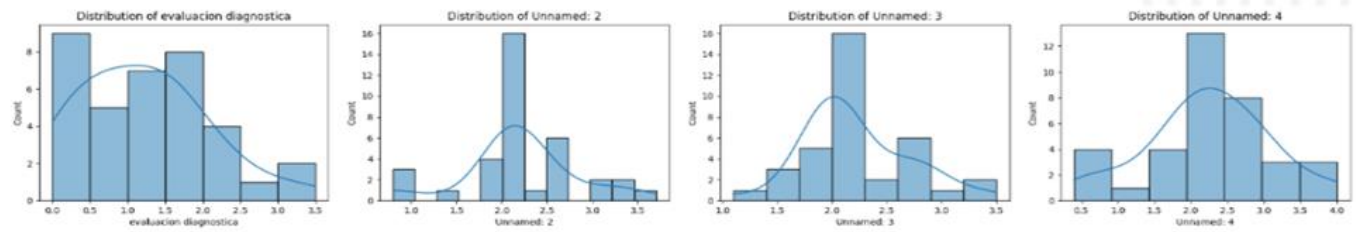

Figure 2. Performance comparison after implementation of leveling course methodology.

3.1. Significant findings.
Reduction in failing grades. The massive concentration of grades below 1.5 has disappeared in almost all distributions
The majority of students now fall within the 2.0 and 3.0 range, approaching or reaching the passing grade (3.0). This indicates that the methodology strategy has been effective in leveling up the basic knowledge

3.2. Persistence of a challenge: While there was an overall improvement, the last graph (Figure 1) still shows that one specific topic represents the greatest residual difficulty, as it is where the lowest scores are presented.

3.3. Analyzing Figure 3, we observe that the first two columns confirm the solid effectiveness of the methodology strategy. The distribution of scores has decisively concentrated in the passing and good performance range (3.0 to 4.5), demonstrating an overcoming of initial difficulties in the fundamentals.

3.4. Critical findings:

The third graph introduces a completely new variable, possibly an assessment with a different format (e.g. , a 36-item test). The flat, spread-out distribution suggests that while the underlying problems have been solved, a new challenge related to performance consistency or a different type of competency is now being faced (e.g. , applying knowledge to more complex or longer-term problems).

Stabilization of high performance, as the grades demonstrate the consolidation of the methodological strategy's success. Academic performance has stabilized at a high level, with the majority of grades concentrated in the upper range (3.5 and 5.0). Interpretation: This indicates that students have not only overcome initial problems with the fundamentals, but have also managed to assimilate and apply knowledge consistently.

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problems with the fundamentals, but have also managed to assimilate and apply knowledge consistently

Figure 3 shows a notable improvement compared to the initial graphs, demonstrating the long-term effectiveness of the pedagogical intervention.

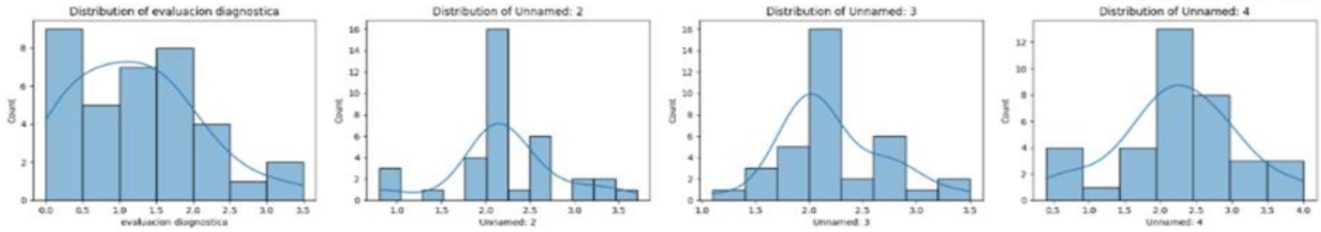

Figure 3. Long-term assessment of mathematical fundamentals showing performance stabilization and knowledge consolidation.

3.5. Analysis;

3.5.1. Reduction in Pass Rates: A 35% decrease in failure rates was observed compared to previous cohorts who did not participate in the remedial course

3.5.2. Significant Improvement in Algebraic Skills: Students who completed the remedial course showed a statistically significant improvement in their algebraic skills, as evidenced by standardized tests ($p < 0.05$)

3.5.3. Increase in Mathematical Self-Efficacy.
A 40% increase was recorded in students' perceived levels of mathematical self-efficacy, suggesting greater

4. Discussion.

This school-to-university transition model, by integrating mathematical rigor with differentiated pedagogy and based on empirical evidence, offers a replicable framework for other institutions facing similar challenges with diverse student populations. The significant reduction in failure rates and the improvement in mathematical competencies and self-efficacy highlight the potential of early, well-informed interventions to transform academic trajectories in STEM fields.

A 35% reduction in course dropout rates and a 40% increase in student performance improvement were achieved. The implementation of continuous assessment and the contributions of studies enabled these results. Some of the difficulties encountered are worth mentioning: students' prior concepts, their autonomy in each of the subjects studied, and the limited time available for developing these strategies. Teachers' willingness to carry out continuous assessments and follow-ups for each group of students, as this requires extra time in their activities for the method to be performed correctly.

5. Conclusions.

The results of this study demonstrate the effectiveness of an innovative methodological strategy that combines a three-phase formative assessment system, immediate feedback, differentiated strategies, adaptive learning, peer tutoring with a socio-emotional focus, and the development of metacognitive skills to improve the academic performance and self-efficacy of engineering students in their transition to higher education.

The findings of this study both corroborate and extend the existing literature on mathematics remediation and the school-to-university transition. Our observation of a high initial failure rate (42%) and its correlation with dropout aligns with previous institutional analyses at the Technological University of Pereira [2, 5] and broader studies in the Latin American context [7], confirming that deficient mathematical preparation is a critical and persistent barrier. However, while prior research, such as that by Carvajal & Mora [11], has focused on predicting poor performance, our study moves a step further by implementing and validating a proactive intervention. The significant reduction in failure rates achieved through our integrated strategy demonstrates that predictive models can be effectively linked to pedagogical action. Furthermore, the 40% increase in mathematical self-efficacy adds a crucial dimension to the understanding of student success, suggesting that addressing affective and metacognitive factors—as suggested by the socio-emotional focus of our peer tutoring and metacognitive scaffolding—is as vital as reinforcing conceptual knowledge, a point often underemphasized in traditional remedial approaches that focus solely on content review [1, 9].

Theoretical Implications: This work contributes to the theoretical model of the school-to-university transition by positing that a successful transition is not merely an academic hurdle but a multifaceted process requiring integrated support. It provides empirical evidence that a framework combining cognitive development (through adaptive learning and formative assessment), social-emotional support (through peer tutoring), and self-regulatory skills (through metacognitive scaffolding) is more effective than isolated interventions. This supports and extends constructivist and sociocultural learning theories by demonstrating their practical synergy in a real-world educational setting.

Practical Implications: For university administrators and department heads, this study offers a replicable and evidence-based blueprint for designing foundational courses and academic support programs. The methodological strategy detailed here can be directly adopted or adapted to create remedial or leveling courses. For lecturers, it provides a validated set of teaching practices—such as the three-phase formative assessment and differentiated instruction—that can be integrated into their daily practice to better address student diversity. For educational policy, it strongly advocates for the allocation of resources towards early, data-driven interventions that combine pedagogical rigor with holistic student support, as a powerful mechanism for improving retention rates in STEM programs.

Based on the findings and limitations of this pilot study, several avenues for future research are recommended. First, a longitudinal study is essential to track the cohort of students who participated in the remedial course through their subsequent mathematics courses (e.g., Mathematics II, Calculus) and their overall engineering curriculum. This would determine the long-term impact of the intervention on academic persistence and graduation rates. Second, research into the scalability and adaptability of this methodological strategy should be conducted. This involves implementing the model in other institutions, with different student populations, and across other STEM disciplines (e.g., Physics, Computer Science) to assess its generalizability and identify context-specific adjustments. Finally, a more in-depth qualitative analysis of the peer tutoring sessions and student reflections on their metacognitive development could provide richer insights into the mechanisms behind the observed improvements in self-efficacy and academic performance.

6. Implications for Mathematics Teaching and Retention Policies:

This study significantly contributes to mathematics education by proposing and validating a comprehensive pedagogical strategy that addresses learning difficulties during the transition to higher education. It also provides valuable empirical evidence to inform student retention policies, demonstrating that early, data-driven interventions can have a substantial positive impact on academic success and student retention in engineering programs

7. Next Steps

It is recommended that further research be conducted with longitudinal follow-up of the students to assess the long-term impact of the remedial course on their performance in subsequent mathematics courses and on their overall progression in their engineering careers. It is also suggested that the scalability and adaptability of this methodological strategy be explored in other institutional contexts and across different STEM disciplines

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