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Analysis of demographic and academic factors influencing mathematical achievement in a Peruvian university competition

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ABSTRACT

This exploratory quantitative study analyzed mathematical achievement among 211 university students participating in the first interfaculty mathematics competition at a private Peruvian university. Using structural equation modeling, mathematical achievement was specified as a latent construct measured by performance in algebra, geometry, number theory, and combinatorics. The model evaluated the effects of gender, age, field of study, motivation, and prior experience in mathematics competitions. Results indicate that prior participation in mathematics competitions and gender significantly predicted achievement, while age, academic discipline, and motivation showed no significant effects. Male students and those with prior contest experience obtained significantly higher scores. The findings highlight the educational value of mathematics competitions, while also revealing persistent gender disparities. Due to the non-random, self-selected sample and the exploratory fit indices of the structural model, the results should be interpreted as associative rather than causal.

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1. INTRODUCTION

The approach to mathematics education has evolved in recent years, emphasizing the development of applicable skills for real-world problem solving [1]–[3]. Within this context, mathematical achievement refers to students' ability to understand, apply, and integrate mathematical concepts, influenced by cognitive, behavioral, and affective factors [4], [5]. Mathematical achievement plays a central role not only in engineering and physical sciences but also in social sciences, health sciences, and business, where quantitative reasoning supports informed decision-making and critical thinking [1], [6]–[8].

Despite its relevance, empirical research on the factors influencing mathematical achievement at the university level remains limited, particularly among students from diverse academic backgrounds [9]. In Peru, evidence suggests that many university students struggle to transfer procedural knowledge to problem-solving contexts. This difficulty reveals gaps between formal instruction and applied mathematical reasoning.

Mathematics competitions have gained attention as educational environments that promote engagement, motivation, and creative problem solving [10], [11]. Although typically extracurricular, these competitions allow students to practice mathematics without grading pressure and to develop positive attitudes toward the discipline [9], [10], [11]. As a result, they offer a valuable context for examining mathematical performance beyond traditional classroom assessments.

At the international level, mathematics competitions have evolved into structured assessment environments guided by implicit syllabi that emphasize reasoning and problem structure over routine computation [10]. While some competitions focus on advanced topics such as linear algebra or analysis, others prioritize transversal areas—algebra, geometry, number theory, and combinatorics—to ensure broader participation across academic disciplines [11]–[13]. These domains enable the evaluation of mathematical achievement independently of students' formal curricula.

Despite growing international research on mathematics competitions and academic achievement, empirical evidence from Peruvian higher education remains extremely limited. Most studies in Peru focus on school-level performance or teaching practices, with little attention to university competitions as a context for assessing transversal mathematical achievement. This study directly addresses this gap through an empirical structural equation analysis of competition performance across multiple academic disciplines.

Previous research identifies variables such as gender and motivation as relevant predictors of mathematical achievement [8], [14]. However, findings related to academic discipline and prior competition experience remain inconsistent [15]. To examine these relationships simultaneously and account for latent constructs, structural equation modeling offers a suitable analytical framework.

Accordingly, this study analyzes mathematical achievement in the context of the first interfaculty mathematics competition held at Universidad Católica de Santa María, Peru, in May 2023. Using structural equation modeling, mathematical achievement is specified as a latent construct measured through performance in algebra, geometry, number theory, and combinatorics. The model evaluates the effects of gender, age, field of study, motivation, and prior participation in mathematics competitions among students from multiple academic disciplines.

This study provides novel empirical evidence on university-level mathematics competitions in Peru. It models mathematical achievement as a latent construct and examines its associations with demographic and experiential factors. In doing so, it contributes to the limited body of research on higher education mathematics assessment in the Peruvian and Latin American contexts.

2. MATHEMATICS COMPETITIONS AND MATHEMATICS ACHIEVEMENT

Mathematics competitions emerged in the 19th century in response to the increasing specialization of mathematics, which restricted access for younger students [10]. These competitions offered challenging, non-routine problems that extended learning beyond the classroom and allowed students to demonstrate mathematical abilities across domains. By emphasizing problem solving, competitions promote creativity, interdisciplinary thinking, and a deeper understanding of the relevance of mathematics in diverse contexts [10], [11]. They also contribute to more positive attitudes toward mathematics and greater student engagement.

Worldwide, several organizations support the development of mathematical problem-solving skills through competitions such as the Mathematical Olympiad, the Putnam Competition, and the American Mathematics Competitions [13]. The Putnam Competition, established in 1927, is a leading university-level examination covering topics including linear algebra, modern algebra, analysis, and number theory. Similarly, the International Mathematics Competition (IMC) and the Iberoamerican Interuniversity Mathematics Competition (CIIM) challenge students internationally in algebra, combinatorics, analysis, and geometry [10].

In Peru, the main initiatives include the Concurso Nacional de Matemáticas (CONAMAT), founded in 1998, and the Olimpiada Nacional Escolar de Matemáticas (ONEM), launched in 2016. However, university-level mathematics competitions remain scarce, and student interest in mathematics has declined, reflecting global trends [16]. Competitions such as the one analyzed in this study may help stimulate mathematical curiosity and counter negative perceptions of mathematics [14].

To evaluate mathematical achievement in Universidad Católica de Santa María's first mathematics competition—one of the few university-level contests in Peru—it was essential to design tasks that assessed transversal mathematical skills. This approach aimed at ensuring inclusivity and equal opportunity. It also sought to promote broad participation across academic fields.

2.1. Mathematics achievement measure

Although mathematics has traditionally been associated with engineering and natural sciences, it is now recognized as a transversal competence relevant to humanities and social sciences. This shift requires assessment approaches capable of capturing mathematical achievement across diverse academic disciplines [4], [5]. Selecting appropriate content is therefore critical to ensure fair evaluation and comparable participation among students from different fields of study [12].

The development of mathematics competitions worldwide has led to an implicit syllabus that emphasizes structural reasoning over routine calculation [10]. As a result, domains such as algebra, geometry, number theory, and combinatorics have become standard indicators of mathematical ability [10], [11]. These areas capture fundamental aspects of mathematical knowledge and problem-solving and are suitable for assessing mathematical achievement independently of disciplinary background. Accordingly, they guided the design of the competition exam used in this study.

2.2. Factors associated with mathematical achievement

Mathematical achievement is influenced by multiple cognitive, demographic, and experiential factors, although empirical evidence at the university level remains limited [9]. Prior research suggests that students' ability to understand and apply mathematical concepts in problem-solving contexts is shaped by individual characteristics and learning experiences [4], [5]. Based on this literature, the present study considers gender, age, field of study, prior participation in mathematics competitions, and motivation as potential factors associated with mathematical achievement [7], [8].

Gender differences in mathematical achievement have been consistently reported in international research, often favoring male students [17]‒[19]. These differences have been linked to disparities in self-efficacy and access to learning opportunities. They have also been associated with sociocultural stereotypes that may discourage sustained engagement in mathematics among female students [20].

Prior participation in mathematics competitions has been associated with higher levels of mathematical performance and more positive attitudes toward mathematics [1], [10], [12]. Competitive problem-solving environments promote inquiry-based learning and strategic thinking. They also foster creativity, which may contribute to improved performance in subsequent mathematical tasks [21].

Motivation is also recognized as an important predictor of mathematical performance, especially intrinsic motivation, which is associated with greater engagement and persistence in learning activities [1], [8], [22]. Although motivation was assessed in this study using a single-item measure, its inclusion allows for an exploratory examination of students' engagement with the competition. Finally, age and field of study were included to account for potential differences related to academic progression and disciplinary background.

3. METHOD

This study followed an exploratory quantitative research design. Data were collected during the first interfaculty mathematics competition organized by Universidad Católica de Santa María, held in May 2023. The contest was open to all undergraduate students, regardless of academic discipline, age, or semester of study. Participation was voluntary, and the event was promoted through institutional email, faculty announcements, social media, and advertising panels within the university. The objectives of the contest were threefold: i) to assess students' mathematical achievement; ii) to explore demographic and experiential factors associated with mathematical achievement; and iii) to examine the educational value of university-level mathematics competitions as assessment contexts.

3.1. Data collection instrument

Mathematical achievement was assessed through a written examination covering four transversal domains: algebra, geometry, number theory, and combinatorics. These areas are commonly used in international mathematics competitions and are considered suitable for evaluating mathematical achievement across diverse academic backgrounds [10], [11]. The exam consisted of eight multiple-choice questions, with two questions per domain, administered in a one-hour, in-person session. Each question had five response options, yielding a total score range from 0 to 8.

The questions were adapted from existing competition problems or specifically designed by a panel of three Universidad Católica de Santa María mathematics professors to ensure appropriate content coverage and difficulty level. Given the large-scale and inclusive nature of the contest, answer sheets were completed using pen-and-paper mark-sense forms. These forms were subsequently processed through computer-based scoring, following established recommendations for mass mathematics competitions [10].

The contest followed a two-stage structure. In the first stage, all registered participants completed the multiple-choice exam. In the second stage, the 50 students with the highest scores advanced to a final round, which included five open-ended questions covering the same domains but at a higher level of difficulty. The second-stage results were used for ranking purposes and were not included in the structural equation analysis.

In addition to the mathematical achievement exam, participants provided demographic information (gender, age, and field of study) and experiential data (prior participation in mathematics competitions and motivation for participation). Motivation was assessed through a single self-reported categorical item in which students selected their primary reason for participating (e.g., interest in mathematics, self-improvement, teacher encouragement, and monetary reward). Motivation was measured using a single self-reported categorical item rather than a validated multi-item scale, which may have reduced its explanatory power in the structural model. This measure was included for exploratory purposes only. The data collected were used to test the theoretical model presented in Figure 1.

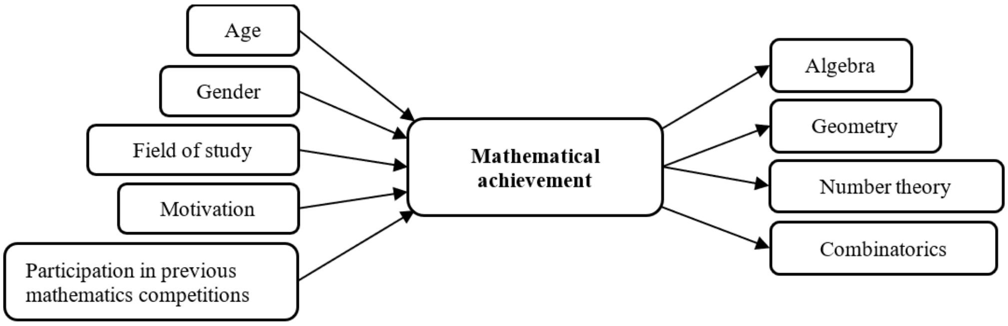

Figure 1. Research model

3.2. Participants

The mathematics competition was open to the entire Universidad Católica de Santa María student population, which exceeds 20,000 students. Despite broad dissemination efforts, only 211 students registered and participated in the first stage of the contest. This sample represents a highly self-selected group of students with pre-existing interest in mathematics, which limits the generalizability of the findings beyond the study context.

The first stage of the contest took place on May 13, 2023. All 211 participants completed the one-hour examination consisting of eight multiple-choice questions. Participants came from a wide range of academic disciplines, including sciences and engineering, health sciences, social sciences, and legal and business sciences. The distribution by field of study and gender is presented in Table 1.

Table 1. Distribution of participants of the first mathematics competition

Field of study	Gender		
	Male	Female	Total
Sciences and engineering	84	37	121
Social sciences	5	8	13
Legal and business sciences	8	9	17
Health Sciences	23	37	60
Total	120	91	211

The second stage was conducted on May 27, 2023, and included the 50 highest-scoring students from the first round. This group represented diverse academic backgrounds, reinforcing the transversal nature of the selected mathematical domains. Descriptive statistical analyses were performed using IBM SPSS Statistics Version 27. Structural equation modeling was conducted using IBM SPSS AMOS Graphics Version 23.

3.3. Validity and reliability

Content validity of the examination was ensured through expert review by three mathematics professors, who evaluated the clarity, relevance, and difficulty level of each question. The four selected domains—algebra, geometry, number theory, and combinatorics—are widely recognized as valid indicators of mathematical achievement across academic disciplines [10], [11]. Although internal consistency reliability could not be estimated at the item level due to the contest format, content validity was supported through expert validation and balanced coverage of the four mathematical domains. Construct validity was further supported through structural equation modeling.

4. RESULTS

Figure 2 presents the distribution of scores obtained by the 211 participants in the mathematics competition. The Kolmogorov–Smirnov test indicated that the score distribution deviated from normality ($p<0.05$), which justified the use of non-parametric analyses and informed the estimation strategy adopted for the structural equation modeling. The mean score was 4.65 on a scale from 0 to 8, with a standard deviation of 2.18, indicating moderate overall performance and substantial variability among participants.

4.1. Structural equation model

Given the non-normal distribution of scores and the unequal group sizes across fields of study (Table 1), the structural model presented in Figure 1 was estimated using the generalized least squares (GLS) method. GLS is appropriate under conditions of heteroscedasticity and unbalanced samples. This is particularly the case in stratified populations where some groups contain relatively few observations.

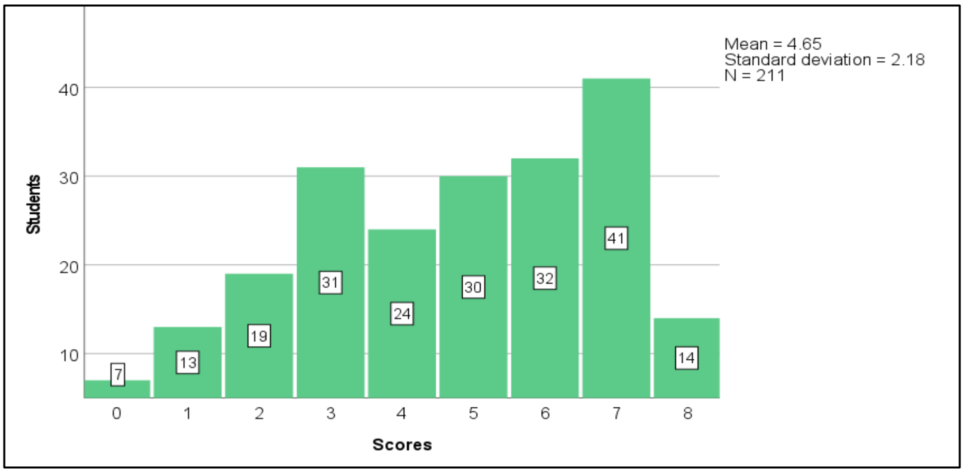

Figure 2. Scores of students

Model fit was assessed using the chi-square ratio (CMIN/DF), the comparative fit index (CFI), and the root mean square error of approximation (RMSEA). The initial model in Figure 3 showed mixed fit results. The CMIN/DF value (1.935) and RMSEA (0.067) met commonly accepted criteria for reasonable fit (CMIN/DF<3; RMSEA<0.08). However, the CFI was 0.638, well below the conventional thresholds of 0.90–0.95, indicating poor comparative fit [23]. Although cutoff values should be interpreted with caution depending on model complexity and sample characteristics [24], a CFI of this magnitude suggests substantial model misspecification.

Table 2 shows that only gender and prior participation in mathematics competitions were significantly associated with mathematical achievement. In contrast, age and field of study did not reach statistical significance. Motivation was also not significantly associated with mathematical achievement.

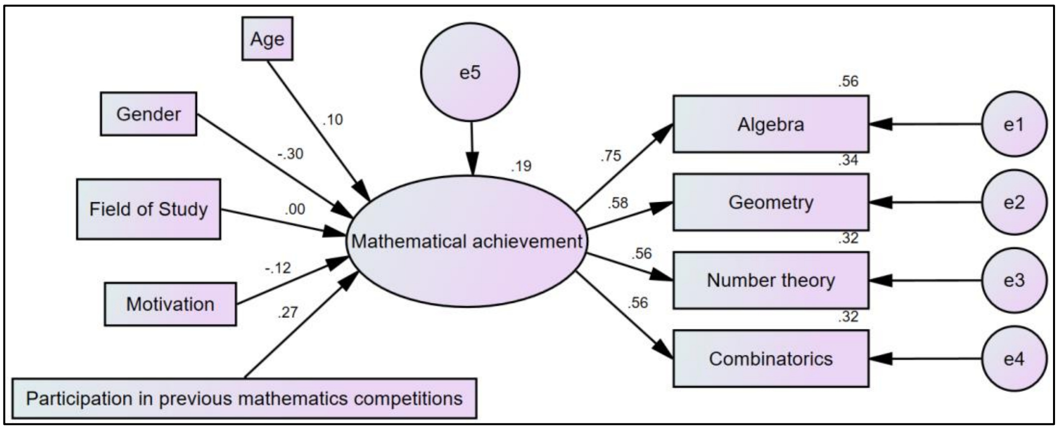

Figure 3. First structural equation model

Table 2. Structural regression weights of predictors on mathematical achievement

Variable	Standardized regression weights	p-value
Gender	-0.300	<0.001
Participation in previous mathematics competitions	0.272	<0.001
Age	0.103	0.192
Field of study	0.001	0.994
Motivation	-0.125	0.113

The lack of significant effects for age and field of study may be attributed to the transversal nature of the selected assessment domains—algebra, geometry, number theory, and combinatorics. These domains are designed to evaluate mathematical achievement independently of students' curricular specialization or academic progression [10], [12]. This interpretation is further supported by the stability of participant proportions across academic areas between the first and second phases of the contest as in Table 3, suggesting comparable opportunities for advancement across disciplines.

Motivation, although theoretically relevant to mathematical achievement [8], was also non-significant. Therefore, it was excluded from the final model. This result is addressed in the discussion section, particularly in light of the methodological limitations associated with its measurement. Consequently, the final model retained only gender and prior participation in mathematics competitions as predictors of mathematical achievement, as in Figure 4. The revised model exhibited improved fit indices, with CMIN/DF=2.201 and RMSEA=0.076, both within acceptable limits, and a CFI of 0.829. Although this value reflects a substantial improvement over the initial model, it remains below the conventional 0.90 threshold, suggesting that the model fit should be interpreted with caution [23], [24].

Among the four domains used to measure mathematical achievement, algebra exhibited the strongest loading on the latent mathematical achievement construct. This may reflect either greater conceptual centrality or higher discriminatory power of the algebra items. In contrast, geometry, number theory, and combinatorics showed similar standardized loadings, ranging from 0.57 to 0.58.

Table 3. Percentage of participants per area in the first and second stages

Field of study	First stage		Second stage	
	N	Percentage	N	Percentage
Sciences and engineering	121	57.35%	28	56.00%
Social sciences	13	6.16%	4	8.00%
Legal and business sciences	17	8.06%	5	10.00%
Health Sciences	60	28.44%	13	26.00%
Total	211	100.00%	50	100.00%

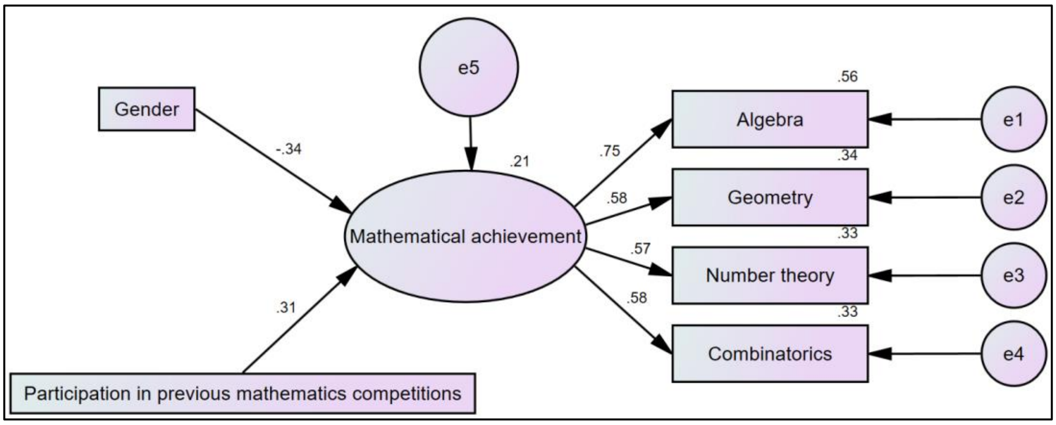

Figure 4. Final structural equation model for mathematical achievement

4.2. Comparison by gender and prior experience in mathematics competitions

Gender differences in mathematical achievement were examined using the Kruskal–Wallis test due to score non-normality. Descriptive statistics are presented in Table 4. This analysis provides a nonparametric comparison between gender groups. The Kruskal–Wallis test indicated a statistically significant difference between male and female students ($H=17.150$, $p<0.001$). The corresponding effect size was moderate ($r=0.29$), and the standardized mean difference further indicated a moderate-to-large effect (Cohen's $d=0.61$). Male students obtained higher mean scores across all four domains as in Table 5, and the top three contest performers were male.

These findings are consistent with prior evidence of gender disparities in mathematics performance [16]. While Peru has shown notable improvements in educational gender parity, persistent gaps in mathematical achievement remain, particularly in competitive and high-performance contexts. Previous studies suggest that differences in confidence, anxiety, and willingness to engage in competitive environments may partially explain this pattern [18], [25], alongside structural factors such as gender bias in educational materials [17].

Table 4. Scores comparison by gender

Gender	N	Mean	Standard deviation
Male	120	5.20	2.03
Female	91	3.92	2.17

Table 5. Scores comparison by gender and topics of evaluation

Gender	Algebra		Geometry		Number theory		Combinatorics	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Male	1.44	0.73	1.51	0.71	1.27	0.73	0.98	0.77
Female	1.13	0.81	1.33	0.76	0.80	0.70	0.66	0.73

Performance differences based on prior participation in mathematics competitions are summarized in Table 6. Students with prior contest experience achieved significantly higher mathematical achievement scores ($H=17.096$, $p<0.001$). The effect size was moderate ($r=0.28$), and the standardized mean difference indicated a moderate-to-large effect (Cohen's $d=0.62$).

As shown in Table 7, these students outperformed their peers across all four mathematical domains. Their representation increased substantially from the first phase of the contest (27.50%). It rose to 52.00% in the final phase, reinforcing the robustness of this association. Overall, these results underscore the role of prior exposure to competitive mathematical environments in enhancing mathematical achievement. This effect is likely mediated by increased familiarity with problem-solving strategies. It may also be influenced by improved performance under pressure [10], [11], [12].

Table 6. Scores comparison by previous mathematics competition experience

Participation in previous mathematics competition	N	Mean	Standard deviation
Yes	58	5.60	2.14
No	153	4.29	2.09

Table 7. Scores comparison by previous mathematics competition experience and topics of evaluation

Participation in previous mathematics competition	Algebra		Geometry		Number theory		Combinatorics	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Yes	1.59	0.68	1.57	0.70	1.33	0.78	1.12	0.80
No	1.20	0.79	1.38	0.74	0.97	0.72	0.74	0.73

5. DISCUSSION

The structural equation model yielded several relevant insights into the factors associated with mathematical achievement as assessed through algebra, geometry, number theory, and combinatorics. No significant relationships were observed between mathematical achievement and students' field of study, age, or motivation. The non-significance of motivation should be interpreted with caution, as motivation was measured using a single self-reported categorical item rather than a validated multi-item scale, which may have reduced its explanatory power within the structural model. Overall, these findings suggest that contest performance was more strongly associated with experiential and psychological factors than with basic demographic characteristics.

The strong effect of prior competition experience supports learning transfer and deliberate practice theories. These frameworks emphasize that repeated exposure to high-level problem-solving environments strengthens domain-specific cognitive schemas. From this perspective, mathematics competitions function not only as assessment tools but also as formative contexts that consolidate advanced mathematical reasoning through sustained practice.

5.1. Variables not related to mathematical achievement: age, field of study, and motivation

The absence of significant effects of age and field of study indicates that the contest tasks effectively captured transversal mathematical competencies that are not strongly dependent on disciplinary background or academic progression. This result aligns with prior studies showing that algebra, geometry, number theory, and combinatorics can serve as general indicators of mathematical achievement across diverse student populations

[10], [12]. The careful design and expert validation of the contest items contributed to a balanced assessment that provided comparable opportunities for students from different academic areas.

Regarding motivation, the lack of a significant association contrasts with previous research reporting positive links between motivation and mathematical achievement [8]. As noted, this discrepancy is likely related to the simplified measurement approach adopted in this study. Additionally, the relatively low participation rate may reflect broader disengagement from mathematics, often associated with prior educational experiences dominated by routine and procedural instruction [10]. These findings highlight the need for improved motivational measurement and engagement strategies in future research.

5.2. Variables related to mathematical achievement: gender and prior participation in mathematics competitions

Gender and prior participation in mathematics competitions emerged as significant predictors of mathematical achievement. The consistent outperformance of male students across the evaluated domains reflects a persistent gender gap in mathematical achievement. This finding is in line with evidence from international assessments such as Programme for International Student Assessment (PISA) [18].

From a psychological perspective, the observed gender gap may reflect differential self-efficacy beliefs, stereotype threat, and early socialization patterns. These factors continue to affect competitive mathematical performance at the university level [17], [18]. Competitive assessment contexts may intensify these mechanisms, influencing confidence, risk-taking, and persistence, particularly among female students.

Prior participation in mathematics competitions showed a strong positive association with mathematical achievement. This result supports learning transfer and deliberate practice theories, which emphasize that repeated exposure to high-level problem-solving environments strengthens domain-specific cognitive schemas and enhances performance [10], [11], [12], [14]. Mathematics competitions thus operate not only as evaluative settings but also as formative environments that promote sustained engagement with complex mathematical tasks [26].

6. CONCLUSION

This study analyzed mathematical achievement among 211 university students from different academic fields who participated in the first mathematics competition at a private Peruvian university. Although participation was limited, the event provided relevant evidence on students' performance in a competitive, extracurricular context. It also highlighted the need to strengthen engagement with mathematical problem solving in higher education.

Mathematical achievement was assessed through transversal domains—algebra, geometry, number theory, and combinatorics—selected for their applicability across disciplines. Using structural equation modeling and nonparametric analyses, the results showed that gender and prior participation in mathematics competitions significantly influenced performance. Male students and those with previous contest experience obtained higher scores, underscoring the educational value of mathematics competitions as environments that promote advanced reasoning and learning transfer. These results also reveal persistent gender disparities in competitive mathematical performance, suggesting the need for institutional strategies that address both skill development and psychological factors affecting participation and confidence.

This study is subject to several limitations. First, participation in the mathematics competition was voluntary, resulting in a self-selected sample that likely overrepresents students with strong prior interest in mathematics. Second, motivation was measured using a single categorical item rather than a validated multi-item scale, which may have reduced its explanatory power. Third, although the exam content was expert-validated, item-level reliability could not be statistically estimated due to the contest format. Fourth, the structural equation model showed borderline fit based on the CFI, indicating that the results should be interpreted cautiously and not as causal effects. Despite these limitations, the findings have clear implications for higher education practice. Universities should institutionalize mathematics competitions as formal enrichment strategies, particularly targeting female participation through mentoring, preparatory workshops, and confidence-building interventions. Future research should incorporate validated motivational measures, include multiple institutions, and explore links between formal coursework and competition performance to better understand mathematical achievement in higher education.

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AUTHOR CONTRIBUTIONS STATEMENT

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Edgar Marin-Ballon	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓
Fiorella Romero-Gomez	✓		✓			✓	✓		✓	✓	✓	✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [EM-B]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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