

Mathematics anxiety and problem-solving ability in numerical methods courses: A repeated cross-sectional study across two Southeast Asian universities

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Abstract

Mathematics anxiety (MA) impedes mathematical learning by taxing cognitive resources, negatively affecting problem-solving ability (PSA). Some evidence suggests that the strength and nature of this negative association may vary across educational and cultural contexts. However, cross-cultural studies on MA and PSA, especially in Southeast Asia, remain limited. This study investigated cohort-level patterns of MA and PSA in a transnational Numerical Methods course at Universiti Tun Hussein Onn Malaysia (UTHM) and Universitas Pahlawan (UP), Indonesia. The study spanned four independent cohorts from 2021 to 2024 and focused on institutional differences and temporal variation during a period of instructional transition. Using a repeated cross-sectional design, a total of 139 undergraduate students across four independent cohorts (UTHM: $n=23$; UP: $n=116$) were assessed during the 2021–2024 academic years using the Mathematics Anxiety Rating Scale and standardized problem-solving tests. Two-way factorial ANOVA examined the effects of university and cohort year on MA and PSA, and Pearson correlation analysis examined the association between the two constructs. A significant main effect of university indicated that UP students reported higher MA and lower PSA scores than UTHM students ($p < 0.001$). Significant year effects were observed for MA and PSA scores across successive cohorts ($p \leq 0.01$), during a period characterized by a transition in instructional modalities from online to hybrid learning. Significant University $\times$ Year interactions indicated differing trends by institution. A moderate negative correlation between MA and PSA was observed ($r = -0.49$, $p < 0.001$).

Keywords:

Higher education, Mathematics anxiety, Numerical methods, Problem-solving ability, Repeated cross-sectional study

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1. INTRODUCTION

Mathematics forms the basis of higher studies and contributes significantly to one's success at the university level. It is also a foundational discipline in higher education and essential for success across many academic and professional domains. However, previous studies reported it as the most anxiety-provoking subject (Ashcraft, 2002; Ramirez et al., 2016). Mathematics Anxiety (MA), a psychological phenomenon characterized by tension and apprehension related to math tasks, remains a significant barrier to learning (Carey et al., 2017; Hendriana et al., 2026; Xiang et al., 2026). MA has been studied extensively over decades, with evidence consistently linking it to cognitive and affective barriers in learning (Diponegoro et al., 2024; Dowker et al., 2016; Listiawati et al., 2025). MA negatively impacts working memory capacity, reduces confidence, and fosters avoidance behaviors, consequently lowering mathematical performance and problem-solving ability (Delima et al., 2024; Maloney & Beilock, 2012; Schoenfeld, 1982).

Theoretical frameworks for understanding MA generally cluster into three perspectives. Cognitive theories highlight how anxiety consumes working memory resources, limiting the capacity to process mathematical information effectively (Ashcraft & Kirk, 2001). MA is associated with avoidance behaviors and reduced mathematical performance, a pattern observed across diverse student populations (Maloney & Beilock, 2012). Affective-motivational theories focus on self-efficacy, motivation, and attribution beliefs as key mediators of anxiety responses (Bandura, 1997; Pajares & Miller, 1994). In addition, sociocultural perspectives emphasize the role of classroom environments, cultural norms, and educational traditions in shaping observed differences in mathematics anxiety (Beilock et al., 2010; Gutierrez, 2002). These models collectively explain why MA can be both a personal and culturally situated experience.

In this context, problem-solving ability (PSA), defined as the application of mathematical concepts to new and complex tasks, is closely tied to competencies in related areas (Jonassen, 2010). The ability to solve problems was considered the hallmark of mathematical competence (Jonassen, 2017). It required more than mere procedural fluency, including conceptual understanding, logical reasoning, and ability to apply knowledge in a new situation (Ashcraft, 2002; Ramirez et al., 2016; Schoenfeld, 1982). Prior studies have reported that PSA was influenced by cognitive dimensions (e.g., prior knowledge, metacognition), affective motivation and anxiety (Ahmed, 2018). High levels of MA impaired PSA because problem-solving activities triggered anxious thoughts, which interrupted attentional focus, and reduced persistence on challenging tasks due to increased avoidance behavior (Beilock & Willingham, 2014). Furthermore, cross-cultural studies showed that educational traditions significantly influenced the development of PSA. High levels of MA tend to interfere with PSA, resulting in a vicious cycle where performance declines, further increasing anxiety (Wigfield & Eccles, 1989). In addition, this has made the relationship between the two variables important for any intervention to work. PSA in mathematics includes conceptual understanding, logical reasoning, and the application of knowledge to novel situations (Jonassen, 2010; Schoenfeld, 2017). Importantly, MA and PSA are reciprocally related: heightened anxiety can disrupt focus and persistence during problem

solving process, while frequent difficulties exacerbate anxiety, creating a negative feedback loop that hinders learning progress (Ramirez et al., 2018).

In the case of Indonesia, the educational approach lacked cohesion and was applied within the context of greater decentralization, regional variety, and uneven budgetary frameworks. Universitas Pahlawan (UP) is a private developing school, with tighter community connections, strong academic support, and rapid growth. It was due to the difficulties such as inadequate technological resources, divergent regional practices, and a greater focus on teacher-led learning encountered in the educational context. In many areas, rote learning persists and is often a barrier to developing problem solving skills. Additionally, a correlation has been established between rigid pedagogy, high-stakes examinations, and limited support systems in students with relatively high MA (Chen et al., 2023).

In contrast, Universiti Tun Hussein Onn Malaysia (UTHM) represents a more established public technical university within Malaysia's comparatively centralized higher education system, with broader access to institutional resources and technological infrastructure. This contrast between UTHM and UP provides a meaningful comparative context for examining how institutional resources and educational environments may shape mathematics learning experiences over time.

Institutional and educational contexts may differ between the participating universities in terms of resource availability, curriculum implementation, and learning support. However, these contextual variables were not directly measured in the present study and therefore cannot be used to explain observed institutional differences.

Several Western studies had been conducted on MA, although less was known about the longitudinal development of cultural and instructional influences in Southeast Asia. This gap was addressed by reviewing how university origin (Malaysia versus Indonesia), and temporal changes in instructional conditions (2021-2024) interacted to influence changes in MA and PSA over time. The education system in Malaysia focused on examination results, bilingualism, and prescribed pedagogy, alongside the use of e-learning. However, Indonesia encountered certain problems, including large class sizes, different regional practices, and rote learning reliance. These systemic differences influenced ways of understanding MA and managing problem-solving in a supportive manner.

Institutional and contextual factors may contribute to observed differences between participating groups in Southeast Asia, a region characterized by diverse educational systems and cultural contexts. Despite cultural and linguistic similarities, Malaysia and Indonesia, differ in educational governance structures, resource distribution, and implementation of instructional policies, which may influence students' learning experiences (OECD, 2024; Padilla-Valdez, 2019). Such contrasts offer a valuable context for comparative study to better understand how cultural and institutional factors influence mathematics learning outcomes.

The COVID-19 pandemic prompted rapid change in higher education delivery, from emergency online instruction to hybrid and face-to-face arrangements, with immediate online offerings in 2020-2021 and progressive hybrid instruction during phase-in between 2022 and 2024. This 4-year duration offered a rare opportunity to observe how students from various cultures and institutional settings adjusted to the changing teaching modes over time. The present study explored how these scope and sequence patterns intersected with cultural

contexts to clarify the resilience and potential vulnerabilities of students in transnational mathematics classrooms.

This study focuses on students enrolled in a Numerical Methods course conducted as part of a transnational academic collaboration between UP, Indonesia, and UTHM, Malaysia. Over four consecutive academic years (2021–2024), students from both institutions have received instruction jointly delivered by lecturers from UP and UTHM. This period covers the COVID-19 pandemic phase where teaching initially occurred fully online, transitioning into a hybrid and face-to-face instructional model in the post-pandemic period (Bozkurt & Sharma, 2020). Moreover, the COVID-19 pandemic catalyzed rapid pedagogical shifts from emergency online teaching to stabilized hybrid models, presenting unique opportunities to investigate how instructional modes interact with cultural and institutional factors in shaping MA and PSA (Bozkurt & Sharma, 2020). Understanding these dynamics over multiple cohorts offers insights into how students adapt to evolving learning environments and how teaching strategies may ameliorate educational disparities.

Despite extensive research on MA and PSA, limited evidence exists regarding how these constructs vary across institutional contexts in Southeast Asian higher education, particularly within transnational courses undergoing instructional transformation. Moreover, few studies have examined cohort-level changes in MA and PSA during transitions from online to hybrid learning environments.

This study contributes to mathematics education research by examining cohort-level patterns of mathematics anxiety and problem-solving ability within a transnational Numerical Methods course across two Southeast Asian institutions. Unlike studies focused on a single institution or a single instructional setting, this study considers institutional context and temporal variation during a period of instructional transition. Specifically, this study aims to: (1) describe cohort-level patterns of MA and PSA across successive cohorts; (2) examine differences associated with institutional contexts; and (3) explore variations in these patterns during the transition from online to hybrid learning environments.

2. METHOD

2.1. Study Design

This study employed a repeated cross-sectional design to investigate MA and PSA among undergraduate students enrolled in a Numerical Methods course across four successive cohorts from 2021 to 2024 at two Southeast Asian universities (see [Figure 1](#)). Each year involved independent cohorts from UTHM, Malaysia and UP, Indonesia. This design enables comparison of aggregated cohort-level trends over time while avoiding assumptions of individual-level change because the same participants are not repeatedly measured (Caruana et al., 2015).

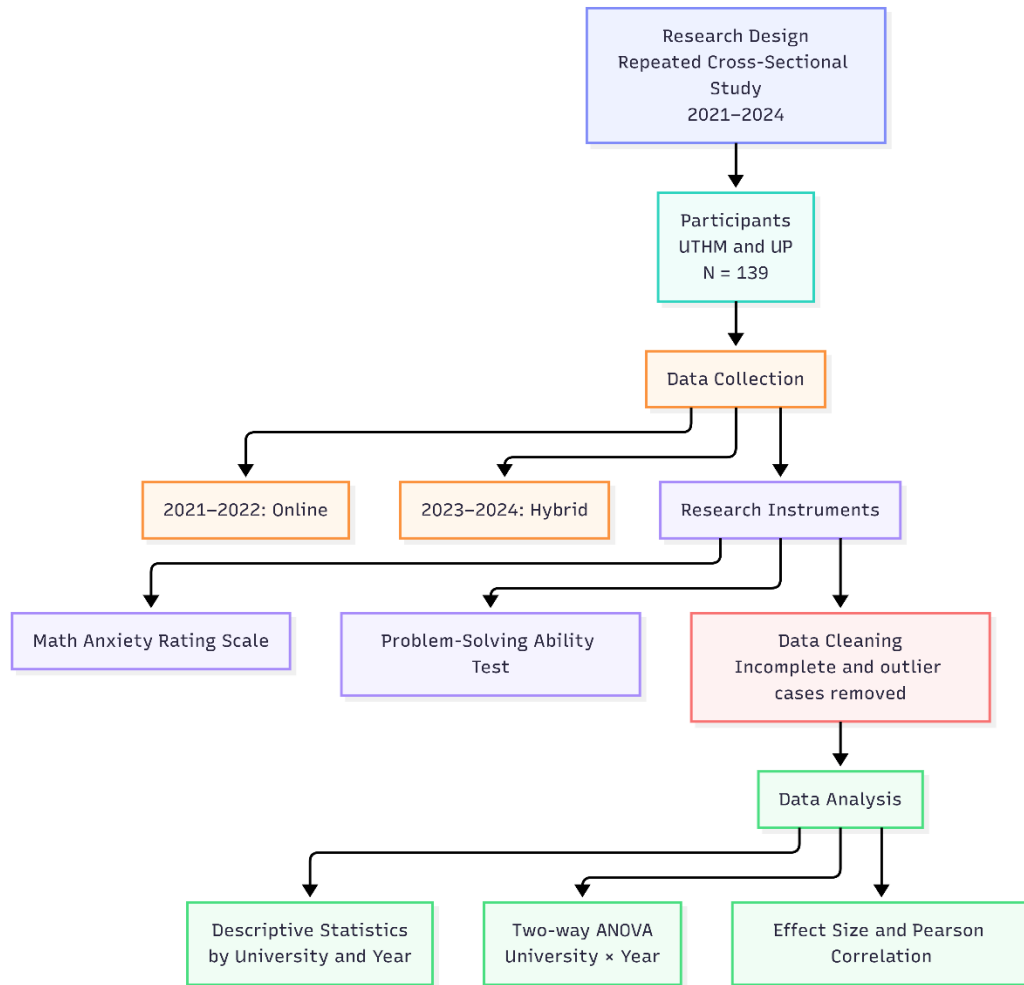


Figure 1. Research methodology flowchart

2.2. Participants

A total of 139 undergraduate students participated across both institutions: 23 from UTHM and 116 from UP, with sample sizes differing by year (see Table 1). Inclusion criteria comprised the enrollment in the Numerical Methods course and consent to participate. Data with incomplete responses were excluded. The sample size imbalance was considered in the analysis to mitigate bias. To address unequal group sizes, Type III sums of squares were applied in factorial ANOVA, which provides adjusted estimates under unbalanced designs. Because the UTHM subgroup sizes within individual years were small ($n = 5\text{--}7$), year-specific estimates and interaction effects were interpreted as exploratory.

Table 1. Participant distribution by year and university

Year	Instruction Mode	UTHM (n)	UP (n)	Total (n)
2021	Online	7	45	52
2022	Online	6	25	31
2023	Hybrid	5	18	23
2024	Hybrid	5	28	33

2.3. Instruments

2.3.1. Mathematics Anxiety Rating Scale (MARS)

The Mathematics Anxiety Rating Scale was adapted from Richardson and Suinn (1972). The scale demonstrated high internal consistency (Cronbach's $\alpha = 0.92$). Cross-cultural adaptation was performed with back-translation procedures to ensure semantic and conceptual equivalence in Malay and Indonesian versions.

2.3.2. Problem-Solving Ability Test (PSAT)

The PSAT consisted of 20 open-ended problems assessing four dimensions of mathematical problem solving. Each response was scored using an analytic rubric covering problem comprehension, strategy selection, mathematical execution, and solution interpretation, with scores ranging from 0 to 5. The scoring process was conducted by one mathematics lecturer with the expertise in Numerical Methods using standardized scoring criteria. The internal consistency of the PSAT scores across the 20 test items was examined using Cronbach's alpha ($\alpha = 0.86$), indicating acceptable consistency among the test items. As only one expert rater was involved, inter-rater reliability could not be estimated; however, scoring consistency was supported through the use of a predefined analytic rubric and standardized scoring guidelines.

2.4. Data Collection Procedure

Ethical approvals were obtained from UTHM and UP institutional review boards. Data collection occurred during the scheduled class sessions for each cohort. In 2021 and 2022, data were collected remotely through supervised online assessments due to COVID-19 restrictions. In 2023 and 2024, a hybrid instructional model was implemented (Bozkurt & Sharma, 2020). Standardized administration instructions and timing protocols were used to ensure procedural consistency.

2.5. Data Analysis

Data cleaning involved excluding incomplete cases and detecting multivariate outliers using Mahalanobis distance at $p < 0.001$. Descriptive statistics were computed for MA and PSA by university and year. A two-way factorial ANOVA (University $\times$ Year) was conducted treating both factors as between-subjects variables, appropriate for repeated cross-sectional data (Tabachnick & Fidell, 2013). Given the unequal and relatively small subgroup sizes, Type III sums of squares were applied, and effect sizes (partial η^2) with confidence intervals were emphasized alongside statistical significance to facilitate a more comprehensive interpretation of the findings. Pearson correlation coefficients were examined to assess the relationship between MA and PSA. Assumptions of normality, homogeneity of variance, and independence were verified and met.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Descriptive Statistics

Table 2 presents the descriptive statistics for MA and PSA scores of students from UTHM and UP, sampled across four academic years (2021–2024).

Table 2. Descriptive statistics of MA and PSA scores

University	Year	N	Mean MA	SD MA	Mean PSA	SD PSA
UTHM	2021	7	3.10	0.50	78.0	5.0
UTHM	2022	6	2.90	0.40	79.5	4.5
UTHM	2023	5	2.70	0.60	80.1	4.7
UTHM	2024	5	2.50	0.50	81.3	5.1
UP	2021	45	4.00	0.80	55.2	6.2
UP	2022	25	3.80	0.70	57.7	5.8
UP	2023	18	3.50	0.90	60.9	6.0
UP	2024	28	3.20	0.70	62.5	5.9

Table 2 shows differences in MA and PSA between the two universities, with UP students displaying higher MA and lower PSA than UTHM students in each year. Notably, both universities exhibit decreasing MA and increasing PSA trends over time, indicating lower cohort-level MA and higher PSA scores across successive cohorts. This finding aligns with previous research highlighting that instructional modality changes and pedagogical support may be associated with lower MA and higher PSA (Bozkurt & Sharma, 2020; Ramirez et al., 2018).

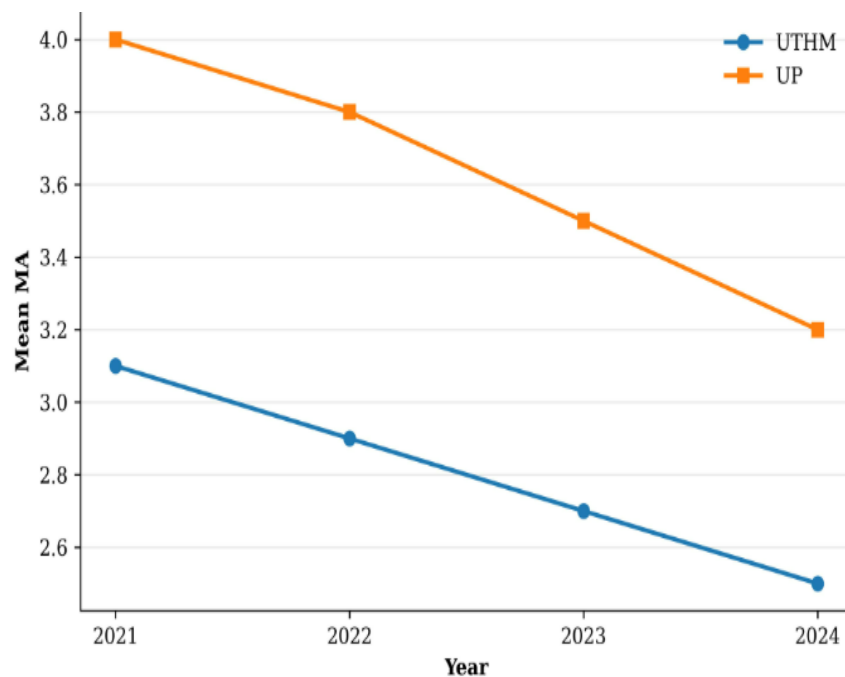


Figure 2. The trend in mean MA scores

Figure 2 presents the trend of Mean MA scores among students enrolled in Numerical Methods courses at UTHM and UP, observed across four independent cross-sectional samples spanning the academic years 2021 to 2024. Given the repeated cross-sectional design of this study, each data point represents a distinct cohort of students rather than the same individuals tracked over time.

As illustrated in Figure 2, UP students consistently reported higher mean MA scores than those at UTHM across all four sampling points. UP students recorded mean MA scores of 4.00, 3.80, 3.50, and 3.20 for 2021 through 2024, respectively, while UTHM students recorded 3.10, 2.90, 2.70, and 2.50 over the corresponding period. The cumulative decline in mean MA (0.80 points for UP and 0.60 points for UTHM) indicates a near-linear downward cohort pattern. Despite this decline, the interinstitutional gap remained relatively stable (between 0.70 and 0.90 points) throughout the observation period. This finding suggests that contextual and structural differences, including differences in curriculum, pedagogical tradition, and instructional support within Numerical Methods courses in each country, may sustain a persistent disparity in anxiety levels between Malaysian and Indonesian students.

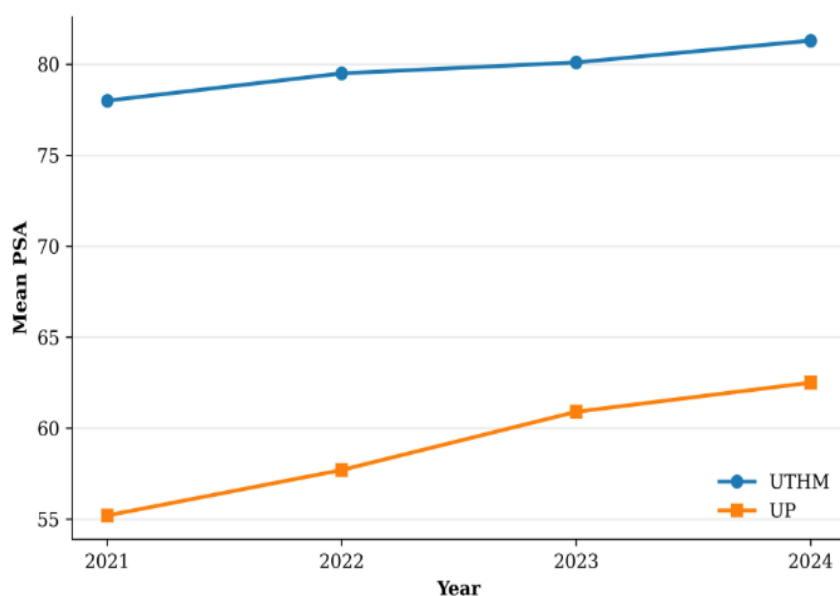


Figure 3. The trend in mean PSA scores

Figure 3 displays the trend in Mean PSA scores among students in both universities based on repeated cross-sectional samples collected from 2021 to 2024. It reveals a consistent upward cohort pattern in PSA scores at both institutions across the four-year observation period, though a substantial and persistent gap between the two universities is clearly evident.

UTHM students recorded mean PSA scores of 78.0, 79.5, 80.1, and 81.3 for the academic years 2021 through 2024, respectively, representing a cumulative increase of 3.3 points over the study period. In contrast, UP students recorded mean PSA scores of 55.2, 57.7, 60.9, and 62.5 across the same years, reflecting a cumulative gain of 7.3 points, a notably larger absolute improvement. Despite this steeper rate of increase observed at UP, the interinstitutional gap remained substantial throughout the observation window, ranging from approximately 17.0 points in 2021 to 18.8 points in 2024. This finding indicates that, while

UP students are improving at a relatively faster pace, the performance disparity between the two institutions has not meaningfully narrowed over the course of this study. Both trajectories follow a near-monotonic upward pattern, with no observed decline at any point across either institution, suggesting that improvements in PSA within Numerical Methods courses are consistent and directionally stable at both UTHM and UP across successive independent cohorts.

3.1.2. Two-way Factorial ANOVA

Table 3 summarizes the results of a two-way factorial ANOVA evaluating the effects of University (UTHM vs UP) and Year (2021–2024) on MA and PSA scores.

Table 3. The results of a two-way factorial ANOVA

Source of Variation	Df	F	p-value	Partial η^2	Dependent Variable
University	1, 131	65.34	< 0.001	0.34	MA
Year	3, 131	7.12	0.001	0.14	MA
University $\times$ Year	3, 131	3.48	0.018	0.07	MA
University	1, 131	58.95	< 0.001	0.31	PSA
Year	3, 131	6.47	0.001	0.12	PSA
University $\times$ Year	3, 131	4.21	0.007	0.09	PSA

Table 3 reveals significant main effects of University and Year were observed for both MA and PSA. The interaction effects suggest that the magnitude and direction of changes across years differ between universities. Effect sizes (partial η^2) range from moderate to large, indicating that the observed differences were accompanied by moderate-to-large effect sizes, based on commonly accepted benchmarks for partial eta squared interpretation (Cohen, 2013). These findings are consistent with previous studies demonstrating that institutional context and temporal factors interplay significantly impacting math anxiety and problem-solving performance (Caruana et al., 2015).

The significant interaction terms indicate that cohort-level patterns differed across the two institutions. Given the unequal subgroup sizes, particularly in the UTHM cohorts, these interaction findings should be interpreted as exploratory rather than as definitive evidence of different institutional trajectories.

Table 4. Correlation between MA and PSA

Variable	1	2
1. MA	—	−0.49**
2. PSA	−0.49**	—

Note: Correlation coefficients are significant at $p < 0.01$

Table 4 demonstrates a moderate negative correlation between MA and PSA ($r = -0.49$, $p < 0.001$), indicating higher levels of mathematics anxiety are associated with lower PSA. This overall association is consistent with previous evidence that higher mathematics anxiety is associated with lower problem-solving performance (Ashcraft & Ridley, 2005; Maloney & Beilock, 2012).

Table 5. Supplementary Pearson correlation analysis for key study variables

Variables	N	Correlation coefficient (r)	95% Confidence Interval	p-value
MA vs. PSA	137	-0.49	[-0.61; -0.34]	<0.001

MA = math anxiety, PSA = problem-solving ability

Table 5 presents the summary of supplementary Pearson correlation analysis between MA and PSA, including correlation coefficient, 95% confidence interval, and significance level. A moderate, negative, and statistically significant relationship is observed.

3.2. Discussion

This study aimed to investigate MA and PSA among undergraduate students enrolled in a transnational Numerical Methods course spanning four academic years (2021–2024) at UTHM and UP. Utilizing a repeated cross-sectional design, the study examined differences between institutions, temporal trends, and the interaction between contextual factors and instructional modalities during the COVID-19 pandemic.

Consistent with findings reported in the literature (Ashcraft & Ridley, 2005; Maloney et al., 2011), MA and PSA were inversely correlated, confirming that higher levels of anxiety are associated with decreased problem-solving performance. This relationship supports cognitive theories positing that MA consumes working memory resources critical to mathematical reasoning (Ashcraft & Krause, 2007). Such a negative relationship may impair mathematical learning progression (Ramirez et al., 2018).

The downward trend in MA scores observed at both institutions is particularly noteworthy in the context of Numerical Methods, a course widely recognized for its high cognitive demand and its reliance on both mathematical abstraction and computational reasoning (Quarteroni et al., 2007). The progressive reduction in MA across successive cohorts may reflect differences in cohort composition, learning experiences, or other unmeasured contextual factors. These findings are consistent with Bozkurt and Sharma (2020), who demonstrated that adaptive instructional modalities can meaningfully reduce mathematics anxiety in technically demanding courses, and Ramirez et al. (2018), who identified instructional support as a key moderator of affective responses to mathematics. Reviews of the literature indicate that MA affects learning motivation, self-regulation, and academic achievement in higher education contexts (Luttenberger et al., 2018).

Furthermore, the inverse relationship between the declining MA trend and the corresponding increase in PSA scores, as reported in Table 2, supports the theoretical framework underpinning this study. The pattern observed across both universities reinforces the well-established proposition that elevated mathematics anxiety functions as a cognitive inhibitor, constraining the working memory resources necessary for effective problem-solving in numerically intensive tasks (Ashcraft & Ridley, 2005; Hembree, 1990). Within the specific context of Numerical Methods education, where iterative procedures and algorithmic reasoning are central competencies, the reduction of MA may be a prerequisite condition for meaningful gains in problem-solving performance.

Collectively, the trends depicted in [Figure 2](#) provide important cross-national evidence that mathematics anxiety in Numerical Methods courses follows a declining cohort pattern over time at both UTHM and UP. It also simultaneously highlights the persistent gap that warrants targeted comparative investigation between the Malaysian and Indonesian higher education contexts. At the higher education level, MA has been linked to lower course grades and higher dropout rates (Núñez-Peña et al., [2013](#)).

The progressive improvement in mean PSA scores observed at both UTHM and UP across the four cross-sectional sampling points is a noteworthy finding that warrants careful interpretation within the broader theoretical and pedagogical context of Numerical Methods education. The upward trend at both institutions, when examined alongside the parallel decline in MA scores (see [Figure 2](#)), provides empirical support for the theorized negative relationship between affective inhibition and cognitive performance in mathematically demanding courses. Specifically, as successive cohorts of students at both universities reported lower mean MA, corresponding cohorts demonstrated higher mean PSA. This pattern is consistent with the cognitive interference model of MA proposed by Ashcraft and Ridley ([2005](#)), positing that anxiety occupies working memory resources otherwise available for complex problem-solving.

The substantially larger cumulative PSA gain observed at UP (7.3 points) relative to UTHM (3.3 points) may reflect a ceiling effect at UTHM, where initial PSA scores were already comparatively high (78.0 in 2021), constraining the margin for further improvement. Conversely, the lower baseline PSA at UP (55.2 in 2021) afforded greater room for measurable growth, consistent with regression-to-the-mean dynamics frequently observed in repeated cross-sectional educational research (Reichardt, [2002](#)). The negative relationship between MA and mathematical performance has been documented as a global phenomenon, transcending cultural and national boundaries (Foley et al., [2017](#)). The larger cohort-level increase in PSA at UP should be interpreted cautiously because baseline differences, cohort composition, and other unmeasured contextual factors may have contributed to the observed pattern. Nevertheless, the persistent and widening interinstitutional gap, increasing from 17.0 to 18.8 points across the study period, indicates that gains at UP, although substantial in relative terms, have yet to translate into comparable absolute performance levels with UTHM students. This observed disparity may be associated with unmeasured differences in student preparation, curriculum implementation, learning resources, and other institutional factors (Yusof & Tall, [1998](#)). Overall, these findings indicate that despite positive affective and cognitive trends in both contexts, targeted interventions to strengthen foundational mathematical competencies and reduce anxiety in computationally intensive courses are needed to narrow the performance gap between Malaysian and Indonesian students.

Differences between UTHM and UP students in both MA and PSA were significant, with UP students exhibiting higher MA and lower PSA consistently across cohorts. This finding is in line with the contrasting educational systems described in the introduction: Malaysia's centralized, government-supported system with bilingual instruction and technology integration (OECD, [2024](#); Padilla-Valdez, [2019](#)) versus Indonesia's decentralized system characterized by infrastructural and resource variability (OECD, [2019](#)). These educational disparities may be associated with the observed differences, reflecting

sociocultural and institutional influences on student affect and achievement (Beilock et al., 2010; Gutierrez, 2002). Observed differences between institutions should not be interpreted as direct effects of nationality, culture, or educational quality. Factors such as students' prior mathematical preparation, socioeconomic background, curriculum implementation, access to technology, and academic support were not measured and may have contributed to the observed differences.

Temporal analyses revealed significant reductions in MA and concomitant increases in PSA over the four-year period, particularly pronounced among UP students. The observed cohort-level reductions in MA and increases in PSA coincided with changes in instructional conditions from online to hybrid delivery. However, the repeated cross-sectional design does not permit causal attribution of these patterns to instructional modality (Bozkurt & Sharma, 2020). The significant interaction effects between University and Year further suggest that institutional contexts may influence how students respond across cohorts to instructional changes. UP cohorts demonstrated greater improvements during the period in which instructional modalities transitioned toward hybrid learning. However, these changes should not be interpreted as causal effects of instructional modality because other institutional and cohort-related factors may have contributed. Such differential effects underscore the importance of tailored instructional and support strategies that account for institutional and cultural contexts (Bandura, 1997; Pajares & Miller, 1994).

The repeated cross-sectional design limits causal inference about individual trajectories but provides robust group-level insights into how MA and PSA evolve under varying contextual pressures. Future research employing longitudinal cohort designs would complement these findings by tracking intra-individual changes and disentangling within-person from between-group effects (Caruana et al., 2015). Additionally, qualitative studies exploring student perceptions and coping strategies may enrich understanding of the complex sociocultural dimensions underpinning MA.

Practically, reducing MA while enhancing PSA requires integrated efforts: improving institutional resources and technology, fostering positive cultural attitudes toward mathematics, and implementing pedagogical practices that build self-efficacy and problem-solving skills (Ramirez et al., 2018; Schoenfeld, 2017). Given the ongoing challenges posed by educational disruptions, hybrid or blended learning models combined with culturally responsive teaching hold promise for supporting diverse learner populations.

This study advances the understanding of MA and PSA in a Southeast Asian transnational context during a period of rapid pedagogical change. The findings highlight significant institutional and temporal influences on these constructs and underscore the need for contextually sensitive interventions to mitigate anxiety and enhance mathematical problem-solving capacities in higher education.

4. CONCLUSION

This repeated cross-sectional study examined Mathematical Anxiety (MA) and Problem-Solving Ability (PSA) among students in a transnational Numerical Methods course at UTHM and UP across four academic years (2021–2024). Both universities demonstrated

decreasing trends in MA and improving trends in PSA across successive cohorts amidst the transition from fully online to hybrid instructional modes following the COVID-19 pandemic. Furthermore, the negative association between MA and PSA underscores the critical role of affective and cognitive factors in mathematics learning outcomes.

However, several methodological limitations must be considered when interpreting these findings. First, the repeated cross-sectional design restricts the analysis to cohort-level aggregate trends rather than individual-level longitudinal changes or causal effects of instructional shifts. Second, institutional comparisons and University $\times$ Year interaction findings should be interpreted with caution due to unequal sample sizes and small UTHM subgroup numbers, which reduce estimate precision. Third, while standard translation and back-translation procedures were applied, formal cross-cultural measurement invariance testing could not be performed due to sample size constraints; thus, observed institutional differences in MA scores may partly reflect variations in measurement properties rather than true group differences. Finally, PSAT responses were evaluated by a single expert rater, precluding the assessment of inter-rater reliability.

Future research should employ larger, balanced samples to conduct formal measurement invariance testing (configural, metric, and scalar), utilize longitudinal tracking of individual changes, and incorporate multiple independent raters to enhance scoring objectivity and strengthen causal inferences.

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Declarations

Author Contribution	: MW: Conceptualization, Project administration, Visualization, Writing - original draft, and Writing - review & editing; FBA: Formal analysis, Methodology, and Writing - review & editing; HMS: Validation, and Supervision; LMR: Data curation.
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Conflict of Interest	: The authors declare no conflict of interest.
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