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Unlocking mathematics success: Global lessons on student achievement, teacher satisfaction, and school environments

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ABSTRACT

This study explores the factors influencing mathematics performance, teacher satisfaction, and school environment across six economies using data from PISA 2022. Employing hierarchical linear modeling, the research examines individual and institutional variables at the student, teacher, and school levels. Key findings reveal significant differences in mathematical performance between high- and low-performing economies, with factors such as socio-economic status, cognitive activation, and teacher support playing critical roles. Additionally, teacher satisfaction is strongly linked to classroom climate and professional alignment with teaching goals. The analysis highlights how systemic and cultural factors influence outcomes, offering policy insights to improve global mathematics education.

Keywords: mathematics performance, teacher satisfaction, school environment, PISA 2022, cross-national analysis

INTRODUCTION

Mathematics education is pivotal in shaping intellectual and economic landscapes worldwide. As a foundation for scientific innovation, technological progress, and critical thinking, proficiency in mathematics is essential for individuals to navigate the complexities of the modern world. Yet, despite its recognized importance, significant disparities in mathematics achievement persist across and within countries, revealing ongoing challenges to the global educational system.

The latest PISA 2022 results, released in June 2024, reveal significant disparities in mathematics performance. Economies like Macao (China), Hong Kong (China), and Australia consistently outperform the Organization for Economic Co-operation and Development (OECD) average, with Macao ranked 2nd globally (average score: 552), Hong Kong ranked 4th (average score: 540), and Australia ranked 16th (average score: 487), reflecting strong student proficiency and effective education systems. Meanwhile, countries like Malaysia (ranked 53rd, average score: 409), Georgia (ranked 60th, average score: 390), and Colombia (ranked 64th, average score: 383) remain below the OECD average of 472, highlighting ongoing systemic challenges in these nations (OECD, 2023b, Volume 1, p. 52-53).

Although prior research has extensively explored student-level factors–such as socio-economic status (SES), gender, and individual attitudes–that influence mathematics outcomes, less attention has been paid to the roles of teachers and schools, particularly in a cross-national context. Teachers play a central role in educational success, with their job satisfaction and teaching methods profoundly influencing student learning. Schools also provide the structural and cultural environments that support or hinder education, with factors like leadership and school climate shaping teacher effectiveness and, in turn, student performance. Furthermore, the interaction between teacher and school influences is complex and varies across different national and cultural contexts. Either focused on single-country analyses or examined teacher and school factors separately, current research limiting the ability to identify broader patterns or generalize findings.

To address this gap, this study conducts a cross-national analysis using data from PISA 2022, employing hierarchical linear modeling (HLM) to analyze nested data at the student, teacher, and school levels. This multilevel approach allows us to capture relationships and interactions between variables at different levels. The impact of peer teachers' qualifications, instructional practices, and professional development on teachers' job satisfaction and student performance in mathematics was examined at the teacher level. Factors such as leadership quality, resource availability, mathematics class settings, and school climate were investigated at the school level to determine their influence on educational outcomes.

The significance of this research lies in its potential to inform educational policies and practices within the studied countries and on a global scale. By identifying critical teacher and school factors that significantly impact mathematics achievement, the findings of this study can guide the development of targeted interventions aimed at improving teacher effectiveness and optimizing school environments. The ability to understand these dynamics across varied cultural and systemic contexts enriches the global discourse on mathematics education and offers evidence-based recommendations for educators, policymakers, and stakeholders striving to elevate educational outcomes. Furthermore, this study contributes to educational theory by embedding teacher and school variables within a multilevel framework, providing a comprehensive view of how educational systems interact to influence learning.

LITERATURE REVIEW

Theoretical Foundations for Understanding Influences on Mathematics Achievement

Understanding the factors that influence mathematics achievement necessitates a comprehensive theoretical framework that incorporates both individual and environmental elements. This exploration draws upon four key theories: Vygotsky's social constructivism, cognitive load theory, and ecological systems theory, as well as instructional design perspectives that emphasize the interplay between these approaches. Collectively, these theories illuminate how classroom interactions, cognitive processing, and environmental contexts shape mathematical learning experiences. Additionally, they highlight the necessity for exploring underdeveloped areas, such as the role of technology in addressing cognitive load and the value of cross-cultural studies in understanding how different contexts influence learning outcomes.

Vygotsky's social constructivism emphasizes that learning is inherently a collaborative process where knowledge is co-constructed through interactions with others, including teachers and peers. This theory is particularly relevant in mathematics education, where teacher-student interactions, scaffolding, and the use of language play critical roles in developing mathematical understanding. For example, research demonstrates that supportive classroom environments–characterized by questioning techniques, collaborative activities, and active discussions–significantly promote deeper engagement with mathematical concepts and lead to improved achievement (Ryan & Patrick, 2001; Staub & Stern, 2002). However, challenges arise when scaffolding is inconsistently applied or when external support systems, such as family and community resources, are insufficient. These gaps point to the importance of cross-cultural studies to examine how socio-cultural and economic contexts influence scaffolding's effectiveness. Moreover, emerging technologies, including AI-driven adaptive learning platforms, have the potential to complement scaffolding by dynamically adjusting instructional content to meet individual needs, yet this remains an underexplored area in research.

Cognitive load theory provides additional insight into the role of instructional design in mathematics education. This theory highlights the need to structure learning environments in ways that reduce extraneous cognitive load, enabling students to focus their cognitive resources on essential problem-solving tasks. van Merriënboer and Sweller (2005) argue that well-designed instructional materials, which minimize distractions and emphasize key concepts, facilitate better cognitive processing of complex mathematical ideas. Empirical evidence supports this, showing that teachers with both deep content knowledge and effective pedagogical strategies are better equipped to help students grasp challenging material (Hill et al., 2008). Sweller et al. (2011) further stress that effective instructional design must account for cognitive load to enhance learning outcomes, particularly in subjects like mathematics. For instance, the integration of structured scaffolding and technology can reduce extraneous load while maintaining task complexity, promoting sustained engagement and learning (Gyan et al., 2021; Majiwa et al., 2020).

Broadening the scope beyond individual interactions, ecological systems theory examines the environmental contexts in which learning occurs. This theory posits that learning is influenced by direct classroom interactions as well as larger systems, such as family, school, and community environments. It provides a framework for understanding disparities in mathematics achievement among students from diverse socio-economic backgrounds. Students from low-income families often face challenges such as limited access to educational resources and under-resourced schools, which collectively hinder their academic progress. Conversely, students from more advantaged backgrounds benefit from a synergy of enriched home environments and strong classroom support. Empirical studies demonstrate the critical role of these broader systems. Lesh and English (2005) found that mathematical understanding and problem-solving abilities are deeply rooted in interactions within family and community support networks, while Gynnild and Lorentzen (2005) emphasized the importance of socio-economic resources in shaping students' mathematical development. These findings suggest that improving mathematics outcomes requires addressing systemic inequalities and fostering stronger partnerships between schools, families, and communities.

Instructional design perspectives build on these theories by integrating their insights to develop comprehensive strategies for mathematics education. Effective curriculum design can incorporate adaptive learning technologies and structured scaffolding to balance cognitive demands while engaging students in meaningful learning experiences. Teacher preparation programs can leverage these frameworks by training educators to combine deep content knowledge with pedagogical techniques tailored to diverse cultural and socio-economic contexts. Educational policies can further support these efforts by prioritizing resource allocation to under-resourced schools, promoting family and community involvement, and facilitating cross-cultural research to identify best practices in scaffolding and ecological support systems.

By integrating social constructivism, cognitive load theory, ecological systems theory, and instructional design principles, a holistic understanding emerges of how individual, cognitive, and environmental factors converge to influence mathematics achievement. This approach not only addresses classroom practices but also acknowledges the critical role of external support systems in shaping student outcomes. It provides a robust foundation for designing interventions that create equitable and effective learning environments, ensuring all students have the opportunity to succeed in mathematics.

Students' Mathematics Performance and Mathematics Teachers' Job Satisfaction

Research consistently demonstrates that teachers' job satisfaction plays a critical role in shaping instructional quality, which in turn significantly impacts students' mathematics achievement. Staub and Stern (2002) found that teachers who experience high levels of job satisfaction are more likely to foster positive learning environments, leading to improved student outcomes. Expanding on this, Klusmann et al. (2008) explored the connection between teachers' self-regulatory patterns and their occupational well-being, finding that satisfied teachers are more inclined to adopt effective teaching practices. These practices, in turn, enhance student motivation and achievement in mathematics, underscoring the interplay between teacher well-being and instructional quality.

The role of emotional and social factors in enhancing job satisfaction has also been well-documented. For instance, Collie et al. (2012) highlighted the effectiveness of social-emotional learning (SEL) initiatives in reducing teacher stress and improving job satisfaction. These improvements are linked to better student engagement and academic achievement. Similarly, Johnson et al. (2012) argued that teachers' working conditions directly influence their professional satisfaction and, consequently, their students' academic success. Cornell et al. (2016) further emphasized the importance of school climate, noting that supportive and collaborative environments enhance both teacher satisfaction and student outcomes.

Recent research has continued to explore how specific conditions and practices affect teacher satisfaction and its downstream effects on student achievement. Dicke et al. (2020) identified a strong relationship between a positive disciplinary climate in the classroom and higher teacher job satisfaction, which benefits students through improved instructional quality. Hwang (2022) revealed that mathematics teachers with high job satisfaction and low stress levels are more likely to employ dialogic instruction, fostering collaborative learning environments that boost student engagement and achievement. Similarly, Salifu and Bakari (2022) demonstrated that adequate support for teachers positively influences their job satisfaction, which in turn enhances students' interest and performance in mathematics.

Further evidence underscores the multifaceted nature of the relationship between teacher satisfaction and student success. Diagne (2023) reiterated the importance of a positive disciplinary climate, showing its correlation with greater teacher satisfaction and improved student achievement. Complementing this, Nurhuda et al. (2023) highlighted that addressing students' mathematics anxiety can lead to better attitudes and achievements in the subject, demonstrating how teachers' emotional well-being indirectly supports student outcomes by creating a conducive learning environment.

Professional development is another key factor in enhancing teacher effectiveness and student outcomes in mathematics education. Bonaccorso et al. (2023) find the transformative effects of professional development frameworks like teaching for robust understanding on teacher practices, while Yu et al. (2023) examine the critical role of mathematics self-efficacy in improving academic achievement across demographic groups. These studies highlight the importance of systemic support and targeted resources in maintaining teacher morale and enhancing instructional effectiveness (Ding et al., 2023; Naftaliev & Barabash, 2024).

School-Level Factors Shaping Students' Mathematics Outcomes

School-level factors significantly influence students' mathematics achievement, and research has consistently demonstrated that variables such as school climate, disciplinary practices, and resource availability are critical determinants of academic success. However, the interplay between these factors and how they collectively shape student outcomes remains underexplored, particularly in terms of mediating influences like school atmosphere and student attitudes.

Ma and Klinger (2000) were among the first to establish the importance of school climate in academic achievement through a HLM study. They identified disciplinary climate–characterized by clear rules and positive relationships within schools–as a key determinant of students' academic outcomes, including mathematics achievement. This foundational research paved the way for subsequent investigations into how orderly school climates reduce behavioral issues and foster environments conducive to learning. Gottfredson et al. (2005) expanded on this by examining the relationship between school climate and student behavior. Their findings emphasized that schools with clear, consistently enforced rules and a supportive environment promote positive student behavior, which correlates with improved mathematics performance.

The role of safety and support within the school climate has also been emphasized in later research. Koth et al. (2008) demonstrated that students' perceptions of school safety and support significantly influence their academic motivation and achievement. Their findings indicate that schools fostering a sense of security and supportive relationships encourage higher levels of student engagement, directly linked to improved outcomes in mathematics. Similarly, Shin et al. (2009), in a cross-national study, highlighted that schools with strong academic traditions and minimal behavioral issues provide environments more conducive to success in mathematics across diverse contexts. This study also pointed to the mediating role of disciplinary climate in bridging resources and student outcomes, suggesting that school atmosphere can amplify the benefits of resource investments.

Beyond school climate, the classroom context also shapes mathematics achievement. Factors such as class size and pupil-teacher ratios play a significant role, particularly for disadvantaged students. Lee and Reeves (2012) found that higher pupil-teacher ratios negatively affect achievement, as larger class sizes limit the individualized attention teachers can provide, exacerbating disparities among disadvantaged students. This highlights the importance of addressing classroom-level factors alongside broader school-level initiatives to ensure equitable access to quality education.

A comprehensive review by Thapa et al. (2013) synthesized findings on school climate, identifying five essential dimensions: safety, relationships, teaching and learning, institutional environment, and school improvement processes. Their work reinforced the idea that a positive school climate–particularly one characterized by supportive relationships and a safe environment–enhances student engagement and academic outcomes in mathematics. Importantly, they noted that safety and relationships may act as mediating factors, linking broader school resources to student performance. This concept was further supported by Bove et al. (2016), who demonstrated that orderly school environments with fewer disruptions create conditions for more effective teaching and better mathematics outcomes. Recent studies echo these findings. Zakariya (2022) highlights effective interventions to enhance self-efficacy, while Hettinger and Steffensky (2022) emphasizes the connection between emotional support, classroom climate, and student interest. These studies complement foundational works by offering contemporary perspectives on how self-efficacy and classroom dynamics influence outcomes.

For disadvantaged populations, school climate plays a particularly critical role. Konold et al. (2018) found that even in underprivileged contexts, positive school environments are closely associated with student engagement and academic achievement. Their findings suggest that supportive climates can mitigate some of the challenges faced by disadvantaged students, particularly in mathematics. Fadiji and Reddy (2021) extended this line of inquiry by focusing on resource availability in South Africa, showing that schools with better resources are able to attract more qualified teachers, which in turn positively impacts student outcomes in mathematics. Their study highlights the interconnected nature of resources, teacher quality, and school climate in shaping educational success.

Cross-National Insights into Mathematics Achievement

Cross-national studies of mathematics achievement provide valuable insights into the factors influencing educational outcomes across diverse cultural and educational contexts. These studies not only reveal differences in student performance but also highlight the underlying factors driving these disparities, such as educational practices, cultural attitudes, and systemic influences. However, the interaction between these factors, their contextual specificity, and their implications for policy development remain underexplored.

Stevenson et al. (1986) compare the mathematics achievement of children from China, Japan, and the United States, demonstrating that American kindergarten children lag behind their Japanese peers in mathematical understanding. By fifth grade, they are surpassed by both Japanese and Chinese children. Importantly, the study attributes these differences not to cognitive abilities–found to be similar across the countries–but to variations in parental involvement, cultural attitudes towards education, and classroom practices. While this foundational research underscores the importance of contextual factors in shaping mathematics achievement, it stops short of examining how these factors interact with one another or how they could mediate educational outcomes in different contexts.

Building on this, Geary et al. (1996) provide a longitudinal perspective, showing that American students have consistently ranked among the lowest in mathematics achievement compared to their East Asian peers. This study highlights the persistent nature of these disparities, yet it does not delve into how recent shifts in educational policies or systemic reforms might address them. Over the past decade, there have been significant policy developments aimed at improving mathematics education in Western contexts, such as the adoption of standards like the common core in the United States. However, these reforms require more analysis to evaluate their effectiveness and potential for reducing achievement gaps.

Leung (2005) shifts the focus to East Asian classrooms, using data from the Third International Mathematics and Science Study (TIMSS). His work reveals that East Asian countries consistently outperform Western counterparts, attributing this to rigorous curricula, high expectations, and culturally embedded teaching practices that emphasize mastery and systematic problem-solving. This analysis highlights the importance of instructional quality but does not account for how factors such as school climate, teacher relationships, or resource availability might mediate these outcomes in different cultural contexts.

Cheng (2014) extends this discussion by identifying specific instructional practices in high-achieving East Asian education systems that enhance student learning and engagement. His findings provide actionable insights for other countries seeking to adopt similar pedagogical strategies. Lessani et al. (2014) also focus on Singapore's exceptional performance in TIMSS, attributing it to a structured curriculum and a strong emphasis on problem-solving. However, both studies would benefit from a deeper critical analysis of how these factors interact with broader societal and systemic influences, such as socioeconomic conditions or gender dynamics, to shape outcomes.

Mullis et al. (2015) provide a comprehensive analysis of mathematics achievement across various countries through the most recent iteration of TIMSS. Their findings reaffirm the dominance of East Asian countries in mathematics performance, while also shedding light on specific instructional practices and systemic characteristics contributing to their success. While their analysis is thorough, it does not fully address the limitations of these practices when applied in different cultural or educational contexts, nor does it explore how factors like school climate or teacher satisfaction might influence outcomes in lower-performing systems. Recently, Thurm et al. (2024) provide a comparative perspective on facilitators' practices in integrating technology into mathematics teaching, shedding light on contextual barriers and enablers across China and Germany.

To summarize, the cross-national insights into mathematics achievement reveal that educational practices, cultural attitudes, and systemic factors significantly influence student outcomes. However, many studies in this area have examined these factors in isolation, with limited attention to how they interact. Additionally, while gender equality policies and societal influences have been acknowledged, their integration into the broader conversation on mathematics education is lacking.

Future research should aim to bridge these gaps by exploring how systemic factors, instructional practices, and cultural attitudes interact in shaping mathematics achievement. Policymakers should also consider targeted strategies that incorporate these insights, such as fostering positive school climates, enhancing teacher training, and addressing gender disparities in education. By critically analyzing these dynamics, this study contributes to a deeper understanding of mathematics education and offers actionable recommendations for improving outcomes across diverse contexts.

Addressing Gaps in the Literature

While the body of research on mathematics achievement is substantial, several gaps remain that this study seeks to address. First, much of the literature focuses on either teacher-level or school-level factors in isolation, without examining how these layers interact. For instance, how teacher assistance impacts student achievement may vary depending on the school environment, such as differences in resource availability or disciplinary climate. This interaction between teacher-level and school-level factors has received limited attention, despite its potential to provide deeper insights into the contextual dynamics of mathematics achievement (e.g., Lee & Reeves, 2012; Thapa et al., 2013).

Second, few studies have employed advanced multilevel modeling techniques–such as HLM–to account for the nested nature of educational data, where students are situated within classrooms, and classrooms within schools. HLM is particularly valuable for analyzing such data, as it allows researchers to disentangle the effects of individual, classroom, and school-level factors simultaneously. For example, studies like Raudenbush and Bryk (2002) highlight the strength of HLM in capturing these interactions, yet its use remains relatively rare in cross-national educational research.

Third, cross-national comparisons of high- and low-performing economies within the same analytical framework are limited. Such comparisons are crucial for understanding how variations in educational policies, cultural attitudes, and systemic structures influence mathematics achievement. For instance, cross-national studies can reveal how countries with differing approaches to teacher training, curriculum design, or resource allocation achieve their outcomes. This research builds on prior work, such as Mullis et al. (2015), to provide a comparative perspective that includes both high-performing economies, like Singapore, and lower-performing ones, offering insights into what promotes success or hinders progress.

Moreover, while previous research acknowledges the importance of cross-national comparisons, there has been little discussion on why such analyses are significant. Cross-national studies help identify not only best practices but also context-specific strategies that may be effective in particular cultural or systemic settings. For example, policies that succeed in resource-rich contexts might require adaptation for resource-poor settings to achieve similar results. By addressing this gap, this study sheds light on the global applicability of educational practices, to provide a more comprehensive understanding of the complex and multifaceted factors shaping mathematics achievement in diverse educational contexts, ultimately offering actionable insights for policymakers and educators worldwide.

METHODOLOGY

This study employs a quantitative, cross-national research design to investigate the factors influencing student mathematics performance and teacher job satisfaction. Data from the PISA 2022 assessment are analyzed for six economies: Macao (China), Hong Kong (China), Australia, Malaysia, Georgia, and Colombia. These economies were selected to represent a range of performance levels, providing insights into both high-performing and lower-performing contexts. The analysis focuses on both individual-level variables, such as SES, student attitudes, and teacher support, and school-level variables, including school resources, disciplinary climate, and teacher satisfaction. To identify key individual-level predictors, stepwise regression is used for its efficiency in narrowing down significant variables from a larger dataset. Additionally, two-level HLM is employed to account for the nested structure of the data, capturing the influence of individual-level factors. This methodological combination ensures a comprehensive analysis of how institutional and individual variables interact to shape outcomes across diverse educational contexts.

Research Design

This study employs a two-level HLM framework to analyze the nested structure of the data, where students are grouped within schools. Specifically, the analysis examines two models: one links student performance to school-level variables (students at Level 1 and schools at Level 2), and the other links teacher satisfaction to school-level variables (teachers at Level 1 and schools at Level 2).

The PISA dataset's structure does not directly establish a "student-teacher-school" connection but instead uses unique tracking numbers to associate each level. This modeling approach captures the hierarchical relationships inherent in the data, allowing for an examination of how teacher- and school-level factors independently influence student performance. While a three-level HLM could theoretically include teachers as an intermediate level, the current dataset and research focus justify the use of separate two-level models to analyze these relationships effectively (Ma & Klinger, 2000).

HLM is particularly well-suited for this analysis because it accounts for the shared variance within clusters, ensuring that the effects of school-level factors, such as school resources and disciplinary climate, on individual outcomes are accurately estimated. School-level variables were selected from the PISA 2022 database, based on their relevance to prior research and theoretical frameworks, and were evaluated for consistency across the six economies included in this study.

The integration of stepwise regression models in the preliminary phase allows for the identification of the most significant individual-level predictors, such as SES and student attitudes. These predictors are then incorporated into the HLM models to explore how each variable interact to influence mathematics outcomes. This methodological combination ensures that both the selection of key predictors and the hierarchical structure of the data are thoroughly addressed, aligning the analytical framework with the study's primary research questions.

Data Source and Sample Selection

This study uses data from the PISA 2022 dataset, managed by the OECD. PISA assesses 15-year-old students' competencies in reading, mathematics, and science through cognitive tests and background questionnaires completed by students, teachers, and school administrators. While 18 economies provided completed teacher questionnaires, this study focuses on six economies to balance depth and breadth in the analysis.

Three high-performing economies–Macau (China), Hong Kong (China), and Australia–and three lower-performing economies–Malaysia, Colombia, and Georgia–were selected to represent a range of performance levels both above and below the OECD average. These economies were chosen based on their performance in mathematics, geographic diversity, and the availability of matched student, teacher, and school-level data. Spanning Asia, Australia, Europe, and South America, these economies provide valuable comparative insights into the factors influencing mathematics achievement and teacher job satisfaction. While the selection of six economies allows for an in-depth analysis of key factors, future research could expand the sample to explore performance variations across a larger set of economies with teacher data.

Students

In Australia, 13,437 students participated (48.8% female, 51% male, average age 15.76). Colombia had 7,804 students (51.4% female, 48.6% male, average age 15.84). Georgia included 6,583 students (48.3% female, 51.7% male, average age 15.85). In Hong Kong, 5,907 students participated (47.9% female, 52.1% male, average age 15.82). Macau had 4,384 students (48.8% female, 51.2% male, average age 15.80), while Malaysia's sample consisted of 7,069 students (51.1% female, 48.9% male, average age 15.84).

Teachers

Australia included 11,397 teachers (58% female, 41.5% male, average age 41.95), with 3,094 mathematics teachers. In Colombia, 2,615 teachers participated (47.04% female, 49.45% male, average age 45.15), with 323 mathematics teachers. Georgia's sample included 3,202 teachers (85.2% female, 13.5% male, average age 51.40), with 360 mathematics teachers. Hong Kong had 2,335 teachers (50.1% female, 48.7% male, average age 41.08), with 548 mathematics teachers. Macau had 1,916 teachers (55.5% female, 44.4% male, average age 38.25), with 270 mathematics teachers. In Malaysia, 3,956 teachers participated (75% female, 25% male, average age 42.22), with 920 mathematics teachers.

Schools

Australia had 743 schools participating, with 52.1% being public schools. In Colombia, 262 schools participated (74% public, 21.4% private). Georgia had 267 schools (88% public). Hong Kong had 163 schools (8% public, 89.1% private). In Macau, 46 schools participated, though public/private distinctions were not applicable. In Malaysia, 199 schools participated (92.5% public). After data matching among students, teachers, and schools and processing missing data, the final number of schools in the study was 487 for Australia, 229 for Colombia, 212 for Georgia, 99 for Hong Kong, 46 for Macau, and 196 for Malaysia.

Variables and Measures

To address the research questions effectively, this study utilizes a multilevel framework incorporating student, teacher, and school variables, as shown in **Table 1**. The categorical and continuous variables are differentiated to ensure accurate modeling and interpretation of the data within the HLM.

Table 1. Dependent and independent variables

Variables	Definition of variables	QN	CV
Dependent variables			
Student's mathematics score	Students mathematics score in PISA 2022	MQ	
SATJOB	Teachers' satisfaction with the current job environment	TC198	
Independent variables			
Students' variables			
AGE	Student's age	ST003	
GENDER	Female/male/not applicable	ST004D01T	√
ESCS	Based on three indicators: HISEI, PAREDINT, and HOMEPOS	MQ	
MATHEF	Feelings about formal and applied mathematics tasks	ST290	
DISCLIM	Answers to situations occurred in their mathematics lessons	ST273	
MATHPERS	Engaged in behaviors indicative of effort and persistence in mathematics	ST293	
MATHEF21	Confidence about mathematical reasoning and 21st century mathematics tasks	ST291	
EXPOFA	Exposure to formal and applied mathematics tasks	ST275	
COGACMCO	Encouraging mathematical thinking	ST283	
COGACRCO	Fostering mathematics reasoning	ST285	
MATHPREF	Whether preferred mathematics over test language and science	ST268 Q01-03	
MATHMOT	Whether more motivated in mathematics than in test language and science class	ST268 Q07-09	
ANXMAT	Attitudes towards mathematics	ST292	
MATHEASE	Whether perceive mathematics as easier compared to the test language and science	ST268 Q05-06,14	
EXPO21ST	About tasks related to mathematical reasoning and 21st century mathematics	ST276	
Teachers' variables			
AGE	Teacher's age	TC002Q01	
GENDER	Female/male/not applicable	TC001Q01	√
PROPWORK	The years of at the school /years of teaching in total	TC007	
TCDISCLIMA	Situations occurred in their mathematics lessons	TC170, 217	
EXPO21	Mathematical reasoning and 21st century mathematics topics	TC217, 223	
COGACMTC	Behaviors indicative of encouraging mathematical thinking	TC217. 227	
COGACRTC	Behaviors indicative of fostering mathematics reasoning	TC217, 228	

Table 1 (Continued). Dependent and independent variables

Variables	Definition of variables	QN	CV
GOALSAND	Teacher's views and goals when teaching mathematics	TC217, 230	
Schools' variables			
Math teacher's qualifications	Percentage of mathematics teachers holding the qualifications by authorities	SC182Q01,06	
Professional development	Percentage of mathematics teachers attending professional development	SC025Q02	
Minutes of mathematics class	The length of a mathematics class	SC175Q01	
SMRATIO	Students-math teacher ratio	SC002	
EDULEAD	Educational leadership	SC201	
INSTLEAD	Instructional leadership	SC201	
MTTRAIN	Math teacher training	SC184	
NEGSCLIM	Negative school climate	SC172	
EDUSHORT	Shortage of educational material	SC017	
STUBEHA	Student-related factors affecting school climate	SC061	

Note. QN: Question number; CV: Categorical variables; & MQ: Multiple questions

Table 2. Descriptive statistics of dependent, student, teacher, and school variables across six economies

	Macau	Hong Kong	Australia	Malaysia	Georgia	Colombia
Dependent variables						
Students' mathematics score	551.49 (90.56)	539.98 (101.73)	486.73 (97.42)	408.75 (73.95)	389.80 (82.19)	383.09 (70.67)
SATJOB	-.32 (.91)	-.34 (.91)	-.08 (.96)	.06 (.88)	.53 (.96)	.62 (.97)
Students' variables						
AGE	15.80 (.29)	15.82 (.29)	15.76 (.29)	15.84 (.29)	15.85 (.28)	15.84 (.28)
GENDER	1.51 (.50)	1.52 (.50)	1.51 (.50)	1.49 (.50)	1.52 (.50)	1.49 (.50)
ESCS	-.45 (.91)	-.45 (1.00)	.39 (.85)	-.66 (1.04)	-.45 (.93)	-.97 (1.19)
MATHEASE	.11 (.31)	.14 (.35)	.13 (.33)	.06 (.24)	.08 (.27)	.09 (.29)
MATHMOT	.05 (.21)	.06 (.25)	.05 (.22)	.04 (.20)	.06 (.25)	.04 (.20)
MATHPREF	.11 (.31)	.13 (.34)	.13 (.34)	.08 (.27)	.11 (.32)	.11 (.32)
TEACHSUP	-.00 (.94)	.11 (1.11)	.14 (1.07)	.34 (1.01)	.23 (1.12)	.48 (1.07)
COGACRCO	.08 (.95)	.04 (1.02)	.13 (.95)	-.05 (.98)	.18 (1.14)	.19 (.13)
COGACMCO	.09 (.94)	.10 (.98)	.14 (.93)	.28 (.94)	.41 (1.09)	.54 (1.04)
DISCLIM	.38 (.88)	.35 (.95)	-.25 (.90)	.22 (.95)	.10 (1.02)	.01 (.90)
EXPO21ST	.11 (.88)	.02 (.90)	.29 (.91)	.20 (.99)	.31 (1.06)	.36 (1.06)
EXPOFA	.02 (.80)	.02 (.84)	.48 (.87)	.19 (.96)	.33 (1.04)	-.03 (1.04)
MATHEF21	-.04 (.98)	-.05 (1.07)	.24 (.93)	-.17 (.85)	-.02 (1.02)	.28 (.87)
MATHEFF	-.11 (1.22)	-.45 (1.26)	-.25 (1.15)	-.76 (1.01)	-.54 (1.25)	-.44 (1.10)
ANXMAT	.28 (1.11)	.23 (1.16)	.16 (1.05)	.51 (.94)	.04 (1.13)	.53 (.98)
MATHPERS	-.32 (.94)	-.25 (.96)	.14 (.93)	-.19 (1.05)	.00 (1.22)	.17 (1.06)
Mathematics teachers' variables						
AGE	38.24 (10.40)	40.65 (10.51)	43.52 (12.41)	43.29 (7.78)	52.43 (10.81)	44.24 (10.38)
GENDER	1.59 (.49)	1.71 (.46)	1.66 (4.23)	1.25 (.43)	1.18 (.39)	1.62 (.486)
PROPWORK	.80 (.27)	.77 (.31)	.58 (.58)	.62 (.33)	.69 (.31)	.53 (.30)
TCDISCLIMA	.56 (.82)	.51 (.86)	-.17 (.98)	.17 (.78)	.54 (.83)	.25 (.86)
EXPO21TC	-.11 (.91)	-.33 (.76)	.26 (.92)	.28 (1.21)	.08 (1.00)	.48 (1.06)
COGACMTC	-.18 (.88)	-.44 (.73)	-.03 (.93)	.02 (1.04)	.36 (.88)	.67 (.94)
COGACRTC	-.07 (.89)	-.51 (.70)	-.11 (.96)	-.31 (1.01)	.84 (.98)	.31 (1.04)
TCMGOALS	.15 (1.04)	-.13 (.83)	.14 (.92)	.12 (1.06)	.50 (1.07)	.23 (1.12)
Schools' variables						
Percent of qualifications	1.00 (.00)	.93 (.17)	.97 (.13)	.92 (.23)	.87 (.26)	.81 (.37)
Percentage of professional development	.69 (.37)	.55 (.39)	.84 (1.17)	.58 (.39)	.46 (.40)	.24 (.35)
Minutes of math class	40.65 (6.5)	44.90 (18.36)	81.03 (112.96)	77.96 (77.48)	43.70 (16.63)	71.01 (89.32)
Students-math teacher ratio	70.53 (21.74)	69.37 (21.96)	79.57 (23.40)	89.28 (18.25)	72.61 (30.14)	94.49 (17.05)
Educational leadership	.07 (.89)	-.41 (1.13)	.64 (.79)	.49 (.85)	.70 (1.01)	.24 (1.38)
Instructional leadership	.07 (.83)	-.41 (1.11)	.70 (.81)	.51 (.90)	.69 (1.02)	.33 (1.23)
Math teacher training	.39 (.78)	.12 (.91)	.68 (.63)	.68 (.69)	.38 (.83)	-.29 (1.04)
Negative school climate	-.26 (.95)	-1.10 (.67)	.27 (.84)	-.41 (.81)	-.88 (.90)	.22 (1.07)
Shortage of material	-.15 (.82)	--	-.72 (.85)	-.14 (.96)	.25 (1.23)	.55 (1.34)
Student factor school climate	-.03 (1.16)	-1.05 (1.11)	.04 (1.10)	-.40 (1.37)	-1.32 (1.42)	.26 (1.21)

Note. Values are presented as mean (standard deviation)

Table 2 provides an overview of the descriptive statistics for the key-dependent, student, teacher, and school variables across the six selected economies, highlighting variations in mathematics performance, student characteristics, teacher qualifications, and school resources between higher- and lower-performing countries.

Table 3. Descriptive statistics for mathematics performance in six economies: Content and process subscales

	Math	MCCR	MCQN	MCSS	MCUD	MPEM	MPFS	MPIN	MPRE
Macau (China)									
Mean	551.49	553.05	551.17	555.78	552.28	551.68	**556.38**	**550.99**	552.39
Standard deviation	90.56	94.59	94.56	96.78	94.92	91.12	98.53	95.94	91.08
Minimum	231.54	177.79	209.97	172.81	153.16	244.43	211.23	244.75	244.33
Maximum	803.63	855.17	864.84	874.96	901.33	838.00	855.98	829.94	835.03
Hong Kong (China)									
Mean	539.98	536.60	544.94	540.51	542.00	**546.88**	542.06	541.17	539.28
Standard deviation	101.73	102.98	110.75	104.31	112.87	111.25	108.67	110.74	100.71
Minimum	225.09	194.68	207.27	141.19	121.02	218.95	200.93	139.68	196.83
Maximum	876.30	843.51	878.47	893.46	903.59	899.27	870.02	882.15	835.08
Australia									
Mean	486.73	486.19	**483.09**	487.59	**492.87**	487.05	484.92	492.58	485.91
Standard deviation	97.42	101.34	102.95	99.03	107.37	107.69	108.27	100.38	99.65
Minimum	168.59	133.88	174.43	154.04	142.29	106.75	140.35	139.26	134.28
Maximum	808.14	833.71	852.90	858.79	845.96	888.16	851.79	806.60	831.14
Malaysia									
Mean	408.75	405.22	404.20	**415.53**	409.22	410.46	404.14	409.77	**401.33**
Standard deviation	73.95	78.08	79.83	78.61	76.51	80.92	84.41	74.97	74.80
Minimum	212.62	139.63	163.10	155.07	136.56	153.46	124.34	173.59	187.46
Maximum	728.55	735.00	717.96	766.12	745.04	767.76	754.58	723.81	795.94
Georgia									
Mean	389.80	384.47	**392.27**	389.34	382.80	392.77	390.31	**382.66**	383.79
Standard deviation	82.19	93.28	81.61	96.98	86.20	82.33	89.74	85.57	91.05
Minimum	174.57	116.71	142.57	78.86	55.48	152.44	95.63	122.59	96.52
Maximum	706.06	778.79	703.11	779.73	740.86	708.60	752.49	711.34	730.14
Colombia									
Mean	383.09	383.07	381.17	**370.11**	**384.53**	380.73	376.80	384.04	376.80
Standard deviation	70.67	78.04	72.45	82.94	77.51	68.84	83.15	79.09	78.86
Minimum	183.27	172.25	173.27	91.70	138.48	183.06	103.58	98.69	94.01
Maximum	674.12	703.96	695.79	699.75	676.33	677.08	759.10	709.76	720.59

RESULTS AND DISCUSSION

Comparative Analysis of Mathematical Performance Subscales

Since the PISA 2000 assessment, results have been reported on a scale with a mean of 500 and a standard deviation of 100 (OECD, 2024, p. 353). The PISA 2022 mathematics framework defines mathematical literacy as the ability to apply, interpret, and reason through mathematical problems in everyday life, equipping individuals to make informed decisions (OECD, 2023a, p. 20). This framework breaks mathematical literacy into four cognitive processes–reasoning, formulating, employing, and interpreting/evaluating–and organizes content into four domains: quantity, uncertainty and data, change and relationships, and space and shape (OECD, 2023a, p. 22). By integrating these cognitive and content elements, PISA 2022 offers a holistic assessment of students' mathematical capabilities, emphasizing their readiness to solve real-world challenges.

For measurement, the PISA mathematics assessment captures mathematical performance through two primary categories: content subscales and process subscales (OECD, 2024, p. 57). The content subscales measure proficiency in specific mathematical domains: MCCR assesses students' understanding of algebraic systems and patterns; MCQN focuses on numerical skills and everyday arithmetic; MCSS evaluates spatial reasoning and geometric understanding; MCUD measures probabilistic thinking and data literacy.

The process subscales assess students' cognitive approaches to problem-solving: MPEM evaluates procedural fluency in applying mathematical methods; MPFS assesses the ability to model real-world situations mathematically; MPIN measures how students apply and interpret mathematical outcomes; MPRE tests logical reasoning and critical analysis.

Together, these subscales provide a comprehensive view of student mathematical performance. For instance, **Table 3** highlights how students from the six economies perform across both content and process dimensions, revealing meaningful patterns. High-performing economies like Macau (China) and Hong Kong (China) excel in MCUD and MPFS, showcasing their students' strength in probabilistic thinking and mathematical modeling. This reflects these economies' emphasis on integrating data literacy and problem-solving into their curricula. Conversely, lower-performing economies such as Colombia and Malaysia show comparative weaknesses in MPRE and MCSS, indicating challenges in fostering critical reasoning and spatial understanding.

Hong Kong and Macau: High performance with variability

Both Hong Kong and Macau perform strongly in mathematics, with high mean scores across all subscales, particularly excelling in problem-solving (MPFS) and procedural fluency in applying mathematical methods (MPEM). This reflects robust educational frameworks in both regions that effectively balance conceptual and applied mathematical knowledge. Their students demonstrate strong advanced mathematical processing and problem-solving abilities, highlighting the strengths of their curricula and instructional practices.

However, notable differences in student performance patterns emerge between the two regions. In Hong Kong, the relatively high standard deviations in scores indicate significant variability in student outcomes. While many students excel, a portion of the student population struggles to keep up, suggesting challenges in providing adequate support for lower-achieving students. This variability may stem from socioeconomic disparities, differences in school resources, or varying levels of parental involvement. To address this, targeted support programs could be implemented, such as additional tutoring for struggling students, enhanced teacher training to identify and address diverse learning needs, and policies aimed at reducing resource gaps across schools.

In contrast, Macau shows a more consistent level of performance among its students, with lower variability in scores. This consistency may point to a more equitable distribution of educational opportunities and uniform implementation of educational policies. However, while the overall performance is strong, Macau’s students show room for improvement in applying and interpreting mathematical outcomes (MPIN), which are crucial skills for adapting to the demands of a dynamic global economy. To address this, Macau could consider curriculum enhancements that emphasize critical thinking and real-world applications of mathematics, such as incorporating more project-based learning and interdisciplinary problem-solving activities into classrooms.

By focusing on tailored solutions, both regions can continue to build on their strengths while addressing specific areas for improvement. For Hong Kong, efforts to support lower-achieving students could reduce performance variability and ensure more equitable outcomes. For Macau, fostering higher-order cognitive skills in mathematical application and interpretation could further enhance its students’ readiness for global challenges. These strategies not only address current disparities but also ensure that both regions remain at the forefront of mathematics education in an increasingly competitive and evolving educational landscape.

Australia: Strength in data literacy but areas for improvement

Australia’s mathematics performance demonstrates notable strength in the uncertainty and data (MCUD) subscale, indicating that students are proficient in probabilistic thinking and data literacy. This reflects the emphasis in Australian curricula on applied mathematics and statistical reasoning, aligning with global trends that prioritize data literacy for real-world problem-solving. However, Australia’s performance in other areas, such as the quantitative skills (MCQN) subscale, is relatively lower compared to regions like Hong Kong and Macau. This subscale assesses numerical skills and everyday arithmetic, suggesting that while Australian students excel in advanced statistical and probabilistic thinking, there may be gaps in foundational numerical competencies.

The underlying causes of this disparity may include differences in curriculum design, where greater emphasis is placed on higher-order skills at the expense of foundational arithmetic. Additionally, variability in teaching quality and resource distribution across schools could contribute to these gaps, particularly in underserved or rural areas. Addressing this issue will require targeted interventions aimed at bolstering core numerical skills to create a more balanced mathematical skill set. Strategies such as revising the curriculum to ensure greater emphasis on foundational arithmetic and providing professional development for teachers to strengthen instructional practices in this area could be effective.

Furthermore, the higher standard deviations in student outcomes indicate disparities in performance across different demographic and geographic groups. These disparities may stem from inequities in access to quality education, particularly for students from lower socioeconomic backgrounds or remote areas. To improve consistency and equity in mathematics performance, Australia could implement targeted support programs, such as additional funding for under-resourced schools, tutoring initiatives for struggling students, and policies to attract and retain highly qualified teachers in disadvantaged regions.

By addressing these gaps and focusing on equitable educational practices, Australia can strengthen its overall mathematics performance and better position itself against top-performing economies. This approach not only enhances student outcomes across all domains of mathematics but also ensures that every student has the opportunity to succeed, regardless of their background or location.

Malaysia, Georgia, and Colombia: Challenges and opportunities for growth

Malaysia, Georgia, and Colombia face significant challenges, with below-average performance across most mathematical subscales. The results highlight persistent difficulties in areas requiring higher-order thinking and reasoning (MPRE), as well as applying mathematical concepts in real-world scenarios (MPFS and MPIN). For instance, in the MPRE subscale, students in these countries scored on average 50-70 points below the OECD mean, indicating significant gaps in critical reasoning and abstract thinking. This suggests that while students may develop basic numeracy skills, they struggle to transition to more complex mathematical tasks that demand analytical and problem-solving abilities.

The standard deviations in these countries are relatively lower than in higher-performing economies like Hong Kong and Australia, suggesting more consistent performance but at a lower level. A majority of students achieve at a similar, modest level, with fewer high achievers and minimal variation in outcomes. This consistency likely reflects systemic challenges, such as insufficient instructional support, curriculum design that prioritizes rote learning over critical thinking, and limited access to high-quality educational resources, particularly in rural and underserved areas.

To address the challenges identified, a comprehensive set of recommendations is proposed, focusing on strengthening the foundational elements of mathematics education through targeted reforms. A key priority is enhancing teacher training and support, as educators play a pivotal role in cultivating higher-order thinking skills among students. Professional development programs should be designed to equip teachers with effective instructional strategies that foster abstract reasoning and problem-solving abilities. For instance, approaches such as inquiry-based learning and collaborative problem-solving exercises could encourage a shift away from rote memorization toward deeper conceptual understanding. By empowering teachers with these tools, classrooms can become dynamic spaces for intellectual exploration.

Equally important is the need for curriculum redesign, which should prioritize real-world applications and critical thinking. Countries like Malaysia, Georgia, and Colombia could benefit from integrating project-based learning and interdisciplinary approaches into their educational frameworks. Such initiatives would enable students to engage with mathematical concepts in practical, relatable ways, fostering a more profound connection between theoretical knowledge and everyday experiences.

Addressing disparities in educational resources is another critical step toward equity and excellence. Governments must implement policies that ensure rural and underserved schools have access to the same quality of instructional materials, digital tools, and experienced teachers as their urban counterparts. Equitable resource allocation is not only a matter of fairness but also a prerequisite for achieving consistent performance improvements across diverse student populations.

Additionally, establishing robust national assessment systems is essential for monitoring progress and identifying areas for targeted interventions. By developing assessments that measure critical reasoning and real-world problem-solving abilities, countries can generate actionable data to inform policy adjustments. These systems would provide an ongoing mechanism to evaluate and refine educational practices, ensuring alignment with evolving global standards.

Predictors of Mathematics Performance: Insights from Student Questionnaires

Table 4 and **Table 5** present the outcomes of stepwise regression models, where the dependent variable is students' mathematics scores in PISA 2022. The models use only student-level predictors on self-reported data from student questionnaires.

Table 4. Stepwise regression analysis of student mathematics scores in high-performing economies

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Constant	R^2
Macau (China)												
MATHEF	38.052*** (.978)	38.934*** (.983)	38.693 (.979)	36.059*** (1.070)	35.541*** (1.070)	35.305*** (1.068)	3.211*** (1.385)	35.174*** (1.069)			556.351*** (1.193)	.261
COGACMCO		-8.335*** (1.265)	-8.326 (1.26)	-8.429*** (1.255)	-9.353*** (1.261)	-9.430*** (1.258)	-10.259*** (1.307)	-10.213*** (1.307)			557.230*** (1.194)	.268
ESCS			4.111*** (.666)	3.980*** (.664)	3.961*** (.661)	3.857*** (.660)	3.820*** (.660)	3.823*** (.660)			558.967*** (1.222)	.274
ANXMAT					-6.669*** (1.157)	-6.837*** (1.154)	-6.892*** (1.154)	-6.985*** (1.154)			560.954*** (1.247)	.280
DISCLIM					7.634*** (1.351)	7.67*** (1.348)	7.646*** (1.347)	7.64*** (1.347)			557.655*** (1.347)	.285
AGE						18.914*** (4.019)	18.469*** (4.021)	18.336*** (4.020)			258.702*** (63.535)	.289
EXPO21ST							3.211** (1.385)	3.173* (1.384)			265.436*** (63.569)	.289
MATHMOT								-7.847* (3.648)			267.999*** (63.553)	.290
Hong Kong (China)												
MATHEF	31.349*** (1.206)	29.223*** (1.198)	30.085*** (1.191)	29.126*** (1.185)	28.835*** (1.182)	25.808*** (1.334)	29.733*** (1.715)	29.508*** (1.713)	29.374*** (1.712)	29.188*** (1.713)	570.394***	.160
ESCS		17.608 (1.515)	17.446*** (1.499)	17.121*** (1.484)	17.544*** (1.476)	17.697*** (1.473)	17.755*** (1.471)	17.845*** (1.469)	17.871*** (1.467)	17.809*** (1.466)	577.187***	.191
COGSCMCO			-12.729*** (1.531)	-14.435*** (1.529)	-16.744*** (1.556)	-16.618*** (1.553)	-15.515*** (1.580)	-15.404*** (1.578)	-15.333*** (1.576)	-17.802*** (1.868)	578.376***	.206
DISCLIM				13.675*** (1.612)	11.844*** (1.624)	11.528*** (1.623)	11.662*** (1.62)	11.952*** (1.62)	11.902*** (1.618)	11.844*** (1.617)	572.692***	.222
TEACHSUP					9.614*** (1.407)	9.303*** (1.406)	9.149*** (1.404)	8.958*** (1.403)	8.869*** (1.402)	8.391*** (1.415)	572.235***	.232
ANXMAT						-5.924*** (1.433)	-6.966*** (1.459)	-6.256*** (1.472)	-6.219*** (1.47)	-6.257*** (1.469)	572.834***	.235
MATHEF21							-7.414*** (2.040)	-7.543*** (2.037)	-7.388*** (2.036)	-7.42*** (2.034)	574.221***	.238
MATHEASE								9.845*** (2.875)	9.691*** (2.872)	10.061*** (2.874)	572.246***	.240
AGE									14.139** (4.941)	14.137** (4.937)	348.709***	.242
COGACRCO										4.448** (1.808)	348.697***	.243
Australia												
MATHEF	48.13*** (.753)	42.298*** (.750)	40.746*** (.757)	38.887*** (.801)	38.247*** (.807)	38.643*** (.807)	41.775*** (1.052)	41.671*** (1.052)	41.518*** (1.053)	41.525*** (1.053)	510.132***	.334
ESCS		28.69*** (1.036)	28.199*** (1.028)	28.382*** (1.026)	28.421*** (1.024)	28.262*** (1.021)	28.425*** (1.020)	28.465*** (1.020)	28.588*** (1.021)	28.565*** (1.020)	495.826***	.391
DISCLIM			10.644*** (.928)	10.172*** (.928)	9.442*** (.934)	9.703*** (.932)	9.711*** (.931)	9.652*** (.931)	9.650*** (.930)	9.636*** (.930)	498.125***	.401
ANXMAT				-5.762*** (.836)	-5.386*** (.837)	-5.536*** (.835)	-6.070*** (.841)	-6.100*** (.841)	-5.880*** (.845)	-5.891*** (.844)	498.432***	.404
TEACHSUP					4.607*** (.789)	5.817*** (.804)	5.921*** (.804)	5.976*** (.804)	5.914*** (.804)	5.888*** (.803)	497.342***	.407
COGACMCO						-4.168*** (.584)	-3.782*** (.589)	-3.766*** (.589)	-3.828*** (.589)	-3.826*** (.589)	498.428***	.410
MATHEF21							-5.899*** (1.275)	-5.862*** (1.275)	-5.923*** (1.274)	-5.933*** (1.274)	500.480***	.412
AGE								8.034*** (2.801)	8.115*** (2.800)	8.203*** (2.799)	373.737***	.412

Table 4 (Continued). Stepwise regression analysis of student mathematics scores in high-performing economies

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Constant	R^2
MATHPREF									6.408*** (2.322)	7.462*** (2.359)	371.511***	.413
MATHMOT										-5.846** (2.323)	370.347***	.413

Table 5. Stepwise regression analysis of student mathematics scores in lower-performing economies

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Constant	R^2
Malaysia												
MATHEF	31.388*** (.844)	26.810*** (.825)	26.105*** (.820)	22.526*** (.897)	26.671*** (1.128)	26.375*** (1.128)	26.376*** (1.127)	26.131*** (1.127)	25.96*** (1.127)	25.956*** (1.127)	437.416***	.186
DISCLIM		21.797*** (.882)	21.633*** (.874)	20.188*** (.881)	20.093*** (.879)	20.346*** (.879)	20.449*** (.879)	20.442*** (.877)	20.493*** (.877)	20.387*** (.878)	428.992***	.260
ESCS			2.623*** (.245)	2.594*** (.243)	2.598*** (.242)	2.574*** (.242)	2.571*** (.242)	2.559*** (.241)	2.560*** (.241)	2.557*** (.241)	429.898***	.274
MATHPERS				8.219*** (.866)	9.200*** (.878)	8.869*** (.880)	9.624*** (.903)	9.340*** (.904)	9.262*** (.903)	9.249*** (.903)	429.034***	.284
MATHEF21					-7.888*** (1.307)	-8.050*** (1.306)	-7.438*** (1.315)	-7.441*** (1.313)	-7.460*** (1.312)	-7.412*** (1.312)	431.035***	.288
EXPOFA						2.265*** (.508)	2.370*** (.508)	2.345*** (.507)	2.352*** (.507)	2.325*** (.507)	430.171***	.291
COGACMCO							-3.335*** (.910)	-6.123*** (1.093)	-6.109*** (1.092)	-6.174*** (1.092)	431.325***	.292
COGACRCO								4.711*** (1.025)	4.784*** (1.025)	4.857*** (1.025)	432.111***	.294
MATHPREF									5.243*** (1.826)	6.532*** (1.889)	431.473***	.295
MATHMOT										-4.325*** (1.636)	431.696***	.296
Georgia												
MATHEF	30.389*** (1.117)	26.147*** (1.119)	23.001*** (1.173)	22.268*** (1.175)	23.044*** (1.175)	22.033*** (1.174)	22.248*** (1.170)	22.270*** (1.167)	20.945*** (1.214)	20.883*** (1.213)	431.060***	.200
ESCS		21.941*** (1.516)	21.326*** (1.502)	21.205*** (1.494)	20.425*** (1.491)	19.958*** (1.480)	19.899*** (1.474)	20.098*** (1.472)	19.729*** (1.472)	19.722*** (1.471)	436.718***	.253
ANXMAT			-10.082*** (1.246)	-9.198*** (1.251)	-9.546*** (1.244)	-9.535*** (1.234)	-9.533*** (1.229)	-9.336*** (1.228)	-8.529*** (1.243)	-8.645*** (1.242)	434.897***	.269
DISCLIM				7.340*** (1.331)	9.220*** (1.359)	8.317*** (1.354)	8.067*** (1.349)	8.075*** (1.346)	7.509*** (1.351)	7.519*** (1.350)	433.816***	.277
COGACMCO					-7.583*** (1.254)	-12.302*** (1.410)	-12.118*** (1.405)	-11.119*** (1.427)	-11.950*** (1.440)	-11.835*** (1.439)	436.853***	.286
COGACRCO						9.661*** (1.359)	9.433*** (1.355)	9.409*** (1.352)	9.152*** (1.350)	8.981*** (1.351)	436.252***	.298
MATHEASE							-5.692*** (1.164)	-5.827*** (1.162)	-5.797*** (1.159)	-5.834*** (1.158)	437.580***	.303
EXPO21ST								-4.769*** (1.275)	-5.237*** (1.278)	-7.089*** (1.475)	438.821***	.307
MATHPERS									4.800*** (1.243)	4.571*** (1.245)	438.408***	.310
EXPOFA										3.807*** (1.516)	437.585***	.311
Colombia												
ESCS	26.264*** (.732)	22.736*** (.718)	22.403*** (.717)	22.496*** (.713)	22.64*** (.711)	22.641*** (.709)	22.60*** (.708)	22.549*** (.708)	22.549*** (.707)	22.656*** (.707)	427.422***	.199
MATHEF		17.306*** (.789)	18.248*** (.797)	16.771*** (.818)	15.715*** (.835)	15.488*** (.833)	15.210*** (.834)	15.198*** (.833)	15.028*** (.834)	14.915*** (.834)	431.555***	.267
COGACMCO			-5.678*** (.816)	-7.265*** (.840)	-7.071*** (.838)	-7.457*** (.838)	-7.365*** (.837)	-7.296*** (.836)	-7.328*** (.835)	-7.358*** (.835)	434.792***	.274
MATHPERS				6.229*** (.846)	5.634*** (.849)	5.066*** (.852)	5.317*** (.853)	5.254*** (.852)	5.114*** (.852)	5.182*** (.852)	434.063***	.281
ANXMAT					-5.169*** (.878)	-4.965*** (.876)	-4.278*** (.889)	-4.330*** (.888)	-4.112*** (.889)	-4.106*** (.888)	436.487***	.286
DISCLIM						5.338*** (.944)	5.803*** (.948)	5.722*** (.948)	5.855*** (.947)	5.723*** (.947)	436.469***	.290
GENDER							7.349*** (1.678)	7.476*** (1.677)	7.155*** (1.677)	7.194*** (1.676)	424.898***	.293
MATHMOT								-4.224*** (1.271)	-5.846*** (1.348)	-5.757*** (1.347)	425.025***	.294
MATHPREF									6.232*** (1.734)	6.237*** (1.732)	424.675***	.295
AGE										8.891*** (2.858)	283.772***	.296

Key similarities across all economies

Across all six economies, mathematics self-efficacy (MATHEF) consistently emerges as one of the most powerful predictors of student mathematics performance: students with higher confidence in their mathematical abilities tend to perform significantly

Table 6. Factors influencing math teachers' job satisfaction: Stepwise regression results of six economies

	Model 1	Model 2	Model 3	Model 4	Model 5	Constant	R^2
Macau (China)							
COGACMTC	.310*** (.061)	.306*** (.060)	.222*** (.067)	.221*** (.067)		-.263***	.089
PROPWORK		-.602*** (.196)	-.572*** (.194)	-.469** (.199)		.215	.120
EXPO21TC			.173*** (.065)	.170*** (.064)		.195	.143
AGE				.011** (.005)		-.304	.157
Hong Kong (China)							
TCDISCLIMA	.278*** (.054)	.251*** (.054)	.254*** (.053)			-.492***	.066
TCMGOALS		.237*** (.055)	.187*** (.059)			-.452***	.109
COGACMTC			.163** (.066)			-.387***	.124
Australia							
TCDISCLIMA	.269*** (.020)	.265*** (.020)	.262*** (.020)	.265*** (.020)		-.026	.078
TCMGOALS		.111*** (.022)	.094*** (.023)	.106*** (.024)		-.041**	.089
COGACMTC			.048** (.023)	.085*** (.028)		-.038*	.091
COGACRTC			-.064 (.027)	-.064** (.027)		-.045**	.093
Malaysia							
TCMGOALS	.246*** (.026)	.230*** (.026)	0190*** (.029)	.182*** (.029)	.186*** (.029)	.029	.090
TCDISCLIMA		.168*** (.036)	.158*** (.035)	.156*** (.035)	.163*** (.035)	.001	.112
COGACMTC			.093*** (.029)	.096*** (.029)	.095** (.029)	.006	.121
AGE				.010 *** (.003)	.010 *** (.003)	-.437***	.130
GENDER					.156** (.063)	-.615***	.135
Georgia							
TCMGOALS	.312*** (.051)	.275*** (.051)				.381***	.112
TCDISCLIMA		.233*** (.062)				.267***	.153
Colombia							
TCDISCLIMA	.350*** (.063)	.346*** (.061)	.296*** (.062)			.531***	.095
AGE		.022*** (.005)	.020*** (.005)			-.449*	.149
COGACMTC			.178*** (.057)			-.476**	.177

better. This underscores the universal importance of fostering self-efficacy to boost student achievement, regardless of the country's overall performance level.

All six economies face challenges with cognitive activation in math classes. The negative relationship between COGACMCO and math performance highlights a potential issue with implementing cognitively demanding tasks. Students may either need more foundational skills to engage with complex tasks effectively, or there may be a misalignment between the complexity of classroom activities and the structure of math assessments. Meanwhile, disciplinary climate (DISCLIM) is critical across six economies, where a well-managed classroom can provide the stability and structure that compensates for other educational shortcomings. Math anxiety (ANXMAT) negatively influences student performance in five economies except Malaysia, with higher levels of anxiety associated with lower mathematics scores. This finding highlights the consistent role that emotional factors play in student learning, regardless of the broader educational context. Reducing math anxiety could be an essential strategy for improving math achievement in higher- and lower-performing economies.

Critical differences between high- and lower-performing economies

In lower-performing economies, the impact of SES is more pronounced. For instance, in Malaysia and Colombia, students from wealthier socioeconomic backgrounds perform substantially better than their peers from disadvantaged backgrounds. This greater disparity indicates that socioeconomic inequalities play a more significant role in shaping educational outcomes in these countries. While SES is still a significant predictor in higher-performing economies, its influence is less pronounced than in lower-performing economies. This suggests that high-performing economies may have more robust mechanisms, such as equitable access to quality education, which help mitigate the effects of socioeconomic disparities.

Gender does not emerge as a strong predictor in higher-performing economies. In these contexts, the coefficients for gender are generally small or insignificant, suggesting that gender differences in math performance are less pronounced. However, in lower-performing economies, gender plays a more significant role. For instance, in Colombia, gender is a significant predictor, with males typically outperforming females in math. This suggests that in these contexts, there may be cultural or structural factors that contribute to gender disparities in mathematics achievement. In some higher-performing economies, Age plays a moderate role. For example, older students tend to perform better in Australia, though this effect is less intense than other predictors like MATHEF or ES. Age tends to have a more substantial positive effect in lower-performing economies like Colombia. This could be because older students may have had more exposure to content or may have repeated grades, which can boost their performance relative to their younger peers. Teacher support (TEACHSUP) is present in higher-performing economies like Hong Kong and Australia but absent in lower-performing economies. This could suggest that in contexts with more resources and better educational systems, teacher support further enhances student outcomes, whereas in lower-performing economies, systemic issues may overshadow the potential impact of teacher support.

Factors Influencing Teachers' Job Satisfaction: Insights from Teacher Questionnaires

Table 6 shows mathematics teachers' satisfaction with their job environment based on various factors across six economies. It reveals several patterns regarding the variables influencing satisfaction.

Key similarities across all economies

Across five economies, except Macau, the disciplinary climate in mathematics (TCDISCLIMA) significantly determines teacher satisfaction. This suggests that classroom management and student behavior are crucial to teachers' perception of their working conditions. In environments where discipline is maintained, teachers report higher satisfaction. Another recurring theme is the importance of pedagogical alignment, captured by the variable goals and views about teaching mathematics (TCMGOALS). Teachers who feel that their teaching aligns with their goals–for example, prioritizing problem-solving skills or emphasizing conceptual understanding–are generally more satisfied. This finding indicates that teachers' satisfaction is closely tied to whether they can achieve their teaching objectives in the classroom. Encouraging mathematical thinking (COGACMTC) is also a variable that plays a notable role in teacher satisfaction. This suggests that their job satisfaction increases when teachers feel they are successfully encouraging students to think mathematically and make connections between mathematical concepts.

Critical differences between high- and lower-performing economies

In Macau, the variable proportion of working years at this school (PROPWORK) has a significant negative relationship with job satisfaction. This suggests that teachers with a longer tenure at a single school report lower satisfaction levels. This could reflect stagnation or lack of professional growth opportunities within the same institution. Additionally, age is a significant factor, indicating that older teachers in Macau might experience reduced satisfaction, possibly due to changing educational dynamics or challenges in adapting to newer methods. Another notable feature in Macau is the importance of teaching mathematical reasoning and 21st century mathematics topics (EXPO21TC), positively associated with job satisfaction. Teachers who frequently teach advanced topics report higher satisfaction, reflecting a sense of professional accomplishment when engaging students in contemporary, relevant mathematics content.

In Hong Kong, TCDISCLIMA and TCMGOALS emerge as the most significant predictors of teacher satisfaction. Teachers in Hong Kong place a high value on maintaining a disciplined classroom and aligning their teaching with their educational goals. While COGACMTC (encouraging mathematical thinking) plays a role, it has a relatively minor impact compared to other variables. This suggests that teachers in Hong Kong prioritize goal alignment and classroom management more than the specific pedagogical technique of fostering mathematical thinking.

In Australia, like in Hong Kong, the disciplinary climate, goals, and views on teaching mathematics are central to teacher satisfaction. However, a unique aspect in Australia is the influence of fostering reasoning (COGACRTC), which hurts later models. This might indicate that teachers in Australia who focus on fostering mathematical reasoning face challenges that reduce their overall satisfaction–due to difficulties in implementing such practices or a mismatch between student abilities and instructional goals. In Malaysia, age is a significant predictor, with younger teachers reporting higher satisfaction levels. This could suggest that younger teachers are more adaptable or aligned with reforms focused on modernizing mathematics education.

Two-level HLM Analysis of Student Mathematics Performance

Table 7 and **Table 8** present the two-level HLM findings that examine the factors influencing student mathematics performance in six economies. The outcome variable is student mathematics scores, with predictors drawn from student-level characteristics (level 1) and school factors (level 2). The results highlight key insights into how individual attributes, classroom practices, and school environments contribute to mathematical achievement across these diverse educational systems.

Age and cognitive development

In Macau, Hong Kong, Australia, and Colombia, age is a significant and positive predictor of mathematics performance. The significant results suggest that cognitive development and extended learning exposure contribute to improved mathematics outcomes. These results highlight the importance of understanding the age-related dynamics in student learning.

Gender and mathematics achievement

Gender differences are significant in Macau, Hong Kong, and Colombia, where there are observable disparities in mathematics performance. Male students perform better in Macau and Hong Kong, whereas in Colombia, girls outperform boys. In Australia, Georgia, and Malaysia, gender differences are insignificant, suggesting more gender equity in mathematics achievement.

Socio-economic status and educational equity

In Australia, Hong Kong, Georgia, and Colombia, the SES variable is highly significant, indicating a strong positive correlation between higher socioeconomic status and improved mathematics performance. This effect is particularly pronounced in Australia and Georgia. Conversely, in Macau and Malaysia, the SES variable does not reach statistical significance, suggesting that SES exerts a comparatively weaker influence on mathematics performance in these contexts.

Emotional and motivational factors: Math anxiety and self-efficacy

In Macau, Hong Kong, Australia, Georgia, and Colombia, mathematics anxiety (ANXMAT) exhibits a significant and negative relationship with math performance, indicating that higher levels of anxiety are consistently associated with lower student achievement in mathematics. However, in Malaysia, the impact of anxiety on math outcomes is not statistically significant, suggesting a comparatively weaker influence in these regions. Conversely, mathematics effort self-efficacy (MATHEF)–students' belief in their ability to succeed–demonstrates a significant and positive effect across all six economies. This relationship is solid in Macau and Australia, underscoring the critical role that students' self-perceived effort plays in enhancing their mathematics performance.

Table 7. Two-level HLM results for student mathematics performance in high-performing economies

	Macau (China)		Hong Kong (China)		Australia	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Students' variables						
AGE	9.611812	3.077**	16.293537	3.613***	9.865292	3.418***
GENDER	9.455423	3.144**	9.737356	2.843**	3.325947	1.931
ESCS	1.108142	1.125	3.279558	2.192*	22.135820	17.178***
MATHMOT	-4.653386	-1.407	-4.887208	-1.304	-3.885777	-1.435
MATHEASE	-.494040	-.226	7.542886	2.454*	3.396630	2.288*
MATHPREF	-.167271	-.052	-.883418	-.170	5.127036	2..260*
DISCLIM	2.548712	1.518	5.677759	3.771***	8.375015	7.875***
TEACHUP	1.459231	1.370	8.645138	5.986***	7.478032	8.045***
COGACRCO	2.771912	1.659	1.485877	0.748	2.225725	1.935
COGACMCO	-9.832492	-6.523***	-10.404259	-6.568***	-12.851036	-11.636***
EXPOFA	-2.216018	-1.458	3.112576	1.498	-.790356	-.674
EXPO21ST	.838209	.578	-3.109287	-1.589	3.260624	2.740**
MATHEF	26.116157	18.516***	19.510746	10.888***	36.954901	32.053***
MATHEF21	-.625503	-.344	-3.506031	-1.626	-4.623703	-3.200**
ANXMAT	-9.827285	-9.301***	-8.711563	-5.421***	-6.444750	-7.204***
MATHPERS	1.757136	1.247	-.541096	-.356	.974237	0.833
Schools' variables						
Percent of qualifications	-	-	.183459	.460	.025286	0.321
Percentage of professional development	.144992	.929	.320637	2.447*	.021398	2.168*
Minutes of math class	.979336	1.721	.059980	.258	-.074052	-1.351
Students-math teacher ratio	.331603	1.243	.307442	1.195	.140259	2.266*
Educational leadership	-21.794527	-.926	-53.227698	-1.993*	1.992796	0.287
Instructional leadership	18.347498	.605	52.323904	1.866	-1.049726	-.162
Math teacher training	13.342272	1.435	-1.015824	-.180	-.249915	-.119
Negative school climate	-6.757325	-1.209	-2.990048	-.397	-10.620251	-5.423***
Shortage of material	15.316530	1.802	-	-	-4.130742	-2.921**
Student factor school climate	-19.952167	-4.741***	-10.300681	-2.250*	4.692916	2.427*

Table 8. Two-level HLM results for student mathematics performance in lower-performing economies

	Malaysia		Georgia		Colombia	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Students' variables						
AGE	4.787133	1.898	9.084214	2.206*	10.201362	3.555***
GENDER	.154565	.104	3.761486	1.439	10.391244	6.216***
ESCS	4.054668	1.326	12.365008	7.321***	8.664331	10.126***
MATHMOT	-1.854607	-1.155	-2.395106	-1.682	-3.147273	-2.433*
MATHEASE	-2.269811	-1.700	-3.81953	-3.973***	-.824500	-.623
MATHPREF	5.039754	2.484*	4.408955	1.931	6.725874	2.504*
DISCLIM	16.681726	16.154***	3.205540	1.984*	2.617161	2.790**
TEACHUP	1.858199	2.084*	1.375583	0.978	-.849135	-.892
COGACRCO	2.368636	2.312*	5.327740	3.928***	1.848215	2.245*
COGACMCO	-3.866659	-3.900***	-8.352820	-6.239***	-5.909698	-5.602***
EXPOFA	6.765952	7.089***	3.364385	2.339*	0.089005	0.100
EXPO21ST	-1.158051	-1.307	-4.621002	-3.045**	-.861636	-.999
MATHEF	18.192325	14.571***	17.209429	11.125***	11.766873	10.669***
MATHEF21	-3.885225	-3.109**	-.783259	-.461	-1.255960	-1.061
ANXMAT	-.141150	-.153	-7.450288	-5.444***	-4.847418	-5.940***
MATHPERS	6.288910	7.134***	6.457706	5.342***	5.222800	6.240***
Schools' variables						
Percent of qualifications	-.105493	-.770	.460317	4.178***	.061640	.893
Percentage of professional development	.060849	1.080	-.000802	-.056	.168155	2.275*
Minutes of math class	-.013066	-.285	-.204747	-1.215	0.093978	0.768
Students-math teacher ratio	.181464	1.241	-.170857	-1.492	0.005471	0.032
Educational leadership	17.442594	0.995	-18.282950	-1.211	-.525152	-.073
Instructional leadership	-13.429664	-.802	19.939499	1.268	.864475	.092
Math teacher training	1.452010	0.444	0.925780	0.231	1.099515	0.444
Negative school climate	0.441089	0.145	3.128546	3.798489	1.478953	0.406
Shortage of material	-5.402961	-2.097*	-2.193953	-.798	-6.707407	-3.050**
Student factor school climate	-5.382176	-2.237*	-4.059318	-1.348	-6.098564	-1.938

Motivation and cognitive engagement

Mathematics motivation (MATHMOT) does not show a significant relationship with math performance in any of the six economies except Colombia, where a negative correlation is observed. This suggests that higher motivation in Colombia may paradoxically reflect students struggling with mathematics, indicating a complex relationship between motivation and performance. In contrast, mathematics ease (MATHEASE), representing students' perceived ease with math, shows a significant and positive effect in Australia and Hong Kong, indicating that students who find math easier and are more confident tend to perform better. However, in Georgia, the relationship is significant and negative, suggesting that self-confidence may be linked to other challenges, possibly related to overconfidence or unmeasured factors. In Macau, Malaysia, and Colombia, MATHEASE is not statistically significant, indicating no clear association between self-perceived math ease and performance in these contexts.

Cognitive activation and instructional practices

Contrary to expectations, cognitive activation in mathematics (COGACMCO) shows a negative association with student mathematics performance in all six economies. This suggests encouraging students to think critically and connect mathematical concepts is a valuable instructional approach, but it may only sometimes translate into immediate performance gains. One possible explanation is that the increased cognitive demands may challenge students, especially those who still need to be fully equipped to handle higher-order thinking, potentially resulting in lower scores.

Classroom climate and teacher support

Disciplinary climate (DISCLIM) and teacher support (TEACHSUP) are essential in shaping student mathematics performance across different economies. Disciplinary climate (DISCLIM) shows a positive and significant relationship with math performance in five of the six economies, with the most potent effects observed in Malaysia and notable impacts in Hong Kong and Australia. This suggests that a well-managed classroom environment significantly enhances students' academic outcomes. In Macau, however, this relationship could be more statistically significant, indicating a stronger or more nuanced connection between classroom discipline and performance. Similarly, teacher support (TEACHSUP) significantly improves math performance in Australia, Hong Kong, and Malaysia, underscoring the importance of supportive teacher-student interactions. However, the influence of teacher support is less direct in Macau, Georgia, and Colombia, where the relationship could be more statistically significant, indicating regional differences in how teacher support affects academic achievement. Together, these findings highlight the critical roles of both classroom environment and teacher support in fostering positive educational outcomes, though the extent of their impact varies across different educational systems.

Leadership, resources, and school climate

School leadership plays varying roles across the six economies. In Australia, collaborative leadership practices positively correlate with student performance, suggesting that shared leadership models support effective teaching and learning. However, in Colombia, top-down leadership appears to have adverse effects, emphasizing the need for context-specific leadership practices. The availability of resources significantly affects performance in Colombia, where a shortage of materials is linked to lower math scores. This highlights the critical need for adequate school infrastructure to support student learning. Additionally, adverse school climates in Malaysia and Colombia reduce student performance, underscoring the importance of safe and supportive learning environments in promoting academic success.

Comparative insights and analysis

Age and self-efficacy positively influence math performance across most regions, highlighting the role of cognitive development and student confidence. However, gender disparities are region-specific: boys outperform girls in Macau and Hong Kong, while girls excel in Colombia. SES significantly affects performance in Australia, Hong Kong, and Colombia, while its impact is less pronounced in Macau and Malaysia, suggesting varied levels of educational equity.

Emotional factors such as math anxiety negatively impact performance in most regions, while motivation has complex effects, particularly in Colombia, where higher motivation correlates with struggling students. Surprisingly, cognitive activation, which promotes critical thinking, negatively correlates with performance, indicating that its short-term benefits may take time. Positive classroom climates and teacher support are crucial in many economies but vary significantly across regions. School leadership and resource availability also play essential roles, especially in contexts like Australia and Colombia, where collaborative leadership and resource shortages, respectively, affect student outcomes.

A key takeaway from this analysis is that improving mathematics achievement requires a multifaceted approach that addresses individual and school-level factors. While cognitive development, self-efficacy, and a positive classroom environment are universally important, the influence of SES, gender, and emotional factors like anxiety and motivation varies across different contexts. This highlights the need for targeted, context-specific interventions to address socioeconomic disparities and foster supportive learning environments. Additionally, while cognitive activation (critical thinking) is essential for long-term success, its immediate impact on performance may need to be more evident, suggesting a need for balanced instructional strategies that align with students' readiness.

This comparison emphasizes that sustainable improvements in mathematics performance require a holistic approach–combining effective instructional practices, emotional well-being support, and resource equity. Policymakers in lower-performing economies can draw lessons from high-performing systems, particularly in leveraging cognitive activation, fostering collaborative leadership, and creating positive school climates. By addressing these factors strategically, educational systems can move toward more equitable and effective student learning outcomes.

Two-level HLM Analysis of Mathematics Teacher Job Satisfaction

The two-level HLM results in **Table 9** and **Table 10** indicate the factors influencing mathematics teacher job satisfaction across six economies. Both teacher-level variables (level 1) and school-level factors (level 2) contribute to variations in job satisfaction, offering insights into how different environments and practices shape teachers' experiences.

Table 9. Two-level HLM results for mathematics teacher's job satisfaction in high-performing economies

	Macau (China)		Hong Kong (China)		Australia	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Teachers' variables						
GENDER	.167566	1.576	.009779	.096	-.006088	-1.551
AGES	.014011	1.181	-.001282	-.142	.002378	1.389
PROPWORK	-.456050	-1.334	-.205413	-.716	.082684	1.602
TCDISCLIMA	.106515	1.549	.221004	3.900***	.225566	10.042***
EXPO21	.159224	2.022*	-.044330	-.570	.004722	.172
COGACMTC	.181946	2.668**	.189740	1.999*	.115380	3.530***
FOSTERRE	-.004682	-.068	.038152	.402	-.068875	-2.293*
GOALSAND	.053543	1.082	.182453	3.133**	.097311	3.976***
Schools' variables						
Percent of qualifications	-	-	-.001250	-.411	.004528	2.635**
Percentage of professional development	-.001176	-.716	.002301	1.423	.000099	.523
Minutes of math class	-.009840	-1.327	.003503	1.252	-.001728	-1.424
Students-math teacher ratio	-.006747	-2.010	-.001098	-.402	-.000952	-.925
Educational leadership	-.421757	-1.284	-.258227	-1.116	.117145	.891
Instructional leadership	0.502355	1.361	.227307	.921	-.117558	-.894
Math teacher training	-.253804	.074922**	-.0067592	-.959	-.073658	-1.682
Negative school climate	.067553	.740	0.171370	1.832	-.094937	-2.895**
Shortage of material	-.011582	-.171	-	-	-.068698	-.2556*
Student factor school climate	-.030757	-.570	-.063240	-1.089	.012171	.349

Table 10. Two-level HLM results for mathematics teacher's job satisfaction in lower-performing economies

	Malaysia		Georgia		Colombia	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Teachers' variables						
GENDER	.161160	2.657**	-.049852	-.358	-.142993	-1.234
AGES	.007129	1.559	.005921	.610	.003795	.636
PROPWORK	.174255	.872	.347609	.823	.095950	.514
TCDISCLIMA	.162686	4.185***	.189974	2.869**	.108095	1.530
EXPO21	-.026816	-.988	.031167	.524	.229282	3.681***
COGACMTC	.093323	2.133*	.102798	1.331	.262458	3.233**
FOSTERRE	.036034	1.038	-.000330	-.005	.103519	1.39
GOALSAND	.170314	5.094***	.213713	3.922***	-	-
Schools' variables						
Percent of qualifications	.000850	.539	-.002145	-.841	-.001812	.998
Percentage of professional development	-.000614	-.665	.000147	.407	.003695	2.131*
Minutes of math class	.000201	.264	.001281	.393	.002769	1.025
Students-math teacher ratio	.000611	.341	.000029	.014	.001440	.372
Educational leadership	-.346624	-1.672	.396052	1.860	-.118616	-.666
Instructional leadership	.282769	1.402	-.297651	-1.339	.156431	.764
Math teacher training	-.000101	-.002	.009760	.127	.140606	2.348*
Negative school climate	-.027047	-.571	.009760	.076836	-.049962	-.615
Shortage of material	.017718	.445	-.017343	-.320	.030185	.625
Student factor school climate	.008789	.031026	.06138	1.308	.013607	.196

Gender, tenure, and teacher satisfaction

Across both high- and lower-performing economies, gender is an inconsistent predictor of teacher satisfaction. In high-performing economies, gender is not statistically significant in the three countries (Macau, Hong Kong, and Australia), indicating that male and female teachers experience similar satisfaction levels. This suggests a relatively gender-neutral environment regarding teacher job satisfaction in these advanced educational systems. In contrast, in lower-performing economies, the effect of gender is more pronounced. In Malaysia, female teachers report higher satisfaction, with gender being a significant positive predictor, while in Georgia and Colombia, gender differences are not significant. This discrepancy may reflect cultural or systemic factors where gender is more vital in shaping professional experiences in some contexts.

Tenure, measured as the proportion of years worked at the current school relative to the total years as a mathematics teacher, has a negative relationship with job satisfaction in Hong Kong and Macau. This could indicate that teachers who have been at the same school for longer may face increasing dissatisfaction due to factors like stagnation, lack of professional growth opportunities, or a mismatch between long-term expectations and reality. In such high-performing economies, long tenures lead to frustration, primarily if school environments do not provide sufficient career progression, recognition, or fresh challenges. Conversely, Colombia shows a positive relationship, though not statistically significant, which suggests that longer tenure might be associated with stronger ties to the institution and higher satisfaction in lower-performing contexts. In Malaysia and Georgia, the tenure effect is insignificant, meaning that tenure alone does not predict job satisfaction in these contexts, likely due to other, more pressing factors such as classroom climate or administrative support.

Classroom management, mathematical thinking, and pedagogical practices

Classroom management (shown by TCDISCLIMA) is a critical determinant of teacher satisfaction in both high- and lower-performing economies. In Hong Kong, Australia, Malaysia, and Georgia, a well-managed disciplinary climate significantly boosts satisfaction. This consistency across varied educational contexts underscores the universal importance of a stable and well-controlled classroom environment. Although classroom management is not statistically significant in Colombia, it could suggest other systemic challenges that overshadow individual classroom dynamics.

Cognitive engagement in teaching (COGACMTC) is a significant positive factor in high-performing economies like Macau and Hong Kong, where teachers who engage students in deeper mathematical thinking report higher satisfaction. This effect is also positive in Malaysia, while it is less pronounced in Georgia and Colombia. This suggests that the success of cognitively engaging practices might depend on the educational system's support for such teaching methods. Exposure to 21st century teaching practices (EXPO21) is significant only in Macau and Colombia, indicating that where these methods are well integrated, they enhance teacher satisfaction.

Qualifications, class time, and student-teacher ratios

The percentage of peer teachers' qualifications has a significant positive effect on satisfaction in Australia, where a higher percentage of peers who hold qualifications may lead to one mathematics teacher's greater recognition and career progression. In contrast, the percentage of qualifications does not significantly impact satisfaction in lower-performing economies, reflecting a disconnect between professional development and job satisfaction in these contexts. This may be due to the need for systemic incentives for more qualified teachers in these regions.

Class time has no significant effect on job satisfaction in economies. This suggests that the amount of instructional time is not a significant determinant of teacher morale, with other factors like classroom dynamics or instructional support likely playing a more critical role.

The student-mathematics-teacher ratio similarly does not significantly affect teacher satisfaction across the six economies. This indicates that the number of students per teacher does not directly predict job satisfaction, reinforcing the importance of the quality of interactions and classroom management over sheer class size.

Leadership, school climate, and resource availability

Instructional leadership, which focuses on improving teaching and learning, demonstrates a positive influence on teacher satisfaction in Australia and Colombia, though the effects are inconsistent across economies. While instructional leadership directly supports classroom practices, broader educational leadership–though less immediately impactful–can still indirectly influence teacher satisfaction through policies and institutional culture. For instance, effective district-level leadership can shape professional development opportunities, resource allocation, and overall school climate, which in turn affect teachers' morale and job satisfaction. Recognizing this indirect influence provides a more nuanced understanding of the leadership-teacher satisfaction dynamic.

The school climate variable, particularly negative school climate, is a strong predictor of dissatisfaction in Australia and Colombia. A poor working environment, characterized by disruptive behaviors or lack of support, significantly diminishes job satisfaction. In high-performing economies like Macau and Hong Kong, school climate may sustain high levels of performance by fostering collaboration, teacher engagement, and innovative practices. In contrast, in lower-performing economies such as Colombia, a positive school climate may act as a critical lever to counter systemic challenges, such as inequitable resource distribution or low teacher morale. The absence of significance in Malaysia suggests that cultural or policy-related factors–such as strong administrative support or high tolerance for challenging working environments–might mitigate the impact of school climate in certain contexts.

Resource shortages significantly lower job satisfaction in Australia and Colombia, underscoring the importance of adequate materials and infrastructure for teaching. Teachers in these economies report frustration when resource constraints hinder their ability to deliver effective instruction, directly affecting their professional fulfillment. In contrast, the lack of significance in Macau and Hong Kong likely reflects more robust resource provision or effective resource management in these high-performing economies. For example, centralized educational systems in these regions may ensure equitable resource distribution, minimizing the disparities often seen in decentralized systems.

Comparative insights highlight important differences in leadership practices and resource management. In Australia's decentralized education system, resource availability may vary widely between regions, amplifying disparities and their impact on teacher satisfaction. In contrast, Hong Kong and Macau's centralized systems seem to mitigate such issues, providing more consistent support. Similarly, instructional leadership in Colombia might be hindered by broader systemic challenges, such as limited access to professional development opportunities, whereas Hong Kong's emphasis on continuous teacher training fosters more direct impacts on teacher morale.

To improve outcomes globally, high- and low-performing economies alike could benefit from targeted leadership training programs that emphasize instructional support while leveraging broader leadership to improve policies and institutional culture. Strengthening school climate through professional development and fostering collaborative environments can also provide meaningful support for teachers, particularly in lower-performing economies where systemic challenges are more pronounced.

Insights from the performance divide: Above and below OECD average economies

The educational context plays a pivotal role in shaping teacher satisfaction, but the relationships between tenure, classroom management, and satisfaction are complex and often influenced by external factors. In high-performing economies like Macau and Hong Kong, longer tenure often correlates negatively with satisfaction, potentially due to professional stagnation or a lack of career advancement opportunities. However, this dissatisfaction may also be influenced by societal expectations or burnout stemming from the pressures of maintaining high academic standards. In contrast, in lower-performing economies, longer tenure tends to foster greater satisfaction, likely because of stronger institutional ties, community bonds, and the fulfillment derived from overcoming systemic challenges. These patterns suggest that professional stagnation in high-performing systems could be mitigated through structured growth opportunities, while resilience in lower-performing contexts might be leveraged to strengthen systemic improvements.

Effective classroom management is universally recognized as a key contributor to teacher satisfaction, providing teachers with a sense of control and accomplishment. In both high- and lower-performing economies, well-managed classrooms improve morale and enable more effective teaching. However, modern pedagogical practices show varied impacts across contexts. In high-performing economies, cognitively demanding teaching methods and 21st century practices enhance satisfaction, reflecting the value placed on academic innovation and professional expertise. In lower-performing economies, the success of these practices often depends on systemic support, such as teacher training, adequate infrastructure, and classroom resources. Without such support, these practices may add to teachers' challenges, underscoring the need for aligned systemic reforms to maximize their effectiveness.

The availability of resources remains a critical determinant of teacher satisfaction, but its impact differs across contexts. In high-performing systems like Australia, material shortages can sharply reduce morale, reflecting teachers' expectations for resource adequacy to meet high academic standards. Comparatively, in lower-performing economies, chronic resource shortages are pervasive but are often met with remarkable teacher resilience. Many educators adapt creatively to resource limitations, finding innovative ways to foster professional pride and maintain instructional quality. Examples include the use of locally sourced materials for teaching or leveraging community support. However, the long-term effects of persistent shortages can lead to burnout, suggesting that systemic reforms to address resource inequities are essential to sustaining teacher motivation.

Professional growth and recognition are particularly salient in high-performing economies, where working with fully qualified peers and clear career advancement pathways significantly enhance satisfaction. Advanced requirements and professional development opportunities often translate into tangible rewards, reinforcing teachers' morale and professional commitment. In contrast, in lower-performing economies, the impact of professional development on satisfaction is limited. Challenges include the quality and relevance of training, misalignment with classroom realities, and a lack of systemic incentives or career progression opportunities. To maximize the impact of professional development, lower-performing systems could prioritize aligning training programs with practical classroom needs and introducing incentives such as recognition programs or pathways for career advancement.

Addressing these issues requires tailored strategies for both high- and lower-performing systems. High-performing economies should focus on mitigating professional stagnation by introducing career development frameworks and fostering innovation within established systems. Lower-performing economies could benefit from leveraging teacher resilience through policies that institutionalize resourceful practices, improving the quality of professional development, and ensuring systemic support for pedagogical reforms. Comparative case studies, such as resource allocation in smaller economies like Macau versus larger systems like Australia, could offer further insights into how systemic differences shape teacher satisfaction and inform actionable solutions.

CONCLUSION

The comparative analysis of mathematical performance across six economies, as evaluated through PISA 2022 data, underscores the multifaceted nature of mathematics education and the factors influencing both student performance and teacher job satisfaction. High-performing economies, such as Macau and Hong Kong, demonstrate exceptional capabilities in advanced mathematical processing and problem-solving. However, variability within student outcomes highlights potential challenges in achieving equity, suggesting a need for targeted interventions to support lower-achieving students. In contrast, Australia excels in data literacy, reflecting a strong emphasis on probabilistic thinking and statistical reasoning, but demonstrates gaps in foundational numerical competencies. This indicates a need for a more balanced mathematical curriculum that bridges core numeracy with advanced applications. Lower-performing economies like Malaysia, Georgia, and Colombia show consistent but modest performance, reflecting systemic issues such as resource shortages, inequities, and inadequate support systems, which call for targeted reforms and resource enhancements.

Key predictors of mathematics performance, such as self-efficacy and disciplinary climate, emerge as universally significant across the economies analyzed. Self-efficacy, which refers to a student's belief in their ability to succeed in specific tasks, drives academic resilience, motivation, and performance. For instance, students who believe they can tackle challenging mathematical problems are more likely to engage deeply and persist in their studies. Disciplinary climate, which reflects the extent to which classrooms are orderly, structured, and free of disruptions, has been shown to enhance both teacher and student success. These findings reinforce existing research while emphasizing the importance of fostering environments where students feel confident and focused (O'Sullivan et al., 2024; Tengaa, 2023; Yang et al., 2024). However, SES, gender disparities, and emotional factors such as math anxiety demonstrate variable impacts, reflecting differing levels of educational equity and socio-cultural dynamics in these economies.

The analysis also highlights the challenges faced by high-performing economies in sustaining excellence without exacerbating emotional barriers such as math anxiety. For example, Hong Kong has implemented structured teacher training programs that balance cognitive demand with emotional support, ensuring that rigorous instruction is paired with practices that build student confidence. Similarly, Macau employs a structured curriculum that emphasizes equity by integrating advanced problem-solving with accessible scaffolding techniques, allowing all students to benefit from high standards. These examples demonstrate how high-performing systems can maintain excellence while addressing emotional challenges.

Lower-performing economies face systemic barriers that require a different set of strategies. Malaysia, for instance, struggles with chronic resource shortages that hinder teacher effectiveness. However, many educators demonstrate resilience by creatively leveraging locally available materials and adapting innovative teaching strategies. These adaptations could be institutionalized and scaled through national initiatives, such as resource-sharing networks or community-driven education programs. The limited effectiveness of advanced pedagogical practices in these economies is often tied to misalignment with classroom realities, insufficient teacher training, or inadequate infrastructure. Aligning professional development programs with teachers' specific needs and classroom conditions, while introducing systemic incentives, could help bridge these gaps and improve outcomes.

The findings of this study suggest several actionable steps to enhance mathematics education. For high-performing economies, strategies to mitigate math anxiety and sustain advanced capabilities include implementing teacher training programs that integrate SEL with rigorous instruction. For lower-performing economies, introducing resource-sharing networks, aligning professional development with local needs, and fostering positive disciplinary climates are critical steps to address systemic challenges. Expanding access to low-cost interventions, such as hiring teaching assistants to reduce student-teacher ratios, can also support student learning in both contexts.

While these findings provide valuable insights, it is important to acknowledge the study's limitations. The reliance on PISA data, which focuses on 15-year-old students, may limit the scope of findings in capturing broader educational dynamics. Additionally, cultural variables, while considered, are inherently complex and warrant further exploration to deepen the understanding of cross-national trends. Future research could address these limitations by integrating qualitative methods or longitudinal data to provide a more comprehensive perspective.

The success of educational systems is shaped by both advanced pedagogical techniques and the broader institutional and socio-economic contexts in which teaching and learning occur. High-performing economies illustrate the benefits of structured, cognitively demanding approaches, but their struggles with emotional barriers like math anxiety highlight the need for balance. Meanwhile, the challenges faced by lower-performing economies underscore the importance of systemic reforms to address resource inequities and provide targeted support. By addressing both the emotional and cognitive needs of students and empowering teachers through supportive environments, educational systems can achieve more equitable and sustainable outcomes. The comparative insights drawn from this study offer valuable lessons for policymakers and educators worldwide, emphasizing the need to bridge performance gaps and build inclusive, resilient education systems

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