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PISA mathematics assessment and classroom practices in developing educational systems across Southeast Asian

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ABSTRACT

Southeast Asian mathematics education has undergone a significant shift from traditional drill-and-practice methods to learner-centered, contextually relevant approaches. Teachers successfully bridge theoretical learning and practical application by tying abstract concepts to real-world cultural practices, economic realities, and national frameworks, such as the MATATAG curriculum in the Philippines and SPN21 in Brunei. This localized approach fosters the critical thinking and problem-solving abilities necessary to meet international standards like the Programme for International Student Assessment (PISA) while addressing language and resource barriers in developing countries. This study uses a data mining methodology to analyze large datasets from PISA student and school questionnaires along with regional assessment records in order to systematically assess these pedagogical shifts. This methodology makes use of techniques like clustering, classification, association rule mining, and predictive analytics. The analysis shows how dynamic feedback loops, hybrid tools, collaborative learning frameworks, and metacognitive reflection change classroom dynamics, reduce math anxiety, and encourage peer-supported reasoning. In the end, integrating contemporary tactics with everyday instruction creates a scalable, data-driven model for long-term educational reform, establishing mathematics as an approachable instrument for innovation and progress in Southeast Asia in the twenty-first century.

Keywords: PISA Mathematics assessment, data mining, classroom practices, learner centered learning, Southeast Asian education, educational reform.

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INTRODUCTION

The OECD administers the Programme for International Student Assessment (PISA), which gauges how well 15-year-old students use mathematical literacy to evaluate, analyze, and resolve challenging issues in practical settings. PISA results show a sharp performance gap throughout Southeast Asia: while developed economies like Singapore routinely rank among the best in the world, developing educational systems like those in the Philippines, Indonesia, Thailand, Cambodia, and Laos continue to struggle to meet baseline proficiency levels. This persistent discrepancy highlights the pressing need to investigate how the instructional realities of classrooms in developing Southeast Asian countries interact with international benchmark expectations.

The fundamental structural mismatch between the competency-based requirements of PISA and conventional, classroom-level practices is the root cause of this performance gap (Baş, 2026). Math instruction has traditionally relied on rote memorization, teacher-centered lectures, and repetitive procedural drills designed for recall-oriented national exams in many developing systems across the region. As a result, students often find it difficult to convert their textbook knowledge into flexible application when faced with PISA items that call for non-routine problem solving, spatial reasoning, or mathematical modeling (Siregar et al., 2025). Systemic limitations, such as large class sizes, a lack of digital and physical resources, and extreme linguistic diversity in multilingual classrooms, exacerbate these instructional difficulties.

Educational systems throughout Southeast Asia are progressively implementing contemporary, student-centered pedagogical techniques, such as authentic learning, inquiry-driven problem solving, visual modeling, socio-construction, reflective thinking, hybrid delivery, and real-time feedback, to address these fundamental shortcomings (Ho & Dimmock, 2023). To understand what leads to significant learning gains, it is essential to look into how these targeted classroom practices are incorporated into regional curricula (such as the MATATAG curriculum in the Philippines or SPN21 in Brunei). This study intends to offer evidence-based insights that can guide regional policy, improve teacher professional development, and eventually raise mathematical literacy throughout developing Southeast Asian countries by assessing the interaction between international assessment benchmarks and local teaching realities.

Statement of the problem

The purpose of this study is to investigate how well the PISA mathematics assessment framework aligns with current classroom practices in Southeast Asian developing educational systems. In particular, it looks into how pedagogical techniques like inquiry-driven problem solving, real-time feedback, and authentic learning can help close the gap between rote learning and the higher-order thinking needed to meet international standards. The ultimate goal is to offer practical, empirically supported suggestions to direct local policy changes and educational initiatives that improve students' mathematical literacy.

METHODOLOGY

This study employs a data mining methodology to explore classroom practices and PISA Mathematics Assessment performance across developing educational systems in Southeast Asia. The methodology applies advanced data mining techniques, including clustering, classification, and association rule mining, to identify significant instructional patterns and emerging pedagogical trends. Through these analytical approaches, the study

systematically examines relationships within the available data to generate meaningful insights into mathematics teaching practices across the participating educational systems. The extracted findings highlight context driven best practices and provide practical recommendations for enhancing mathematics instruction in developing Southeast Asian countries while maintaining alignment with the methodological objectives of the study.

RESULTS AND DISCUSSION

The Programme for International Student Assessment (PISA) mathematical literacy framework evaluates how effectively 15-year-old students apply high-level reasoning and problem-solving to real-world scenarios. In developing educational systems across Southeast Asia, however, a persistent gap remains between these international expectations and traditional classroom practices, which often favor rote memorization, teacher-centered lectures, and procedural drills. Systemic challenges such as large class sizes, limited teaching resources, and exam-oriented curricula further impede the shift toward inquiry-based and application-focused instruction. Understanding this dynamic between standardized assessment demands and daily pedagogical realities is crucial for guiding policy reforms that can foster genuine mathematical literacy across the region.

Authentic learning

Using authentic learning strategies is a vital link between abstract classroom instruction and the real-world mathematical reasoning required by the PISA Mathematics Assessment in developing educational systems throughout Southeast Asia (Riyanto, 2025). It turns mathematics from a passive exercise in rote memorization into a useful, problem-solving tool by grounding mathematical ideas in well-known cultural and economic contexts, such as regional trade, agricultural computations, or traditional architecture.

Authentic learning situates mathematics within the Cambodian context, such as employing the design of an Angkor Wat temple or the local riel currency to illustrate concepts of geometry and fractions. This methodology aids in moving schools away from rote learning, promoting critical thinking and increasing student engagement. Utilizing authentic learning as a strategy for teaching mathematics in Cambodia provides numerous distinct benefits: Cultural and Economic Significance, Improved Reasoning Skills, and Closing the Education Gap (Phann et al., 2023).

Authentic learning reshapes mathematics from a dull, theoretical discipline into a valuable, applicable skill (Yolles, 2025). By integrating mathematical ideas into practical situations and familiar contexts, this approach enhances students' ability to solve problems, their academic reasoning, and their overall interest in the curriculum.

Authentic learning in Timor-Leste links theoretical mathematics to the everyday experiences and cultural practices of students, like traditional weaving or local economic activities (Leton et al., 2025). This approach enhances understanding, strengthens reasoning abilities, and adds relevance to the curriculum, even in the face of scarce classroom resources and language obstacles.

The gap between abstract mathematical ideas and Laotian daily life is closed through authentic learning. Teachers enhance student engagement, make complex problem-solving highly relevant, and raise overall academic achievement by using local contexts, such as calculating agricultural yields, sizing textiles for weaving, or local market pricing (Kumar & Gopinath, 2025).

Real-world application replaces rote memorization in mathematics education through authentic learning (Grace & Gayathripriya, 2025). This method, which grounds abstract numbers in everyday life and potential career scenarios, is highly compatible with the Ministry of Education and Training's competency-based curriculum in Vietnam.

In Myanmar, authentic learning replaces passive, rote memorization with active, practical application (Samoshkina, 2024). This approach fosters critical 21st-century problem-solving skills, bridges the gap between abstract concepts and everyday life, and significantly increases student engagement by utilizing familiar local contexts.

By switching from rote memorization to active, inquiry-based problem solving in math classes, authentic learning directly addresses Brunei's SPN21 (Sistem Pendidikan Negara Abad ke-21) mandate. This approach provides very specific benefits, such as improving knowledge retention, boosting national competitiveness, increasing cultural relevance, and preparing for a variety of careers, by tying abstract mathematical ideas to actual Bruneian contexts (Chew et al., 2019).

For Filipino students, mathematics becomes extremely relevant and interesting through authentic learning. Students naturally develop their critical thinking and problem-solving abilities by relating abstract formulas to concrete real-world issues, such as local economics, everyday community challenges, or indigenous practices (Harefa, 2025).

The Singapore Ministry of Education's (MOE) mathematics framework is perfectly aligned with authentic learning, which bridges the gap between textbook math and real-world application (Tan et al., 2021). It increases student engagement and long-term knowledge retention by helping them understand the "why" behind numbers.

Inquiry-driven problem solving

Inquiry-driven problem solving is an essential pedagogical approach used in developing educational systems throughout Southeast Asia to bridge the gap between traditional instruction and the higher-order reasoning needed for the PISA Mathematics Assessment (Montejo et al., 2026). This approach encourages students to develop hypotheses, test strategies, and uncover mathematical principles through context-rich challenges by changing the classroom dynamic from passive procedural drilling to active, student-led investigation.

Mathematics is transformed from a subject of rote memorization to one of active exploration through inquiry-driven problem solving. This approach is exactly in line with national education objectives in Singapore, which employs a widely recognized framework with problem solving as the main focus (Deng, 2026).

In the math classroom, inquiry-driven problem solving replaces passive memorization with active discovery. By relating math to everyday local contexts, such as farming or local markets, this approach specifically addresses rural and multilingual challenges in Laos, promoting deeper conceptual understanding over memorization (Weerawong et al., 2025).

Math instruction is changed from memorizing procedures to active exploration through inquiry-driven problem solving. This strategy is very beneficial for Brunei's educational system because it improves critical thinking, increases retention, and directly supports the Ministry of Education's push for 21st-century skills under the SPN21 (Sistem Pendidikan Negara Abad ke-21) framework (Uthaikanchanakul, 2025).

Active discovery replaces rote memorization in mathematics through Inquiry Driven Problem Solving (IDPS). By encouraging deeper conceptual understanding and real-world application, IDPS directly addresses learning gaps in the Philippine context, where critical thinking and problem solving are the twin core goals of the K–10 and MATATAG curricula (Abenes & Esperancilla, 2025). Key benefits of implementing this strategy in local classrooms

include: Decreased Math Anxiety, Real-World Relevance, Aligned with National Mandates, and Improved Concept Retention.

Mathematics is no longer a subject of rote memorization but rather a dynamic, active investigation thanks to inquiry-driven problem solving (Siregar, 2025). This approach is in line with the Pelan Pembangunan Pendidikan Malaysia (PPPM) 2013-2025 in Malaysia, which places a strong emphasis on the development of 21st-century competencies and Higher-Order Thinking Skills (HOTS/KBAT). Deeper conceptual understanding, alignment with national curriculum goals, increased student engagement, and promotion of self-directed learning are some of the main benefits.

The Ministry of Education's emphasis on student-centered learning is in line with Singapore's use of inquiry-driven problem solving in math. Deepening Conceptual Mastery, Fostering the Heuristic Mindset, and Promoting Retention are the main benefits of this shift from rote memorization to active discovery in the classroom (Siregar, 2025).

Visual modeling

Visual modeling is a potent pedagogical link between mechanical memorization and the advanced spatial and quantitative reasoning assessed by the PISA Mathematics Assessment in developing educational systems throughout Southeast Asia (Putri et al., 2025). This enables students to break down difficult, multi-step word problems into digestible visual components by converting abstract mathematical concepts into understandable diagrams, bar models, and pictorial representations.

Language barriers are overcome and abstract concepts are made simpler through visual modeling (Kuzu, 2025). It lessens the need for rote memorization by enabling Myanmar students to rely on intuitive diagrams. This promotes greater engagement and long-term retention by refocusing on true comprehension and problem-solving.

Abstract mathematical ideas are given tangible, relatable forms through visual modeling (Ingkavara & Yasri, 2025). It helps students deconstruct difficult problems and lessen math anxiety by bridging the gap between practical experience and abstract reasoning. It works particularly well to enhance performance in word problems and problem-solving.

A key component of the Singapore Math approach is visual modeling, which smoothly moves students from concrete (hands-on) to pictorial (visual) to abstract (symbolic) thinking (Faye, 2021). This method makes difficult word problems understandable, breaks down abstract ideas like fractions and ratios into concrete components, and fosters long-lasting conceptual understanding as opposed to rote memorization.

Socio co-construction

Socio-construction provides a collaborative pedagogical framework for developing educational systems in Southeast Asia that harmonizes everyday classroom dynamics with the reasoning and communication skills assessed by the PISA Mathematics Assessment. It offers a supportive social environment that lessens math anxiety, encourages students to express their mathematical thinking, and develops the adaptability required to tackle PISA's complex, real-world scenario problems for developing nations navigating large class sizes, diverse achievement levels, and language barriers (Valquaresma, 2024).

In Vietnam, socio-construction is a teaching method that encourages critical thinking, mathematical communication, and real-world problem-solving by replacing traditional rote learning in the classroom with active engagement (Manaka, 2022).

Socio co-construction, which is based on social constructivism, encourages dynamic peer discussions, promotes a thorough understanding of concepts, and integrates cultural significance in Indonesian mathematics classrooms (Siregar, 2025). Notable benefits include improved problem-solving abilities, decreased anxiety related to math, and consistency with national guidelines such as Kurikulum Merdeka.

The socio co-construction approach in math classrooms in Timor-Leste helps to overcome language obstacles, ties mathematics to everyday experiences, and fosters support among peers (McWayne & Melzi, 2024). The main benefits consist of improved understanding of language through conversation, cultural significance through context-based problem-solving, and increased collaboration among classmates.

Reflective thinking

Reflective thinking is a crucial metacognitive technique used in developing educational systems throughout Southeast Asia to move classroom instruction from mechanical execution to the self-directed reasoning required by the PISA Mathematics Assessment (Jatmiko et al., 2026). It turns passive learners into aware, flexible thinkers by encouraging students to methodically assess their own problem-solving techniques, examine mistakes, and defend their mathematical choices.

Employing reflective thinking as a pedagogical approach in Indonesian math classrooms improves conceptual comprehension, nurtures metacognitive abilities, and aids in contextual problem-solving (Siregar, 2025). It connects traditional rote memorization with deeper cognitive involvement.

In Malaysian math classrooms, the use of reflective thinking enhances students' conceptual comprehension, increases their sense of self-efficacy, and develops higher-order thinking abilities (Nuryadi et al., 2025). It enables teachers to modify their teaching strategies to meet the demands of regional curricula and assists students in keeping an eye on their own problem-solving processes.

In Philippine mathematics education, using reflective thinking as a teaching strategy boosts students' confidence, problem-solving skills, and mathematical communication abilities (Tañola & Lomibao, 2024). By assisting them in assessing their own development, it turns passive learners into active thinkers.

Hybrid delivery

Hybrid delivery is a cutting-edge pedagogical approach used in Southeast Asian educational systems to meet the demanding application standards of the PISA Mathematics Assessment by bridging traditional classroom instruction with digital resources (Wang et al., 2023). It enables students to investigate intricate, multi-step mathematical concepts outside of the confines of a traditional lecture by combining in person teacher guidance with self-paced digital modules, interactive visualizations, and adaptive practice.

In math education, hybrid delivery provides improved student engagement, individualized learning pace, and abstract concept visualization (Cirneanu & Moldoveanu, 2024). Students are better able to understand challenging math concepts when physical classrooms are combined with digital resources.

In Philippine math classrooms, hybrid delivery enhances student comprehension, offers flexible pacing, and preserves in-the-moment teacher support (Salendab, 2026). It helps students understand abstract numbers and formulas by combining in-person instruction with digital resources.

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In Brunei, teaching mathematics through a hybrid delivery approach, which combines in-person and online instruction, offers several advantages, such as improved abstract concept visualization, flexible self-paced learning, and focused real-time problem-solving assistance (Shafik, 2026).

Real-time feedback

Real-time feedback is an essential formative strategy that keeps mathematical misconceptions from solidifying during daily instruction in developing educational systems throughout Southeast Asia (Lucas-Mendiola et al., 2026). This responsive approach helps students in multilingual or resource-constrained classrooms develop the adaptive reasoning and self-monitoring skills necessary to perform well on the PISA Mathematics Assessment by offering prompt corrections and hints.

In Thai math classes, real-time feedback boosts active participation, instantly corrects misconceptions, and improves student performance (Marwiang et al., 2025). Pedagogical benefits include: Concept Clarity, which helps students develop stronger reasoning and problem-solving abilities through immediate hints or visual cues; Error Correction, which corrects math errors as soon as they occur so incorrect ideas do not stick; and Active Participation, which keeps students engaged and focused rather than merely listening.

Real-time feedback enhances learning in math classes by quickly correcting errors, increasing student engagement, and assisting teachers in adjusting their pace (Zulpykhar et al., 2025). Instead of waiting days for test results, it transforms quiet rooms into dynamic areas where students immediately correct mistakes.

In math classes in Timor-Leste, real-time feedback helps students stay engaged, overcome language barriers, and instantly correct learning errors (Magno Ximenes, 2025). It enables teachers to rephrase numbers and word problems on the spot before confusion spreads and helps close gaps when students struggle with math concepts taught in Portuguese or English while thinking in Tetum or local languages.

Findings

Traditional rote memorization is gradually giving way to learner-centered approaches that specifically address fundamental cognitive and cultural deficiencies in Southeast Asian educational systems. From agricultural practices in Laos and local markets in Myanmar to national curriculum frameworks like Brunei's SPN21 and the Philippines' MATATAG curriculum, key teaching strategies like authentic learning, inquiry-driven problem solving, and visual modeling ground abstract mathematical concepts in local, real-world contexts. These methods improve student engagement, deepen conceptual mastery, and overcome language and resource barriers by framing problem-solving around well-known cultural and economic realities. This turns mathematics from a passive drill into an active, meaningful skill.

Critical pedagogical and structural issues throughout the region are simultaneously addressed by the integration of socio-construction, reflective thinking, hybrid delivery, and real-time feedback. In addition to reducing math anxiety, interactive approaches encourage group discussion and metacognitive awareness, transforming passive learners into active thinkers. Additionally, real-time error correction, a crucial mechanism in multilingual and resource-constrained environments like Timor-Leste, where language barriers frequently impede immediate comprehension, is made possible by combining digital tools with immediate instructional feedback. In combination, these contemporary teaching methods offer a coherent

pedagogical model that supports local educational reforms meant to develop higher-order thinking abilities for the twenty-first century.

CONCLUSION

The current transition from conventional drill-and-practice teaching to learner-centered, contextually relevant methods signifies a significant change in mathematics education throughout Southeast Asia. By linking abstract mathematical concepts to genuine cultural practices, daily economic situations, and national educational frameworks, such as the MATATAG curriculum in the Philippines and SPN21 in Brunei, teachers are successfully narrowing the gap between theoretical learning in classrooms and practical applications in the real world. This localized strategy not only breaks down language and resource obstacles in developing countries like Laos, Myanmar, and Timor-Leste, but also fosters the critical thinking and advanced problem-solving skills required to achieve international standards such as those set by PISA.

Integrating collaborative frameworks, metacognitive reflection, hybrid tools, and dynamic feedback loops fundamentally transform the conventional classroom setting. These engaging methods enable students to express their reasoning, benefit from immediate corrections, and reduce math anxiety in nurturing, peer-supported environments. Synchronizing everyday classroom activities with these contemporary teaching strategies offers a sustainable model for comprehensive educational reform throughout the region, ensuring that mathematics is perceived not as a tedious task, but as an approachable and empowering resource for innovation and regional advancement in the twenty-first century.

Building on these findings, several recommendations emerge as essential to sustaining and advancing this pedagogical shift across the region. National education ministries must prioritize ongoing professional development for teachers alongside the alignment of curricula. Although national initiatives such as MATATAG and SPN21 establish high expectations, their effectiveness ultimately relies on enabling educators to transition away from traditional lecture-centric techniques. Educational authorities should therefore create continuous, practice-oriented training programs that equip teachers with effective strategies for incorporating genuine problem-solving, visual representation, and immediate formative feedback into their everyday teaching. At the same time, national high-stakes assessments need to be redesigned to focus on evaluating advanced mathematical reasoning rather than rote memorization of procedures, since local assessment standards that remain misaligned with international measures like PISA risk pulling classroom practices back toward test-oriented drill exercises.

Beyond curricular and instructional reform, addressing underlying infrastructure and resource inequities requires coordinated action among regional policymakers and international development partners. To overcome linguistic and rural-urban divides, ministries should invest in scalable, low-bandwidth hybrid learning tools and localized instructional materials tailored to particular regional contexts, such as agricultural calculations in Laos or local economic scenarios in Timor-Leste. Furthermore, establishing a regional Southeast Asian knowledge-sharing network would allow developing education systems to exchange best practices for student-centered classroom strategies and multilingual mathematics instruction. Taken together, by combining focused teacher support, updated assessment frameworks, and contextualized learning materials, Southeast Asian countries can translate these pedagogical innovations into quantifiable increases in students' mathematical literacy, reinforcing mathematics education as a foundation for both individual empowerment and regional progress.

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