Implementation of a Dual Curriculum for Strengthening Students' Numeracy Competence: A Mixed-Methods Case Study

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ABSTRACT

Numeracy is a key 21st-century competency that enables students to apply mathematical understanding in real-life contexts. However, despite continuous curriculum reforms, Indonesian students' numeracy performance remained below international standards as shown in national and global assessments. Limited studies had explored how the integration of international curricula contributed to improving numeracy learning in Indonesian schools. This study analyzed the implementation of a dual curriculum integrating the Indonesian National Curriculum and the Singapore Curriculum and its impact on strengthening secondary students' numeracy competence. A mixed-methods approach with a case study design was employed at a private high school in Pekanbaru that consistently applied both curricula. Data were collected through an AKM-based numeracy test, in-depth interviews, classroom observations, and document analysis of curriculum and textbooks. The findings revealed that students were strong in procedural skills, particularly in algebra, but still struggled with reasoning, mathematical communication, and open-ended problem solving. These challenges were influenced by limited reading literacy, dominance of procedural exercises, and insufficient exposure to contextual problems. Document analysis showed that the Singapore Curriculum emphasized problem solving and spiral content structure, while the Indonesian Curriculum focused more on conceptual mastery and logical thinking. The study highlighted the need to strengthen reasoning-based and contextual numeracy learning through adaptive textbooks, continuous teacher training, and reflective teaching practices within dual curriculum implementation.

Keywords: *curriculum implementation, dual curriculum, mathematics learning, numeracy competence*

1. INTRODUCTION

Numeracy is a key 21st-century competency that enables students to solve contextual problems. Yet Indonesian students continue to perform at low levels. Results from the Asesmen Kompetensi Minimum (AKM) and PISA 2022 show that most remain at the basic level of mathematical literacy (OECD, 2023b), indicating ongoing challenges in implementing the secondary mathematics curriculum. Numeracy outcomes are shaped not only by curriculum quality but also by teachers' pedagogical competence (Nugraheni & Jailani, 2020).

Singapore presents a contrasting profile. About two-fifths of its students reached Levels 5–6 in PISA 2022 (OECD, 2023a), and TIMSS 2019 consistently placed Singapore at the top in lower secondary mathematics (Mullis et al., 2020). These results

align with its curriculum, which positions mathematical problem solving as the central instructional focus (Ministry of Education Singapore, 2021).

Several Indonesian schools have attempted to improve numeracy by integrating elements of international curricula. One school in Pekanbaru implements a dual curriculum combining the National Curriculum with Mathematics subjects based on the Singapore curriculum. This arrangement requires teachers to reconcile two curricular frameworks and students to adapt to more demanding numeracy expectations. To examine these dynamics, this study employs a mixed-methods approach using numeracy assessments, interviews, observations, and curriculum document analysis.

Studies on numeracy, representation, and statistical reasoning have been conducted in Indonesia (Supriadi et al., 2023; Viryanto & Kismiantini, 2024; Yuntari & Hamdi, 2024), but they rarely address the implementation of international curricula or their integration into local practice. This study therefore investigates how curriculum policy, teaching practices, and numeracy outcomes interact within a dual-curriculum context.

The novelty of this research lies in its analysis of the combined implementation of the Indonesian National Curriculum and the Singapore Curriculum in secondary mathematics. It compares curricular frameworks, examines classroom practices along with teacher and student experiences, and analyzes numeracy test results that were developed in line with the AKM model. The findings aim to support the development of adaptive pedagogical strategies and responsive curriculum policies.

This study addresses three questions:

1. What is the profile of students' numeracy competence across domains, cognitive levels, and item formats?
2. How do teaching practices and teacher–student experiences reflect dual curriculum implementation?
3. What key differences exist between both curricula, and what implications do they hold for enhancing numeracy competence?

2. METHODOLOGY

This study employed a sequential explanatory mixed methods case study design. Quantitative data were collected first using an AKM aligned numeracy test to examine students' numeracy performance, followed by qualitative data collection to explain and contextualize the quantitative findings. The case study was conducted in a private senior high school in Pekanbaru selected purposively due to its dual curriculum implementation, namely the Indonesian National Curriculum and the Singapore Curriculum, and its strong numeracy outcomes.

The population comprised students and mathematics teachers at the selected school. For the quantitative phase, one class was selected through simple random

sampling, and all students in the class participated in the numeracy test. For the qualitative phase, purposive sampling was used to select mathematics teachers, two students representing high and moderate numeracy achievement, and the vice principal for curriculum affairs. Curriculum documents and mathematics textbooks from both curricula were included as secondary data sources.

The primary quantitative variable was students' numeracy performance, operationally defined as the ability to apply mathematical knowledge across content domains and cognitive levels. Numeracy performance was measured across Geometry and Measurement, Algebra, and Data and Uncertainty at the Knowing, Applying, and Reasoning levels. The main instrument was a researcher developed numeracy test aligned with the AKM framework, comprising multiple choice, complex multiple choice, true and false, matching, short answer, and open ended items. Content validity was established through expert review, and reliability was examined using internal consistency measures.

Quantitative data were analyzed descriptively, while qualitative data were analyzed using Miles and Huberman's interactive model. Integration occurred through triangulation to generate an explanatory understanding of factors influencing students' numeracy performance within the dual curriculum context.

3. RESULT AND DISCUSSION

Student' Numeracy Profile

Numeracy test results from 25 eleventh-grade students showed that Algebra achieved the highest mean score (66.6), followed by Data & Uncertainty (61.2), while Geometry & Measurement was lowest (57.0) (see Figure 1). This confirms earlier evidence that geometry and spatial representation remain relatively weak domains for Indonesian students (OECD, 2019, 2023c).

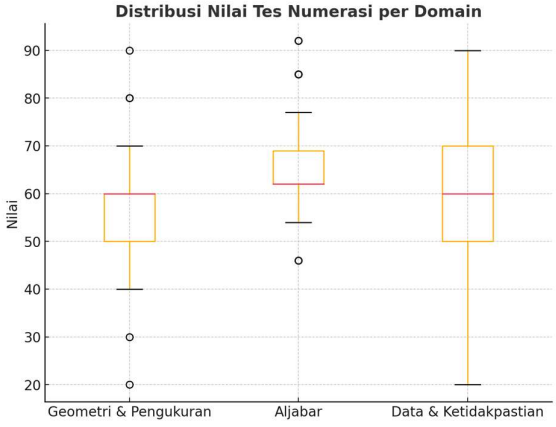

Figure 1. Distribution of Numeracy Test Scores by Domain

At the cognitive level, students scored highest on Knowing (72.4), slightly lower on Applying (71.2), and markedly lower on Reasoning (45.3) (see Figure 2). This pattern

indicates strong procedural fluency but limited higher-order reasoning, consistent with PISA and TIMSS findings (Mullis et al., 2020; OECD, 2019; Supriadi et al., 2023).

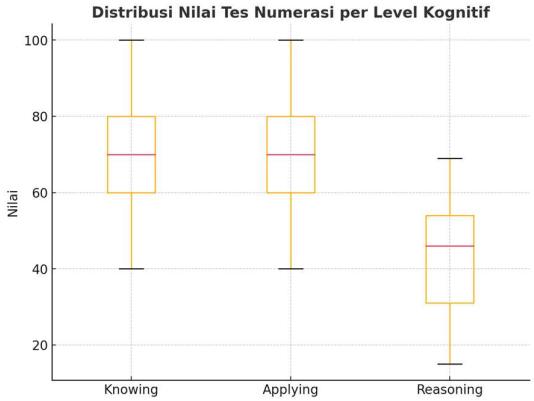

Figure 2. Distribution of Numeracy Test Scores by Cognitive Level

By item type, students performed best on multiple-choice (83.2) and complex multiple-choice (75.6), moderately on true–false (69.6) and matching items (58.8), and weakest on short-answer (50.1) and open-ended items (20.3) (see Figure 3). Low performance on open ended tasks indicates that students experience difficulty expressing their mathematical thinking in written form (Ministry of Education Singapore, 2021; OECD, 2023a), confirming Viryanto & Kismiantini's (2024) findings about weak argumentation when responding to open response items. Oktiningrum et al. (2016) therefore stress the need for PISA-type, locally contextualized items to cultivate argumentative thinking in Indonesia.

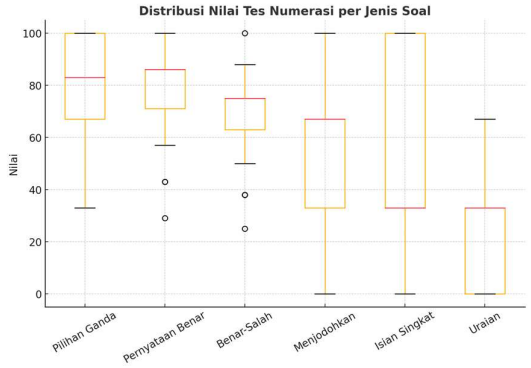

Figure 3. Distribution of Numeracy Test Scores by Item Type

Overall, these results suggest that students are more habituated to closed-format and routine tasks, while reasoning and communication remain underdeveloped (Setiawan, 2019). Although the school has implemented a Singapore-based curriculum that strengthens procedural and algebraic skills, the central challenge is still to foster mathematical reasoning and numeracy literacy through open-ended and argumentative activities (Lindorff et al., 2019; Rezat, 2024; Ministry of Education, 2021; OECD, 2023).

Student Interview Findings

Interviews with two students who completed the numeracy test offer contextual support for these patterns. Both students perceived the test as moderately to highly challenging. Student 1 attributed the difficulty to forgotten content, whereas Student 2 reported greater confidence but pointed out that some three dimensional area items contained incomplete information. These responses underscore the importance of clarity and completeness in test stimuli (Oktiningrum et al., 2016).

Both students agreed that interpreting texts, images, and tables was more challenging than performing calculations. Student 1 struggled with long texts requiring sustained concentration, while Student 2 found diagrams harder to interpret. These difficulties mirror OECD (2019, 2023b) findings on challenges in processing visual and verbal representations. Geometry was seen as the most difficult domain, not only because of formula recall but also due to limited conceptual understanding, consistent with TIMSS evidence of Indonesian students' weaknesses in contextual geometry (Mullis et al., 2020). Student 2 further reported that true–false items were cognitively demanding because each statement had to be evaluated separately, aligning with the lower quantitative performance on this format.

Both students reported some exposure to AKM-style questions since Grade 10 but at limited frequency. They recognized that such items require more analytical and critical thinking than routine exercises, consistent with the higher-order aims of the AKM framework (Ministry of Education Singapore, 2021). Despite difficulties, both expressed positive attitudes towards mathematics: Student 1 enjoyed geometry's imaginative aspects, while Student 2 preferred computation and found geometry less engaging. These positive dispositions are in line with Russo & Minas (2020) and Wen & Dubé (2022), who argue that students may still enjoy mathematics when they experience it as "challenging yet rewarding."

Finally, both indicated that instruction needs to be more varied and interactive, with technology integrated through explanations, group work, digital quizzes, and multimedia, while also acknowledging that poor technology management may cause distractions. Such recommendations support Gustafsson et al. (2024), who emphasize the need to adapt instructional media to sustain classroom effectiveness. Overall, the interviews reinforce that numeracy challenges stem from conceptual and procedural demands, stimulus and context interpretation, and limited exposure to diverse problem formats.

Classroom Observation Findings

Classroom observations were used to connect learners' reported challenges with actual teaching practices. Lessons typically began with greetings, a short prayer, and

an apperception activity that linked prior knowledge to the day's objectives, consistent with the principle of cognitive readiness (Tak et al., 2025).

During the main phase, the teacher facilitated small-group discussions in which students read and interpreted problem stimuli and presented their solutions. These activities encouraged metacognitive processes in which students evaluated peer strategies and reflected on their accuracy. (Firmansyah et al., 2025). The teacher provided scaffolding when students encountered difficulty, thereby extending their Zone of Proximal Development in line with research showing the benefits of metacognitive interventions and scaffolding for mathematical literacy and proportional reasoning (Kholid et al., 2025; Murtafiah et al., 2024).

The lesson closed with a reflective summary, jointly constructed by teacher and students, to consolidate key ideas and connect them to subsequent material. This finding is consistent with the meta analysis by Muncer et al. (2022), which demonstrates a positive association between metacognitive processes and mathematical performance. Collectively, interviews and observations show that major challenges include interpreting complex stimuli, especially in geometry, and limited experience with contextual numeracy tasks. Meanwhile, students' procedural strengths and positive attitudes are supported by interactive teaching that remains largely procedural.

Teacher and Vice Principal Interview Findings

Interviews with the mathematics teacher and vice principal clarify the curricular and institutional context. The school follows the national curriculum while also adopting the Singapore curriculum, taught in English. Although content overlaps, the national curriculum is more theoretical, whereas the Singapore curriculum emphasizes application, literacy, and earlier introduction of statistical topics such as histograms, which supports progressive reasoning development (Lindorff et al., 2019; OECD, 2023c). The vice principal explained that the dual curriculum aims to strengthen students' international competitiveness in PISA, TIMSS, and mathematics olympiads, consistent with Jin & Chen (2023). The Singapore curriculum is implemented via an additional Mathematics subject of three instructional hours per week.

Lesson planning for both Matematika and Mathematics is conducted at the beginning of the year through teacher meetings and internal training. External experts are invited to enrich teaching approaches and develop more realistic, contextual problems, in line with findings on PISA-based tasks and numeracy literacy (Oktiningrum et al., 2016). Classroom assessments use multiple choice, true and false, matching, and essay questions, and consistent exposure to text based and context based items in school examinations has contributed to strong AKM numeracy performance. As a result, this school records the highest level of numeracy literacy in

Riau Province. However, the teacher noted that around 80% of students still prefer asking the teacher to reading long texts themselves, pointing to reading literacy limitations that affect numeracy, especially on items requiring data interpretation from texts, tables, or graphs (OECD, 2019; Supriadi et al., 2023).

Institutionally, the school supports curriculum implementation through teacher professional development, visits from consultants and external speakers, and benchmarking with national and international schools (Nugraheni & Jailani, 2020; Gustafsson et al., 2024). Regular communication with parents further strengthens student learning, consistent with evidence on the role of parental support (Wang et al., 2023). Teacher performance evaluations are followed by competency enhancement programs, echoing recommendations in teacher evaluation literature (Rajadurai, 2023). An internal research team uses assessment data to guide innovations in contextual learning that link mathematical concepts to real life contexts, as recommended by Viryanto & Kismiantini (2024). These efforts are reinforced by the use of Singapore based textbooks, digital platforms, and the proficiency of teachers and students in English and Mandarin, which expands access to international learning resources (Mullis et al., 2020a).

Overall, the interviews show that high numeracy outcomes are underpinned by the synergy of curriculum policy, classroom practice, teacher development, research-based innovation, and a collaborative school culture, creating a reflective and contextually grounded learning ecosystem.

Mathematics Textbook Analysis Findings and Local Adaptation Needs

Document analysis of *New Discovering Mathematics*, the Singapore-based textbook used in Mathematics, examined how far learning resources align with the intended contextual approach. The book is systematically organized and aligned with international trends, yet several challenges arise in the Indonesian context: many problem situations are not closely connected to students' daily lives, and numerous mathematical terms originate from external contexts. This is consistent with Revina (2021), who warns that adopting Realistic Mathematics Education without local adaptation can produce linguistic, cultural, and pedagogical barriers.

From a curriculum resources perspective, textbooks are part of a broader ecosystem that must align with teachers' practices and students' experiences (Rezat, 2024). Thus, textbook development and selection should consider not only content but also contextual fit. Studies by Sunzuma & Umbara (2025) and Oktiningrum et al. (2016) underline the importance of integrating culture and technology, through ethnomathematics and PISA-like problems rooted in Indonesian cultural heritage, to increase relevance and strengthen students' connection with learning contexts. The analysis therefore confirms that numeracy enhancement depends on curriculum design,

classroom practice, and the school's capacity to adapt global materials to local cultural and linguistic realities.

Indonesian and Singaporean Curriculum Comparison Findings

A comparative analysis of the Indonesian and Singaporean secondary mathematics curricula further clarifies how curricular orientation shapes numeracy competencies. The Indonesian national curriculum stresses conceptual understanding, logical reasoning, and adaptive skills (Ministry of Education Singapore, 2021), but research indicates that it continues to place limited emphasis on applications drawn from real life. By contrast, Singapore's curriculum is explicitly oriented toward mathematical problem solving and application (Kaur, 2014), fostering higher order thinking and mathematical literacy.

These differences are evident in textbook and task design. Singaporean textbooks prioritize investigative and operational approaches (Nurhikmayati et al., 2025), employ more contextual and visual tasks (Purnomo, 2024), and adopt exploratory task designs even in introductory topics such as sets (Hendriyanto et al., 2023). The Singaporean curriculum is systematically structured around concepts, skills, processes, metacognition, and attitudes (Sumliyah et al., 2025) and aligns with international assessments in which Singaporean students consistently outperform Indonesian students in reasoning and problem solving (Mullis et al., 2020; OECD, 2019, 2023c). High-performing systems also embed values such as integrity and systematic thinking in mathematics learning (Serçe & Acar, 2021). Content mapping by Ayu & Wijaya (2022) shows that Singapore applies a spiral curriculum design, with topics revisited and deepened over time, while Indonesia tends to cover major topics within a single year. This spiral structure supports the gradual building of deeper conceptual connections, which is crucial for sustained numeracy development.

To further clarify how these curricular orientations translate into structural and pedagogical differences, the key features of the Indonesian and Singaporean secondary mathematics curricula are summarized in Table 1. The comparison highlights contrasts in overall goals, content organization, embedded values, learning approaches, textbook characteristics, and the positioning of mathematical literacy, providing a clearer picture of how each system frames and supports the development of students' numeracy competence.

Table 1. Comparison of the Indonesian vs Singaporean Mathematics Curricula

Aspect	Indonesia	Singapore
General Orientation	Emphasizes conceptual understanding, logical, analytical, and systematic thinking, as well as adaptability in daily life (Merdeka Curriculum).	Emphasizes mathematical problem solving as the core of the curriculum, with a strong focus on real-world application and problem solving.

Aspect	Indonesia	Singapore
Content Distribution	Major topics are completed within a single academic year (e.g., algebra, geometry, trigonometry, statistics), with calculus introduced in Grades XI–XII.	Topics are distributed progressively through a spiral curriculum, developing skills from basic to advanced levels over time.
Curricular Values	Emphasizes discipline, independence, patience, perseverance, and rational thinking. Integrity is not explicitly stated.	Emphasizes perseverance, open-mindedness, and integrity as integral values in mathematics education.
Learning Approach	Mentions problem solving and project-based learning, but classroom practice remains largely monodisciplinary within mathematics.	Problem solving and project-based learning are implemented collaboratively and across disciplines, including the integration of applied mathematics.
Text books	Contain numerous verification and non-applicative problems, with a stronger theoretical focus.	Rich in visual representations, contextual problems, operational investigations, and mathematical modeling tasks.
Mathematical Literacy	Not yet an explicit framework within the curriculum, though introduced through the Minimum Competency Assessment (AKM).	Mathematical literacy is integrated as a core competency framework encompassing concepts, skills, metacognition, and attitudes.

Overall, students demonstrated relatively strong procedural skills, particularly in algebra, tasks at lower cognitive levels, and closed format items, while their reasoning, communication, and open ended problem solving abilities were less well developed. These challenges can be attributed to gaps in conceptual understanding, limitations in reading literacy, restricted experience with contextual problems, and differences in curricular structure. The implementation of a dual curriculum indicates that strengthening numeracy depends on alignment among instructional practices, assessment approaches, textbook adaptation, and institutional support.

4. CONCLUSION

This study shows that students possess strong procedural numeracy but weak reasoning, especially in Geometry & Measurement and in open-ended item formats. Their stronger performance on closed format tasks, together with their difficulties in interpreting texts, diagrams, and contextual information, addresses the first research question concerning students' numeracy profiles. Classroom observations and interviews further reveal that dual curriculum implementation supports procedural fluency but offers limited opportunities for learning that emphasizes reasoning. Students' challenges are reinforced by reading-literacy demands, while curriculum comparison shows that the Singapore curriculum's problem-solving and spiral progression differ markedly from Indonesia's more conceptual coverage. These

differences help explain how teaching practices and curricular structures shape the experiences of teachers and students, thereby addressing the second and third research questions.

In light of these conclusions, teachers are encouraged to incorporate more open-ended and contextual tasks, including PISA-like problems, and to explicitly teach strategies for interpreting written and visual information to strengthen reasoning. Schools should enhance professional development that focuses on metacognitive scaffolding and literacy-integrated mathematics instruction, while curriculum developers and policymakers need to revise materials and guidelines to support culturally grounded tasks that emphasize reasoning. Through coordinated improvements in classroom practice, curriculum design, and institutional support, students can develop numeracy proficiency that is both procedurally sound and contextually meaningful.

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