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Creative thinking and mathematical communication in numeracy literacy-based thematic learning: Indonesian-Malaysian student comparison

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ABSTRACT

Creative thinking and mathematical communication are essential competencies in primary mathematics education, particularly within numeracy literacy–based learning. This study compared these competencies among secondary school students in Indonesia and Malaysia. A quantitative comparative design was employed involving 114 students (57 Indonesian and 57 Malaysian). Data were collected using validated instruments and analyzed using descriptive statistics, normality and homogeneity tests, independent samples t-tests or Mann–Whitney U tests, and effect size analysis. The results showed that Indonesian students achieved higher mean scores and more consistent performance than Malaysian students in both competencies. Significant differences were identified, with meaningful effect sizes.

Keywords: creative thinking, mathematical communication, thematic learning, numeracy literacy

INTRODUCTION

The rapid advancement of science and technology in the twenty-first century has transformed the competencies expected of students. Education is no longer concerned solely with the mastery of factual and procedural knowledge but increasingly emphasizes students' ability to generate ideas, solve unfamiliar problems, communicate reasoning, and collaborate in complex situations (Ameeque, 2026). These competencies are particularly important in mathematics education because mathematics provides a system for analysing relationships, constructing arguments, representing quantitative information, and making reasoned decisions in dynamic real-world contexts (Hadar & Tirosh, 2019; Erwin, 2025). Within this broader educational demand, mathematical creative thinking and mathematical communication should not be treated as separate outcomes. Creative mathematical ideas acquire educational value when students can represent, explain, justify, and refine them, while mathematical communication becomes intellectually substantive when students are encouraged to propose alternative strategies, examine different representations, and negotiate the validity of possible solutions. Investigating these constructs together therefore provides a more complete account of how students generate mathematical ideas and transform them into reasoned, communicable knowledge.

Mathematical creative thinking is understood in this study as a domain-specific capacity to produce mathematically meaningful ideas, strategies, representations, or solutions that are both appropriate to a problem and relatively novel within the learner's context. This definition distinguishes mathematical creativity from creativity in a general psychological sense. General theories of creativity developed by Guilford (1967) and Torrance (1974) remain useful for identifying divergent-thinking processes, but they do not by themselves fully explain what makes an idea mathematically creative. In mathematics, novelty must be accompanied by mathematical relevance, logical coherence, and the potential to illuminate relationships, patterns, or alternative solution pathways. Mathematical creativity is therefore not reduced to producing a large number of responses; it involves exploring the structure of a problem, shifting between strategies and representations, constructing non-routine connections, and developing ideas into defensible mathematical solutions. This domain-specific conception also situates creativity within authentic mathematical activity, in which ideas emerge through problem interpretation, representation, reasoning, evaluation, and

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interaction with others. This emphasis on novelty and appropriateness is consistent with the standard definition of creativity (Runco & Jaeger, 2012).

Based on this conception, the dimensions proposed by Guilford and Torrance are retained as analytical indicators but are interpreted specifically within mathematical problem solving. Fluency refers to the ability to generate several mathematically relevant ideas or solution possibilities. Flexibility concerns movement across different categories of strategy, representation, or reasoning rather than the repetition of superficially different answers. Originality refers to the production of an uncommon yet mathematically valid approach relative to the responses typically produced by students in a comparable context. Elaboration concerns the ability to extend, clarify, verify, and systematically develop an initial idea into a complete solution. Thus, fluency, flexibility, originality, and elaboration are not assumed to constitute mathematical creativity automatically. They function as observable dimensions of a broader domain-specific construct whose products must remain meaningful, valid, and relevant within mathematics. These dimensions guide the development of the research instrument and the interpretation of students' mathematical creative thinking profiles (Guilford, 1967; Torrance, 1974).

Mathematical communication is conceptually connected to mathematical creative thinking because ideas cannot be examined, validated, or improved unless they are made accessible through language and representation. In this study, mathematical communication is defined not merely as a set of observable presentation skills but as a cognitive, social, discursive, and epistemic practice through which students construct and negotiate mathematical meaning. Cognitively, communication helps students organize and clarify their reasoning. Socially and discursively, it allows them to exchange interpretations, question alternative strategies, and respond to the reasoning of others. Epistemically, it enables mathematical claims to be justified, evaluated, and revised according to accepted forms of evidence and logical consistency. Students communicate mathematically through oral and written language, symbols, diagrams, tables, graphs, and other representations that make their problem-solving processes open to examination (Fazira et al., 2025; Nguyen et al., 2024; NCTM, 2000; Sjunnesson, 2020; Tong et al., 2021). Recent evidence also examines instructional support for elementary students' mathematical communication through the RADEC learning model (Muhdiati et al., 2025).

This conception is supported by social constructivist theory, which views mathematical understanding as developing through active participation, representation, dialogue, and the negotiation of meaning rather than through the passive reception of procedures (Mahadini et al., 2025). From this perspective, communication is not simply the final presentation of an answer. It is part of the process through which understanding is formed. When students explain an alternative strategy, compare representations, question an assumption, or revise an argument in response to feedback, they simultaneously communicate and reconstruct their mathematical knowledge. Social interaction may also stimulate creativity by exposing students to different perspectives and encouraging them to reorganize or extend their initial ideas. Mathematical creative thinking and mathematical communication are therefore mutually reinforcing: creativity expands the range of ideas available for discussion, whereas communication subjects those ideas to explanation, critique, verification, and refinement.

Consistent with this integrated framework, mathematical communication is examined through students' ability to: (1) express mathematical ideas clearly in oral or written form; (2) use mathematical symbols and language appropriately; (3) represent mathematical relationships through diagrams, tables, graphs, or other visual forms; (4) explain problem-solving processes systematically and logically; (5) interpret and evaluate mathematical information or the reasoning of others; and (6) respond to feedback by clarifying or revising mathematical ideas. These indicators are informed by the mathematical communication standards of the National Council of Teachers of Mathematics and related empirical studies in mathematics education (Azkia & Susanti, 2025; Fitriani & Yudhanegara, 2023; Gashaj et al., 2025; Genç et al., 2025; NCTM, 2000; Sukmawati, 2018). They represent communication as meaning-making and mathematical justification rather than merely as the correct use of notation.

The two competencies are examined within the framework of numeracy literacy. In this study, numeracy literacy refers to the capacity to mobilize mathematical knowledge, quantitative reasoning, data interpretation, and appropriate representations to understand problems, evaluate information, and make justified decisions in meaningful everyday, social, and interdisciplinary contexts (Gashaj et al., 2023; Getenet & Getnet, 2023; Edwards et al., 2023; Yim, 2024). This definition distinguishes numeracy literacy from several related constructs. It is broader than computational proficiency and functional numeracy because it requires interpretation, critical judgment, and context-sensitive decision making rather than the routine execution of calculations. It overlaps with mathematical literacy in applying mathematics to real-world problems, but the emphasis in the present study is on the practical and interdisciplinary use of quantitative information within thematic learning rather than on performance within a specific international assessment framework. Numeracy literacy is therefore treated as an applied interdisciplinary competence, while mathematical knowledge and procedures constitute resources used within that competence.

Numeracy literacy provides a meaningful setting in which mathematical creative thinking and communication can operate together. Contextual numeracy problems are frequently open to more than one interpretation, representation, strategy, or defensible decision. Students must identify relevant quantitative information, connect it with mathematical concepts, formulate possible strategies, and assess the reasonableness of their conclusions. These demands create opportunities for fluency, flexibility, originality, and elaboration. At the same time, students must explain assumptions, present evidence, translate among verbal, numerical, symbolic, and visual representations, and justify why a particular conclusion is appropriate. Numeracy literacy consequently functions as the contextual arena in which creative mathematical ideas are produced and made accountable through communication (Cartwright, 2020; Bell et al., 2023; Husna et al., 2024).

Thematic learning is the pedagogical framework used to organize these numeracy experiences. It is defined here as an approach that connects concepts and learning activities through a meaningful theme drawn from students lived, social, or interdisciplinary contexts (Shabirah & Mahsun, 2024; Buchanan et al., 2025). Its theoretical basis is compatible with constructivist and contextual perspectives on learning: students develop understanding by linking new mathematical ideas to prior knowledge,

applying them to coherent situations, using multiple representations, and discussing their interpretations with others. Thematic learning is not understood simply as attaching a real-life story to a conventional exercise. It involves structuring a theme so that students must identify relevant information, formulate mathematical relationships, explore possible solutions, communicate interpretations, and reflect on the implications of their reasoning. Related elementary-school research examines learning interest under thematic and character-integrated thematic instruction (Syamsuddin et al., 2021).

Within numeracy literacy–based thematic learning, mathematics is therefore positioned neither as an isolated collection of formulas nor merely as a supporting component of other subjects. It becomes an analytical tool for investigating issues embedded in a theme and making evidence-based decisions (Lechner et al., 2021; Hornburg et al., 2024; Mutik et al., 2024). This approach is theoretically conducive to mathematical creative thinking because authentic thematic problems may allow different assumptions, strategies, and representations. It is also conducive to mathematical communication because students must articulate how mathematical evidence relates to the context, compare interpretations, and defend their conclusions. The instructional context thus establishes a coherent relationship among the constructs: thematic learning supplies an integrated and meaningful problem context; numeracy literacy defines the use of quantitative reasoning within that context; mathematical creative thinking generates and develops possible approaches; and mathematical communication represents, tests, and refines the resulting ideas.

Despite this theoretical potential, implementation remains challenging. Mathematics instruction in many settings continues to emphasize routine procedures, predetermined solution methods, final answers, and teacher-centred explanation (Koparan et al., 2023; Ouyang & Chan, 2025). Such practices restrict opportunities for students to explore alternatives and communicate reasoning in flexible and meaningful ways (Permata Ayu & Supriadi, 2022; Guohua et al., 2025). Teachers may also experience difficulty designing thematic activities that integrate numeracy literacy systematically, while limited learning resources, curriculum demands, and test-oriented assessment cultures may further constrain implementation (Klochkova et al., 2016; Perdana & Suswandari, 2021; Handayani, 2023; Zittoun & Cabra, 2024; Cheung et al., 2025; Salsabila et al., 2025). Empirical reports indicating that students' creative thinking and mathematical communication remain underdeveloped in several Southeast Asian settings reinforce the need to examine how these competencies are manifested in actual learning contexts (Latifa & Pratama, 2025).

Indonesia and Malaysia constitute analytically relevant cases because they combine broad regional and educational similarities with identifiable differences in how higher-order competencies are framed and implemented. Both are Southeast Asian education systems in which mathematics curricula emphasize the application of knowledge beyond routine computation, thereby providing a common conceptual basis for comparing mathematical creative thinking and communication. In Indonesia, the current national curriculum explicitly identifies critical reasoning, creativity, collaboration, and communication as intended student competencies and promotes contextual, flexible, and student-centred learning, with literacy and numeracy embedded across learning activities (Pusat Standar & Kebijakan Pendidikan, 2026). In Malaysia, the Standards-Based Curriculum for Secondary Schools and the Malaysia Education Blueprint explicitly embed Higher Order Thinking Skills, including reasoning, reflection, problem solving, decision making, innovation, and the communication of ideas, within curriculum and assessment reform (Azid et al., 2022). Thus, the comparison is not based merely on geographical proximity or nationality. It examines two systems that pursue related twenty-first-century outcomes through policy architectures that differ in their terminology, curricular organization, assessment emphasis, and expected modes of classroom enactment.

The expected differences are grounded in a comparative-contextual framework rather than in the assumption that nationality independently determines student performance. Following the multilevel logic of comparative education, particularly the Bray and Thomas (1995) framework, educational outcomes are interpreted as products of interacting system-, school-, classroom-, and student-level conditions. At the system level, curriculum standards, assessment policies, teacher-development structures, and resource distribution shape the opportunities formally available for numeracy, creativity, and communication. At the school and classroom levels, these policies are mediated by school leadership, teacher preparation, task design, instructional time, assessment practice, and the fidelity with which curriculum intentions are enacted. At the student level, socioeconomic background, prior achievement, language, cultural norms of participation, and familiarity with open-ended tasks may influence how students generate and communicate mathematical ideas. Country membership is therefore used as a contextual grouping variable that locates the sampled students within different configurations of these conditions, not as a self-sufficient explanatory variable.

This distinction is especially important because formal curriculum intentions do not necessarily produce equivalent learning opportunities. A policy may explicitly promote creativity or higher-order thinking while classroom practice remains dominated by teacher explanation, procedural exercises, and examinations. Conversely, teachers may create dialogic and exploratory learning opportunities even under relatively prescriptive curriculum conditions. International evidence also demonstrates that mathematics performance varies with socioeconomic background, school context, teacher support, and learning opportunities, indicating that national averages cannot be interpreted independently of their social and institutional composition (OECD, 2023). PISA 2022 reported different average mathematics outcomes for Indonesia and Malaysia, but such differences describe performance patterns at the system level and do not identify the instructional or cultural mechanisms responsible for them (OECD, 2023). For this reason, the present study uses policy differences to justify the selection of contrasting contexts while treating curriculum implementation, teacher characteristics, assessment practices, school conditions, socioeconomic composition, language, and cultural influences as relevant interpretive factors and potential confounders.

The comparative purpose is therefore to identify whether the sampled educational settings display different profiles of mathematical creative thinking and mathematical communication under numeracy literacy–based thematic learning, and then to interpret those patterns in relation to their documented contexts. The comparison does not test whether one national system

is inherently superior to the other and does not infer that any observed score difference was caused by national policy. Instead, it applies a most-similar-context comparative logic: the two cases share regional proximity and broad commitments to higher-order and applied mathematical learning, while differing in the policy framing and enactment of those commitments. This combination permits theoretically meaningful comparison because similarities help establish a common basis for measurement, whereas contextual differences provide plausible, but not automatically causal, explanations that can guide subsequent investigation.

Although previous studies have examined mathematical creativity, mathematical communication, numeracy literacy, and thematic instruction, the unresolved problem is not merely that these studies have generally been conducted within a single country or have addressed one competency at a time. The more fundamental conceptual gap concerns the fragmented treatment of idea generation and idea communication in mathematics education. Creative thinking is often assessed as an individual capacity to produce fluent, flexible, original, and elaborated responses, whereas mathematical communication is evaluated separately as the ability to present symbols, representations, explanations, or arguments. This separation leaves insufficient understanding of how students transform an emerging or non-routine mathematical idea into an explicit representation, justify its validity, respond to alternative interpretations, and refine it through communication. Consequently, existing research provides only a partial explanation of mathematical performance in contextual tasks: it may show how many ideas students produce or how clearly, they communicate, but it does not adequately explain the interdependent process through which mathematically creative ideas become communicable, examinable, and defensible.

A second gap concerns the role of numeracy literacy–based thematic learning in connecting these competencies. Existing studies frequently report positive associations between contextual instruction and either creativity, communication, or numeracy performance. However, the theoretical mechanism linking them remains insufficiently specified and empirically examined. Contextual quantitative problems may expand opportunities for alternative strategies and representations, but they also require students to evaluate the relevance of information, make assumptions, connect mathematical results with a real situation, and justify a decision to others. It therefore remains unresolved whether students who display strong idea-generation profiles also demonstrate correspondingly strong representational and justificatory communication, or whether uneven profiles emerge—for example, students may generate several solutions but be unable to justify them, or communicate procedures accurately without producing flexible or original approaches. Examining the indicator profiles of both constructs within the same tasks can address this unresolved relationship rather than merely placing two outcome variables side by side.

A third gap is comparative and explanatory. Current evidence does not establish whether the relationship between mathematical creative thinking and communication is expressed consistently across educational settings that share broad commitments to higher-order learning but differ in curriculum framing, assessment emphasis, and classroom enactment. The scarcity of direct Indonesia–Malaysia comparisons is therefore not treated as sufficient justification by itself. Instead, the comparison is theoretically valuable because it tests the contextual robustness of the integrated framework: if similar indicator relationships appear in both sampled settings, the findings would support the proposition that creativity and communication are mutually connected within contextual numeracy activity; if different or uneven profiles appear, the findings would indicate that their relationship may be sensitive to learning opportunities and contextual mediation. In either case, the comparison can refine current understanding by distinguishing potentially recurring competency patterns from patterns that may depend on particular educational settings.

This study consequently advances knowledge in three respects. Conceptually, it integrates mathematical creative thinking and mathematical communication as complementary processes of generating, representing, testing, and refining mathematical ideas. Empirically, it analyses both total performance and indicator-level profiles within numeracy literacy–based thematic tasks, allowing convergent and divergent patterns between the competencies to be identified. Comparatively, it examines whether these patterns are reproduced across two selected educational settings while using a multilevel framework to avoid reducing contextual variation to nationality. The intended contribution is therefore not to claim that one country or curriculum is more effective, but to develop a more context-sensitive explanation of how creative and communicative mathematical competencies coexist and vary in authentic quantitative problem solving.

Accordingly, this study aims to profile and compare the mathematical creative thinking and mathematical communication skills demonstrated by secondary school students in selected numeracy literacy–based thematic learning contexts in Indonesia and Malaysia. It addresses the following questions: (1) What are the levels and indicator profiles of students' mathematical creative thinking in the two selected contexts? (2) What are the levels and indicator profiles of students' mathematical communication in the two selected contexts? (3) What convergent or divergent patterns can be identified between students' mathematical creative thinking and mathematical communication profiles? and (4) Are there statistically significant differences between the sampled groups in mathematical creative thinking and mathematical communication? The findings are expected to clarify the conceptual relationship between generating and communicating mathematical ideas, provide evidence about the contextual robustness of that relationship, and inform the design of future studies and learning activities that integrate creativity, justification, representation, and numeracy reasoning. Any differences identified are interpreted as differences between the sampled educational settings rather than as direct evidence of the superiority of a country, curriculum, or instructional approach.

LITERATURE REVIEW

Mathematical creative thinking, mathematical communication, numeracy literacy, thematic learning, mathematical literacy, higher-order thinking skills, and twenty-first-century competencies are related but not interchangeable concepts. Twenty-first-century competencies constitute the broadest educational category and commonly include creativity, critical thinking,

communication, collaboration, and problem solving. Higher-order thinking skills refer more specifically to cognitive processes that require students to analyse, evaluate, create, and make reasoned decisions rather than merely recall information or reproduce procedures. Within this broader domain, mathematical creative thinking and mathematical communication are discipline-specific competencies. Numeracy literacy and mathematical literacy concern the application of mathematical knowledge, whereas thematic learning is a pedagogical approach through which such application may be organized. Establishing these distinctions is essential because the present study does not treat all seven terms as equivalent outcomes.

Mathematical creative thinking is defined as students' capacity to generate and develop mathematically relevant, valid, and relatively novel ideas, strategies, or representations. Fluency, flexibility, originality, and elaboration describe observable dimensions of this capacity. Fluency concerns the production of several relevant responses; flexibility involves movement across qualitatively different strategies or representations; originality concerns an uncommon but mathematically defensible response; and elaboration concerns the extension and refinement of an idea into a coherent solution. Mathematical creativity is therefore narrower than general creativity because novelty alone is insufficient: the resulting idea must also satisfy mathematical constraints and contribute meaningfully to problem resolution (Fineldi & Hidayati, 2023; Nadjafikhah & Yaftian, 2013; Ningsih et al., 2024; Yayuk et al., 2020). Related work examines definitions and assessment practices (Sipahi & Bahar, 2025), support for creative thinking in mathematics education (Švecová et al., 2014), and creative responses in algebra, linear-equation word problems, and statistics (Maryati & Nurkayati, 2021; Nesti et al., 2023; Permatasari et al., 2023).

Mathematical communication refers to the process of constructing, representing, explaining, evaluating, and revising mathematical meaning through spoken language, written explanations, symbols, diagrams, tables, graphs, and other representations. It is not merely the accurate presentation of a final answer. Communication enables students to make assumptions explicit, organize reasoning, justify procedures, compare alternative solutions, and evaluate whether a conclusion follows from the available evidence. Accordingly, mathematical communication has cognitive, representational, social, and epistemic functions. Its cognitive function supports the organization of thought; its representational function translates relationships across mathematical forms; its social function enables ideas to be negotiated with others; and its epistemic function makes mathematical claims available for justification and critique (Aljura et al., 2025; Andika et al., 2025; Sfard & Kieran, 2001; Sriraman, 2009). Related studies examine mathematical communication in mathematics learning (Suhenda & Munandar, 2023) and in solving story problems across levels of mathematical ability (Samawati & Ekawati, 2021).

Numeracy literacy is defined in this study as the capacity to use mathematical knowledge, quantitative information, and representations to interpret contextual problems, evaluate alternatives, and make justified decisions. It extends beyond functional numeracy, which may be limited to practical calculation, because it includes critical interpretation, reasoning, and judgment. Numeracy literacy overlaps with mathematical literacy in its emphasis on applying mathematics to real-world situations. However, mathematical literacy generally emphasizes the broader cycle of formulating, employing, and interpreting mathematics, whereas the present use of numeracy literacy foregrounds the interpretation and communication of quantitative information across everyday and interdisciplinary themes. Thematic learning, by contrast, is not a student competency. It is an instructional organization that connects concepts and activities through a meaningful theme. Numeracy literacy–based thematic learning therefore refers to a pedagogical setting in which students use quantitative reasoning to investigate contextual and interdisciplinary problems (Geiger et al., 2015; Ningsih et al., 2024).

Relationship between Mathematical Creative Thinking and Communication

Previous studies broadly converge on the proposition that open-ended, contextual, and non-routine tasks provide stronger opportunities for mathematical creativity than exercises with a single predetermined procedure. Such tasks allow students to produce several possible strategies, move among representations, connect mathematical ideas with cultural or everyday contexts, and elaborate initial responses (Fineldi & Hidayati, 2023; Nadjafikhah & Yaftian, 2013; Ningsih et al., 2024; Yayuk et al., 2020). Research on mathematical communication similarly indicates that problem-oriented learning can strengthen students' ability to express ideas, organize procedures, and justify conclusions because students must make their reasoning visible rather than provide only a numerical answer (Aljura et al., 2025; Andika et al., 2025; Sfard & Kieran, 2001; Sriraman, 2009). Across these studies, the recurring pattern is that cognitively demanding tasks create opportunities for both idea generation and reasoned explanation. This perspective is also developed in work on problem solving and problem posing (Silver, 1997).

Nevertheless, the literature does not establish that the two competencies develop automatically or proportionally. A student may generate multiple strategies but fail to explain why they are valid, whereas another student may communicate a familiar procedure accurately without demonstrating flexibility or originality. Positive outcomes reported for problem-based, discovery, ethnomathematics-based, or differentiated learning should therefore not be interpreted as evidence that the instructional label itself produces creativity and communication. The effects may depend on the openness and cognitive demand of the task, the quality of teacher questioning, opportunities for student dialogue, familiarity with the context, prior mathematical knowledge, and the criteria used to assess performance. This provides an alternative explanation for variation across previous findings: differences attributed to a learning model may instead reflect differences in implementation quality, task structure, teacher support, sample characteristics, or measurement. Discovery learning has also been examined in relation to mathematical understanding and creative thinking (Lubis, 2020; Purwaningrum, 2020). Creative self-efficacy, perceived creativity, and computational thinking provide additional perspectives on mathematical creative thinking (Suherman & Vidákovich, 2024).

The relationship between creative thinking and communication is better understood as reciprocal rather than sequential or interchangeable. Creative thinking expands the range of mathematical possibilities available to students, while communication externalizes those possibilities through language and representation. Once expressed, an idea can be compared, questioned, justified, and refined, potentially generating further creative development. Communication therefore functions not only as

evidence of completed thinking but also as a mechanism that can reorganize and improve it. Conversely, creativity gives mathematical communication substantive content by requiring students to explain non-routine choices and alternative representations. This reciprocal view extends research that examines creativity and communication as isolated achievement variables and provides the central theoretical proposition of the present study.

Numeracy Literacy–Based Thematic Learning as a Connecting Mechanism

Studies of numeracy-oriented learning generally report that contextual tasks can improve relevance, engagement, mathematical literacy, creative thinking, or communication (Geiger et al., 2015; Ningsih et al., 2024). However, the literature differs in how context is assumed to operate. One explanation is motivational: familiar contexts may increase student interest and participation. A second is cognitive: contexts require students to identify relevant quantities, connect information, select mathematical tools, and evaluate the reasonableness of results. A third is discursive: contextual problems require students to explain assumptions and justify why a mathematical conclusion is appropriate for the situation. These explanations are complementary but should not be conflated, because an engaging theme does not necessarily generate cognitively demanding or communicatively rich mathematical activity.

The effectiveness of thematic learning consequently depends on the relationship between the theme and the mathematical work required. When a theme merely decorates a routine calculation, students have little opportunity to demonstrate flexible thinking or substantive communication. In contrast, a well-designed numeracy literacy task presents information that must be interpreted, permits more than one plausible strategy or representation, and requires a contextually justified decision. Such a task can activate creative thinking through the generation and evaluation of alternatives and activate communication through representation, explanation, and argumentation. Numeracy literacy–based thematic learning is therefore conceptualized as an enabling pedagogical condition rather than a direct cause of student competence. The gap between recommendations and classroom use of connecting tasks has also been studied through mathematics teacher knowledge (Leikin & Levav-Waynberg, 2007).

This interpretation helps explain why previous research does not always produce uniform results. Differences may arise from whether the tasks are genuinely open-ended, whether students have sufficient prior knowledge, whether teachers permit multiple methods, whether classroom discourse values explanation over speed, and whether assessment rubrics distinguish mathematical validity from surface novelty or verbal fluency. Cultural and linguistic familiarity with task contexts may also facilitate or constrain students' ability to express mathematical ideas. Thus, evidence of positive outcomes should be interpreted alongside competing explanations involving task design, implementation fidelity, teacher preparation, assessment practice, and student background rather than being attributed solely to a named instructional approach. Studies in other settings examine high school students' numeracy literacy in solving mathematics problems (Ladyawati & Maftuh, 2025), digital coding devices and creativity in early childhood (Tang et al., 2024), and Magic Book resources for elementary students' critical thinking and mathematical communication (Sugandi et al., 2025). These studies concern different populations and do not directly establish effects in the present sample.

Cross-Context Evidence from Indonesia and Malaysia

Indonesia and Malaysia both emphasize mathematical literacy, higher-order thinking, and twenty-first-century competencies, but policy intentions are mediated by curriculum organization, assessment expectations, teacher preparation, school resources, and classroom norms. International assessment evidence indicates that mathematics and creative thinking remain important concerns in both systems, while also demonstrating variation in performance and learning conditions (OECD, 2023; Wijaya et al., 2024). These data establish a shared policy problem but do not demonstrate that one national system or instructional approach is more effective. National performance differences may reflect socioeconomic composition, language, school selection, access to learning resources, teacher support, or students' prior opportunities to work with open-ended tasks.

Accordingly, findings from Indonesia and Malaysia should be compared through a multilevel contextual perspective. National curriculum policies define intended competencies; schools and teachers translate those intentions into learning opportunities; and students respond to tasks through resources shaped by prior knowledge, socioeconomic background, language, and culture. This perspective resolves a common weakness in cross-national research by treating country membership as a contextual grouping variable rather than an independent causal mechanism. It also directs attention toward patterns of convergence and divergence. Similar profiles across the two settings would suggest that the relationship between mathematical creativity and communication may be relatively robust across contexts. Different profiles would suggest that the relationship is mediated by contextual or instructional conditions requiring further investigation.

Critical Synthesis and Unresolved Issues

Three conclusions emerge from the reviewed literature. First, open-ended and contextual mathematical tasks generally provide opportunities for creative thinking and communication, but reported benefits vary according to task design, implementation, teacher support, student background, and measurement. Second, creativity and communication are theoretically reciprocal, yet empirical studies commonly assess them separately and therefore provide limited evidence about whether students who generate multiple or original strategies can also represent and justify those strategies. Third, cross-national achievement evidence identifies differences between Indonesia and Malaysia but does not explain whether similar or different profiles of creativity and communication occur when students engage with numeracy literacy–based thematic tasks.

These conclusions identify an unresolved theoretical issue rather than merely an absence of previous comparisons. It remains unclear whether mathematical creative thinking and mathematical communication form complementary profiles across contexts or whether they develop unevenly in response to different learning opportunities. The present study addresses this issue by

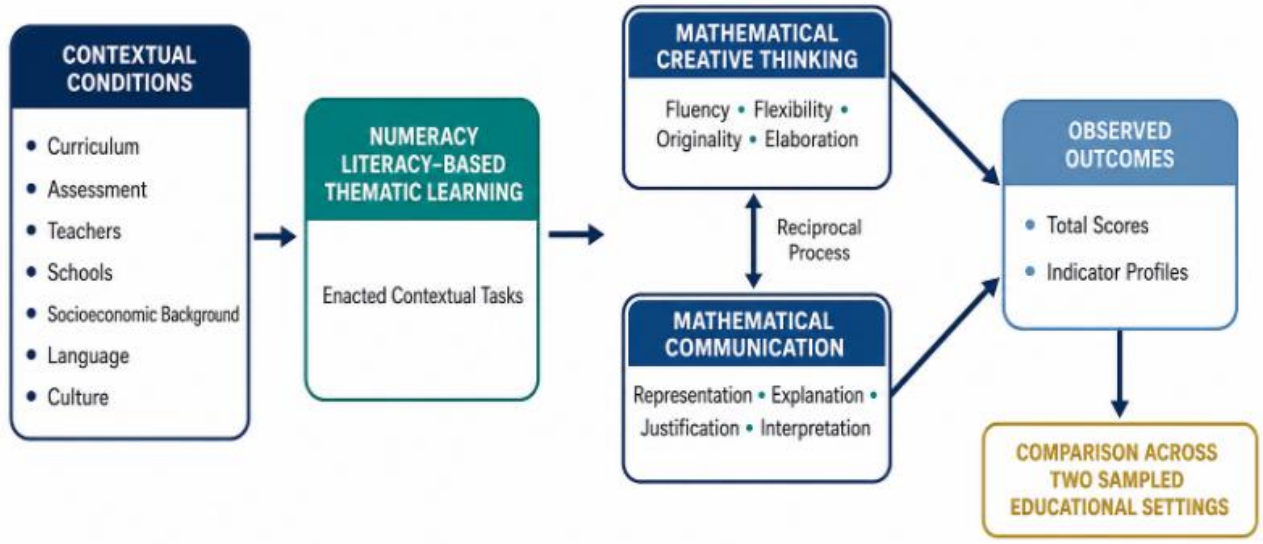


Figure 1. Proposed conceptual framework (Source: Authors' own elaboration)

examining both constructs through aligned indicators within the same pedagogical framework and by comparing their profiles across two selected educational settings. Its contribution is therefore to test the contextual robustness of an integrated creativity–communication framework, not to rank national systems or attribute group differences directly to curriculum policy.

Conceptual Framework

The proposed framework positions educational context, numeracy literacy–based thematic tasks, and the two student competencies at distinct but connected levels. Curriculum orientation, assessment practice, teacher preparation, school resources, socioeconomic background, language, and cultural participation norms constitute contextual conditions. These conditions shape how numeracy literacy–based thematic learning is enacted, including task openness, contextual authenticity, representational demand, teacher questioning, and opportunities for dialogue. Within these tasks, mathematical creative thinking and mathematical communication operate reciprocally: fluency, flexibility, originality, and elaboration expand possible mathematical responses, while representation, explanation, justification, evaluation, and revision make those responses explicit and refine their mathematical quality. The observable outcomes are students' total scores and indicator-level profiles. Country membership locates students within a configuration of contextual conditions but is not treated as a direct causal predictor.

Research Questions and Hypotheses

Based on the theoretical synthesis, the study addresses the following research questions:

RQ1. What are the levels and indicator profiles of mathematical creative thinking demonstrated by students in the selected Indonesian and Malaysian educational settings?

RQ2. What are the levels and indicator profiles of mathematical communication demonstrated by students in the two selected settings?

RQ3. What convergent or divergent patterns occur between students' mathematical creative thinking and mathematical communication profiles within each setting?

RQ4. Do the sampled Indonesian and Malaysian student groups differ significantly in mathematical creative thinking and mathematical communication?

Because the contextual framework predicts potential variation but does not provide a sufficient theoretical basis for assuming the superiority of either national group, non-directional hypotheses are formulated:

H1. There is a statistically significant difference in mathematical creative thinking scores between the sampled Indonesian and Malaysian students.

H2. There is a statistically significant difference in mathematical communication scores between the sampled Indonesian and Malaysian students.

H3. The indicator-level profiles of mathematical creative thinking and mathematical communication differ between the two sampled educational settings.

METHOD

Research Design

This study used a cross-sectional, non-experimental comparative design to describe and compare mathematical creative thinking and mathematical communication among students from two selected primary-school contexts: SD Telkom Makassar in Makassar City, Indonesia, and a participating primary school in Johor, Malaysia. No instructional treatment was assigned, manipulated, or evaluated, and no pretest–post-test comparison was conducted. Accordingly, the design does not estimate the effectiveness or causal impact of numeracy literacy–based thematic learning. It compares students' performance at one point in time after their participation in naturally occurring instructional settings that incorporated contextual quantitative tasks.

The unit of comparison was the sampled school context rather than the national education system as a whole. "Country" was used only as a label distinguishing the two school-based groups. Because all Indonesian participants were drawn from one school and all Malaysian participants from another, country, school, curriculum enactment, teacher characteristics, and other contextual influences could not be statistically separated. Observed differences were therefore interpreted as differences between the two sampled educational settings and not as evidence of national differences, curriculum superiority, or instructional effectiveness.

For this study, a numeracy literacy–based thematic learning context was operationally defined as an instructional setting in which students: (1) encountered quantitative problems embedded in an identifiable real-life or interdisciplinary theme; (2) selected and applied relevant mathematical concepts rather than merely reproducing a stated procedure; (3) interpreted numerical, verbal, tabular, graphical, or diagrammatic information; (4) considered or generated more than one strategy or representation when permitted by the task; and (5) explained or justified a conclusion in relation to the problem context. The term therefore referred to the characteristics of the learning opportunities available to students and not simply to a curriculum label used by a school.

The presence and comparability of this instructional context were examined at SD Telkom Makassar and the participating primary school in Johor through four complementary sources: curriculum-document review, lesson-plan review, semi-structured teacher interviews, and non-participant classroom observations. The same review protocol and verification checklist were used at both sites so that the comparison did not depend solely on the names of the national curricula or on teachers' self-reports.

First, the curriculum-document review examined the official curriculum and school-level instructional documents used by each site. At SD Telkom Makassar, the review covered the applicable Indonesian primary-school curriculum, mathematics learning outcomes, numeracy guidance, school curriculum documents, and documents describing the school's contextual or technology-supported learning practices. The review also considered the broader Telkom Schools learning orientation, including hybrid learning and the Playing, Living, and Studying concept, only where school-specific documents confirmed its implementation at SD Telkom Makassar. At the Johor school, the review covered the Malaysian Primary School Standard Curriculum (Kurikulum Standard Sekolah Rendah/KSSR), the applicable Mathematics Curriculum and Assessment Standard Document (Dokumen Standard Kurikulum dan Pentaksiran/DSKP), school-based assessment guidance, and school-level mathematics documents. Particular attention was given to KSSR expectations regarding Higher Order Thinking Skills and mathematical communication, both of which are explicitly incorporated into Malaysian primary mathematics curriculum guidance.

Second, the lesson-plan review examined eight mathematics lesson plans or teaching modules from each school for the same or comparable grade level and instructional period. The Indonesian materials included [The documents analyzed at SD Telkom Makassar were teaching modules and student worksheets], whereas the Malaysian materials included [Rancangan Pengajaran Harian/teacher modules/student worksheets]. Each document was coded for: (1) the presence of a meaningful real-life or interdisciplinary theme; (2) use of numerical, verbal, tabular, graphical, or diagrammatic information; (3) opportunities to select or generate strategies; (4) opportunities to use multiple representations; (5) requirements to explain or justify answers; (6) opportunities for mathematical discussion; and (7) alignment among learning objectives, activities, and assessment. To improve comparability, reviewers evaluated the cognitive and communicative demands of the planned tasks rather than expecting identical lesson formats in both curriculum systems.

Third, semi-structured interviews were conducted with five Grade 5 mathematics teachers at SD Telkom Makassar, Indonesia, and five Year 5 mathematics teachers at the participating primary school in Johor, Malaysia. The interview guide contained the same core questions in both settings and explored teachers' interpretation of numeracy literacy, frequency of contextual mathematical tasks, use of thematic connections, encouragement of alternative strategies, use of student explanations and representations, assessment of creative responses, classroom-language practices, and constraints affecting implementation. Interviews lasted approximately five minutes, were conducted in Indonesian, audio-recorded with permission, and summarized using a structured comparison matrix. Curriculum-specific follow-up questions were permitted, but they were mapped onto the same analytical domains.

Fourth, five Grade 5 mathematics lessons were observed at each site, with one lesson delivered by each participating mathematics teacher, using a common non-participant observation sheet. Observations recorded the nature of the tasks, teacher questioning, students' opportunities to propose different methods, the use of mathematical symbols and visual representations, requests for explanation or justification, teachers' responses to unusual solutions, patterns of classroom interaction, the use of contextual information, and assessment feedback. Each criterion was rated on a four-point implementation scale: 0 = not observed, 1 = minimally observed, 2 = adequately observed, and 3 = consistently and substantively observed. Field notes were used to document examples, contextual features, and differences that could not be adequately represented by numerical ratings.

Evidence from the four sources was triangulated using a site-comparison matrix. A criterion was classified as verified when it was supported by at least two data sources, one of which had to be either lesson-plan evidence or classroom observation. The

Table 1. Verification of numeracy literacy–based thematic learning across the two primary-school settings

Verification criterion	SD Telkom Makassar, Indonesia	Score	Primary school in Johor, Malaysia	Score	Comparative interpretation
Curriculum alignment	Learning activities were aligned with Grade 5 mathematics outcomes and numeracy competencies in the applicable Indonesian curriculum.	3	Learning activities were aligned with Year 5 Mathematics standards under KSSR and DSKP, including HOTS.	3	Strong alignment was identified at both sites.
Task contextuality	Tasks frequently used everyday contexts, digital information, shopping, measurement, and school-related situations.	3	Tasks frequently involved money, measurement, data, time, and community situations.	3	Both sites consistently used meaningful contextual problems.
Thematic integration	Mathematics was integrated with technology, environmental issues, daily activities, and other learning themes.	3	Mathematics was connected with science, health, the environment, and community themes, although integration varied across lessons.	2	Thematic integration was more consistently visible at SD Telkom Makassar.
Strategy openness	Students were occasionally encouraged to use alternative strategies, although teacher-guided procedures remained evident.	2	Students were regularly encouraged to compare methods and apply different HOTS-oriented strategies.	3	Both provided strategy choice, but it was more consistently observed in Johor.
Representational demands	Students used numbers, mathematical symbols, tables, diagrams, and digital or visual representations.	3	Students used symbols, tables, diagrams, models, and written representations.	3	Multiple representations were substantively required at both sites.
Explanation and justification	Students explained their procedures, but detailed justification was not consistently required in every lesson.	2	Teachers regularly asked students to explain methods and justify the suitability of their answers.	3	Explanation occurred at both sites, with stronger consistency in Johor.
Mathematical discourse	Question-and-answer exchanges and group discussions occurred, but teacher-led interaction remained relatively dominant.	2	Student explanations, peer comparisons, and teacher probing were consistently incorporated into classroom interaction.	3	Mathematical discourse was evident in both settings but more sustained in Johor.
Assessment alignment	Worksheets, classroom questioning, and formative assessments evaluated contextual problem solving and mathematical representations.	3	Classroom and school-based assessments were aligned with KSSR, DSKP, and HOTS-oriented mathematical tasks.	3	Assessment was strongly aligned with curricular expectations at both sites.
Total implementation score		21/24		23/24	Both sites met the criteria for numeracy literacy–based thematic learning.

review was conducted by two reviewers with expertise in primary mathematics education and educational assessment. Both reviewers independently coded 100% of the curriculum documents, lesson plans, teacher-interview summaries, and classroom-observation records from the two schools. Coding discrepancies were discussed and resolved through consensus based on the established operational definitions. The verification results are presented in **Table 1**, covering curriculum alignment, task contextuality, thematic integration, strategy openness, representational demands, explanation and justification, mathematical discourse, and assessment alignment at SD Telkom Makassar and the participating primary school in Johor.

Population and Sample

Data collection was conducted over a three-month period during the second semester of the 2025/2026 academic year. Instrument development, expert review, language adaptation, and cross-context examination were completed before the school-based fieldwork. The three-month fieldwork included curriculum and lesson-plan reviews, teacher interviews, classroom observations, and test administration. Scoring, data verification, and statistical analysis were conducted immediately after data collection. Data collection took place from February to April 2026.

The Indonesian site was SD Telkom Makassar, a private primary school located at Jl. A. P. Pettarani No. 4, Gunung Sari, Rappocini District, Makassar City, South Sulawesi, Indonesia. The school is administered by Yayasan Pendidikan Telkom and was accredited A. During the study, it implemented the Kurikulum Merdeka integrated with information technology in classroom learning. The school is situated in an urban area of Makassar and serves students from diverse family backgrounds. Its classrooms are supported by digital learning facilities, including projectors, smart televisions, multimedia facilities, internet access, and other technology-assisted learning resources. The participating Grade 5 cohort consisted of 57 students aged approximately 10–11 years. Five Grade 5 mathematics or classroom teachers participated in the curriculum review, interviews, and lesson observations. Information concerning teacher qualifications and teaching experience was obtained through the teacher-background questionnaire and is reported descriptively rather than used as evidence of equivalence between the two sites. The address, private status, accreditation, and use of Kurikulum Merdeka integrated with information technology are reported by the official SD Telkom Makassar website.

The Malaysian site was a participating primary school located in Johor, Malaysia. The school's official name was withheld in the manuscript in accordance with institutional permission and research confidentiality requirements. It implemented the Primary School Standard Curriculum or Kurikulum Standard Sekolah Rendah and the Year 5 Mathematics Curriculum and Assessment Standard Document or Dokumen Standard Kurikulum dan Pentaksiran. The curriculum emphasizes mathematical reasoning, problem solving, communication, representation, and Higher Order Thinking Skills. The participating Year 5 cohort

consisted of 57 students aged approximately 10–11 years. Five-Year mathematics teachers participated in the curriculum review, interviews, and classroom observations. The language used for test administration was matched to the language used in the participating mathematics classroom, with translated versions reviewed to preserve equivalent mathematical meaning and cognitive demand. The emphasis on Higher Order Thinking Skills and mathematical communication is stated in the official KSSR Year 5 Mathematics curriculum.

The two sites were not considered completely equivalent. Comparability was established on the basis of the students' educational stage, approximate age, Grade 5–Year 5 curriculum content, exposure to contextual mathematical tasks, sample size, number of participating teachers, assessment duration, and administration procedures. Differences in curriculum terminology, school governance, classroom language, technological resources, assessment practices, teacher preparation, and socioeconomic composition were documented as contextual qualifications. Socioeconomic equivalence was not assumed when comparable family-level data were unavailable. These contextual factors were not statistically controlled and were therefore considered potential confounders when interpreting between-group differences.

Research Variables

The study examined two outcome variables: mathematical creative thinking and written mathematical communication. The grouping variable represented the two sampled school contexts: SD Telkom Makassar, Indonesia, and the participating primary school in Johor, Malaysia. This grouping variable was used solely to organize the comparative analysis and was not treated as an explanatory measure of nationality or national educational quality. Because one school represented each location, differences between the groups could not be separated from differences in school characteristics, curriculum enactment, teachers, assessment practices, language, culture, or socioeconomic background.

Mathematical creative thinking was operationalized through four indicators: fluency, flexibility, originality, and elaboration. Fluency referred to the ability to generate multiple mathematically relevant responses. Flexibility concerned the use of qualitatively different strategies or representations. Originality referred to an uncommon but mathematically valid response, whereas elaboration concerned the systematic development, clarification, and verification of a mathematical idea. The instrument contained eight open-ended items, with two items representing each indicator. The items were developed with reference to Guilford's divergent-thinking framework, Torrance's creativity dimensions, and Silver's application of creativity to mathematical problem solving. Each item was embedded in a contextual numeracy problem appropriate for Grade 5 and Year 5 students.

Written mathematical communication was operationalized through four indicators: written mathematical expression, use of mathematical representations, logical explanation and justification of procedures, and interpretation of mathematical information. The term "written mathematical communication" was used because the instrument consisted of essay items and did not directly assess students' oral communication. The test contained eight open-ended items, with two items representing each indicator. Its development was informed by the mathematical communication standards of the National Council of Teachers of Mathematics and related mathematics education research.

A test blueprint was prepared to map each item to its intended indicator, mathematical content, contextual theme, cognitive demand, and scoring criteria. The Indonesian and Malaysian versions maintained the same mathematical structure, number of items, targeted indicators, response requirements, administration time, and scoring rules. Linguistic and contextual modifications were limited to expressions necessary for student comprehension and were not permitted to change the mathematical demand of the tasks.

Student responses were evaluated using indicator-specific analytical rubrics ranging from 0 to 4. A score of 0 indicated no relevant response; 1 indicated minimal evidence of the intended competency; 2 indicated partially correct but incomplete evidence; 3 indicated substantially correct, coherent, and adequately developed evidence; and 4 indicated complete, mathematically valid, clearly communicated, and well-developed evidence. Specific descriptors were prepared for each indicator because originality, flexibility, elaboration, representation, and justification required different observable evidence. Each instrument produced a possible total score ranging from 0 to 32.

Before administration, the instruments and scoring rubrics were reviewed by two mathematics education specialists for mathematical accuracy, indicator alignment, content relevance, language clarity, developmental suitability, and contextual appropriateness. Because only two specialists participated, their evaluations were treated as preliminary content-validity evidence rather than conclusive evidence of construct validity or cross-cultural equivalence. The manuscript should report the criteria used by the specialists, the items revised following their recommendations, and any quantitative content-validity indices that were actually calculated.

Cronbach's alpha coefficients were 0.75 for mathematical creative thinking and 0.80 for written mathematical communication. These values indicated acceptable preliminary internal consistency. However, alpha was not interpreted as evidence of unidimensionality, construct validity, or cross-context measurement equivalence because both instruments contained open-ended items representing multiple indicators.

Because responses were evaluated using analytical rubrics, scoring consistency was examined separately from internal consistency. Two trained raters independently scored the anonymized responses using the same rubrics and benchmark responses. Inter-rater reliability for total scores was ICC(2,1) = 0.91 (95% CI [0.87, 0.94]) for mathematical creative thinking and ICC(2,1) = 0.93 (95% CI [0.90, 0.95]) for written mathematical communication, using a two-way random-effects model with absolute agreement and single measurements. Quadratic weighted kappa coefficients ranged from 0.76 to 0.84 across creative thinking indicators and from 0.81 to 0.86 across written mathematical communication indicators. Any scoring disagreements were resolved through discussion after the initial agreement coefficients had been calculated. Broader issues in choosing and interpreting

Table 2. Comparative descriptive statistics of students' mathematical creative thinking

Descriptive Statistics	Malaysian Students	Indonesian Students
Sample Size (N)	57	57
Mean	85.18	89.63
Median	85.00	90.00
Mode	95	90
Standard Deviation	8.96	2.86
Range	30	16
Minimum Score	65	78
Maximum Score	95	94

agreement measures are discussed by Rau and Shih (2021) for nominal data; that discussion does not validate the weighted-kappa estimates required for the present ordinal scores.

Data Analysis

Data analysis consisted of preliminary screening, descriptive analysis, and inferential comparison. Before analysis, the dataset was examined for data-entry errors, impossible scores, missing responses, and univariate outliers. The number and proportion of missing responses were reported for each item and group. Decisions to exclude participants or treat incomplete responses followed prespecified criteria and were reported transparently.

Descriptive statistics were calculated separately for students from SD Telkom Makassar and the participating Johor primary school. These statistics included sample size, mean, standard deviation, median, interquartile range, minimum, maximum, skewness, and 95% confidence intervals for mathematical creative thinking and written mathematical communication scores. Indicator-level scores were also presented to describe fluency, flexibility, originality, elaboration, written mathematical expression, representation, explanation and justification, and interpretation. Categories such as "high" or "very high" were used only when their cut-off values and theoretical basis were explicitly stated.

Distributional assumptions were examined using the Shapiro–Wilk test, histograms, and Q–Q plots. Variance equality was evaluated using Levene's test and the observed variance ratio. Because substantial differences in group variances were possible, Welch's independent-samples t-test was used as the primary test for comparing group means when score distributions were reasonably symmetric and free from influential outliers. For each outcome, the analysis reported the group means, mean difference, t statistic, degrees of freedom, two-sided p-value, and 95% confidence interval.

The magnitude of each group difference was estimated using Hedges' g, accompanied by a 95% confidence interval. Hedges' g was selected because it provides a small-sample correction to Cohen's d. Effect sizes were interpreted as the magnitude of differences between the two sampled school contexts and not as evidence of instructional effectiveness or national superiority.

When an outcome demonstrated severe non-normality or influential outliers that could not be resolved through data verification, the Mann–Whitney U test was used as the primary nonparametric alternative. The analysis reported the U statistic, two-sided p-value, and rank-biserial correlation or Cliff's delta. Parametric and nonparametric tests were not simultaneously used to confirm the same hypothesis without a predefined sensitivity-analysis rationale.

The comparisons of the two total scores were treated as the primary inferential analyses. Indicator-level comparisons were classified as secondary analyses. When separate tests were performed across multiple indicators, the Benjamini–Hochberg procedure was applied to control the false-discovery rate. The statistical significance level was set at $\alpha = 0.05$, and all tests were two-sided.

The results were interpreted as differences between the sampled students at SD Telkom Makassar and the participating primary school in Johor. They were not interpreted as causal effects of numeracy literacy–based thematic learning or as representative differences between Indonesian and Malaysian primary-school populations. Potential influences of school characteristics, teacher preparation, curriculum implementation, assessment practice, language, and socioeconomic background were considered when discussing the findings.

RESULTS

Descriptive Analysis of Students' Mathematical Creative Thinking Ability

Descriptive statistical analysis was conducted to provide an overview of the characteristics of students' mathematical creative thinking ability in both national contexts.

Table 2 shows that students from the Indonesian school achieved a higher mean creative-thinking score (M = 89.63, SD = 2.86) than those from the Malaysian school (M = 85.18, SD = 8.96). Indonesian scores were less variable (78–94) than Malaysian scores (65–95). Both distributions were negatively skewed, indicating that scores were concentrated toward the upper end. These findings describe differences between the two sampled schools and should not be interpreted as evidence of national or instructional superiority.

Tables 3 and **4** list the garden designs generated by the Indonesian and Malaysian students, respectively." ALSO: the text and Table 5 say six designs including an L-shaped garden, but Table 3 lists only five rectangles. Add row 6: L-shaped (8 × 8 m minus 4 × 4 m) | 48 m² | 32 m.

Table 3. The student generated five rectangular designs - Indonesian student's solution

Design	Dimensions	Area	Perimeter
1	(1xtimes48) m	48 m^2	98 m
2	(2xtimes24) m	48 m^2	52 m
3	(3xtimes16) m	48 m^2	38 m
4	(4xtimes12) m	48 m^2	32 m
5	(6xtimes8) m	48 m^2	28 m

Table 4. The student generated three rectangular designs – Malaysian student's solution

Design	Dimensions	Area	Perimeter
1	(3xtimes16) m	48 m^2	38 m
2	(4xtimes12) m	48 m^2	32 m
3	(6xtimes8) m	48 m^2	28 m

Table 5. The students' creative-thinking profiles

Indicator	Indonesian student	Malaysian student
Fluency	High: generated six mathematically valid designs.	Good: generated three valid designs.
Flexibility	High: used rectangular and composite designs and different calculation strategies.	Moderate: produced several solutions but used only rectangular designs.
Originality	High: created a valid L-shaped garden.	Limited: used common rectangular factor pairs.
Elaboration	High: provided complete area and perimeter calculations and a detailed justification.	Good: calculations were systematic and correct, but the explanation was less developed.
Overall profile	Demonstrated all four creative-thinking dimensions comprehensively.	Demonstrated good fluency and procedural accuracy, but less flexibility and originality.

Profile of Indonesian and Malaysian Students' Mathematical Creative Thinking Ability

To provide a more detailed illustration of Indonesian and Malaysian students' mathematical creative thinking profiles, an open-ended contextual mathematics task was used to examine fluency, flexibility, originality, and elaboration. **Table 5** summarizes the creative-thinking profiles across the four indicators. The following task and responses how students' solution strategies were analysed across these four indicators.

A school plans to build a literacy garden with an area of exactly 48 m^2.

1. Create at least three different garden designs.
2. Each design may be rectangular or a combination of several shapes.
3. Calculate the area and perimeter of each design.
4. Determine which design requires the least fencing.
5. Explain your solution and justify your final choice.

The task assesses four dimensions of mathematical creative thinking: fluency, flexibility, originality, and elaboration.

Indonesian student's solution

The student also created an L-shaped design by removing a 4×4m section from an 8×8m square.

$$\text{Area} = (8 \times 8) - (4 \times 4) = 64 - 16 = 48 \text{ m}^2$$

The perimeter of the L-shaped garden was:

$$P = 8 + 4 + 4 + 4 + 4 + 8 = 32 \text{ m}$$

The student selected the 6×8m rectangular design because it had the smallest perimeter:

$$P = 2(6 + 8) = 28 \text{ m}$$

Therefore, this design required the least fencing.

Malaysian student's solution

The calculations were:

$$P_{3\times16} = 2(3 + 16) = 38 \text{ m}$$
$$P_{4\times12} = 2(4 + 12) = 32 \text{ m}$$
$$P_{6\times8} = 2(6 + 8) = 28 \text{ m}$$

The student selected the 6×8m design because its perimeter was the smallest. Therefore, it required the least fencing.

The Indonesian response demonstrates a broader range of strategies and representations, particularly through the additional L-shaped design. The illustrative Malaysian response is mathematically accurate and systematic but relies on a single category of shapes. Both students correctly conclude that the 6×8 m rectangle requires the least fencing.

The definitions and theoretical explanations of fluency, flexibility, originality, and elaboration as dimensions of creative thinking based on the theories of Joy Paul Guilford (1967) and Ellis Paul Torrance (1974) have been discussed comprehensively in the Introduction section as the conceptual foundation of this study. This profile suggests that numeracy literacy–based thematic

Table 6. Comparison of mathematical creative thinking ability between Malaysian and Indonesian students

Creative Thinking Indicator	Indonesian Students	Dominant Category	Malaysian Students	Dominant Category	Comparative Pattern
Fluency	Generated several mathematically valid garden designs, including five rectangular designs and one composite design.	High	Generated three mathematically valid rectangular designs.	Good	Both produced multiple correct solutions, but Indonesian students generated a greater number of alternatives.
Flexibility	Used different shapes, representations, and calculation strategies, including rectangular and L-shaped designs.	High	Used different dimensions but remained within the same rectangular design and calculation procedure.	Moderate	Indonesian students demonstrated a broader variety of strategies and representations.
Originality	Produced an uncommon but valid L-shaped design by modifying a square while maintaining the required area.	High	Produced correct solutions based on commonly used rectangular factor pairs.	Limited	Originality was more evident in the Indonesian students' solutions.
Elaboration	Presented complete area and perimeter calculations, compared all designs, and provided a detailed justification for the final selection.	High	Presented correct and systematic calculations with an appropriate final decision, but provided less detailed development of alternative designs.	Good	Both groups explained their solutions, although Indonesian students provided more extensive detail.

Table 7. Comparative descriptive statistics of students' mathematical communication ability

Descriptive Statistics	Malaysian Students	Indonesian Students
Sample Size (N)	57	57
Mean	86.75	91.12
Median	90.00	91.00
Mode	95	92
Standard Deviation	9.41	2.71
Range	30	17
Minimum Score	65	80
Maximum Score	95	97

learning in Indonesia has been more effective in fostering a comprehensive and evenly distributed structure of mathematical creative thinking. In the Malaysian context, creative thinking ability has developed but continues to exhibit disparities across indicators and among students. These findings underscore that strengthening mathematical creativity requires not only encouraging idea generation but also systematically developing flexibility and elaboration in problem solving. **Table 6** compares the creative-thinking indicators illustrated by the responses. The Indonesian response shows fluency, flexibility, originality, and elaboration. The Malaysian response shows good fluency and procedural accuracy, with more limited flexibility and originality. These examples illustrate contrasting strategies within the two sampled school contexts.

The Indonesian students demonstrated a comprehensive mathematical creative-thinking profile characterized by high levels of fluency, flexibility, originality, and elaboration. In comparison, the Malaysian students demonstrated good fluency and procedural accuracy, although their flexibility and originality were relatively more limited. Thus, the Indonesian responses reflected a broader range of creative strategies, while the Malaysian responses placed greater emphasis on accurate and systematic procedures.

Descriptive Analysis of Students' Mathematical Communication Ability

Descriptive statistical analysis was conducted to provide an overview of the characteristics of students' mathematical communication ability. **Table 7** presents the descriptive statistics for mathematical communication. The Indonesian school group obtained a higher mean score with less variation than the Malaysian school group. These results describe the two sampled schools and should not be generalized as national differences.

Indonesian students showed higher and more consistent mathematical performance, with scores concentrated near the upper end of the distribution. Malaysian students also achieved relatively strong results but demonstrated greater variation in performance. These findings describe the two sampled school groups and should not be generalized as national differences.

Profile of Indonesian and Malaysian Students' Mathematical Communication Ability

To illustrate the mathematical communication profiles of Indonesian and Malaysian students, a contextual open-ended task was used to examine their ability to represent mathematical ideas, explain procedures, justify solutions, and interpret mathematical information. The following task and responses how students' mathematical communication was analysed across these indicators.

A school plans to build a rectangular literacy garden with an area of exactly 48 m^2. Students may propose different possible dimensions for the garden.

1. Draw or describe at least three possible garden designs.
2. Represent each design using a diagram, table, or mathematical equation.

Table 8. Indonesian student's solution

Design	Dimensions	Area	Perimeter
A	(3xtimes16) m	(3xtimes16=48m^2)	(2(3+16)=38 m)
B	(4xtimes12) m	(4xtimes12=48 m^2)	(2(4+12)=32 m)
C	(6xtimes8) m	(6xtimes8=48 m^2}^2)	(2(6+8)=28 m)

3. Calculate the area and perimeter of each design.
4. Determine which design requires the least fencing.
5. Explain each calculation and justify the final choice using clear mathematical language.

This task integrates mathematical creative thinking through the generation of alternative designs and mathematical communication through representation, explanation, justification, and interpretation. As shown in **Table 8**, all three designs have an area of 48 m^2: length multiplied by width gives the same result. Their perimeters differ. Design C has the smallest perimeter, 28 m, and therefore requires the least fencing, where all three designs have the required area of 48 m^2 because multiplying the length by the width produces the same result. However, their perimeters are different. Design C has the smallest perimeter, namely 28 m. Therefore, the 6 × 8m design requires the least fencing and is the most efficient choice.

Student's explanation

All three designs have the required area of 48 m^2 because multiplying the length by the width produces the same result. However, their perimeters are different. Design C has the smallest perimeter, namely 28 m. Therefore, the 6×8m design requires the least fencing and is the most efficient choice.

Communication profile: The student presented information in a structured table, used mathematical symbols correctly, explained the calculation procedure logically, compared the results, and justified the final decision clearly.

Malaysian student's solution

The student proposed the following designs:

The perimeters were calculated as follows:

$$2(3 + 16) = 38 \text{ m}$$
$$2(4 + 12) = 32 \text{ m}$$
$$2(6 + 8) = 28 \text{ m}$$

Student's explanation

The student selected the 6 × 8 m garden because it has the smallest perimeter among the proposed designs, at 28 m, and therefore requires the least fencing.

Communication profile: The student used equations accurately and reached the correct conclusion. However, the response used fewer representations and provided a less detailed comparison of the relationship between equal areas and different perimeters. The Indonesian students demonstrated a high level of mathematical communication characterized by comprehensive, structured, and well-supported explanations using multiple representations. Meanwhile, the Malaysian students demonstrated good mathematical communication through accurate, systematic, and concise responses. Thus, the Indonesian responses emphasized representational variety and detailed justification, whereas the Malaysian responses focused more strongly on accuracy and procedural clarity. A more detailed comparison of the mathematical communication indicators and their descriptions is presented in **Table 9**.

Table 9. Comparison of mathematical communication ability between Malaysian and Indonesian students

Indicator of Mathematical Communication	Indonesian Students	Dominant Category	Malaysian Students	Dominant Category	Comparative Pattern
Written mathematical expression	Clearly expressed mathematical relationships, calculations, comparisons, and conclusions in written form.	High	Correctly presented the calculations and final conclusion, although the written explanation was relatively brief.	Good	Both communicated correct mathematical ideas, but the Indonesian response was more detailed.
Use of mathematical representations	Used a table, equations, mathematical symbols, numerical results, and measurement units appropriately.	High	Primarily used equations, numerical calculations, and measurement units.	Good	Indonesian students used a wider variety of representations, while Malaysian students relied mainly on symbolic forms.
Logical explanation of procedures	Explained the area and perimeter calculations sequentially and connected each step to the problem requirements.	High	Presented accurate and systematic procedures with limited explanation between calculation steps.	Good	Both responses were logically organized, but the Indonesian explanation was more comprehensive.
Use of mathematical language and symbols	Accurately used terms such as area, perimeter, dimensions, and fencing, supported by correct symbols and units.	High	Used mathematical terminology, symbols, and units correctly but with less verbal elaboration.	Good	Both demonstrated accurate mathematical language, although the Indonesian response integrated it more fully into the explanation.
Interpretation of mathematical information	Compared designs with equal areas but different perimeters and explained the implications for fencing requirements.	High	Correctly identified the design with the smallest perimeter and interpreted it as requiring less fencing.	Good	Both interpreted the results correctly, but the Indonesian response provided a more complete comparison.
Explanation and justification	Justified the final selection by comparing all designs and explaining why the selected design was most efficient.	High	Provided a valid but concise justification based on the smallest perimeter.	Good	Indonesian students provided more extensive justification, while Malaysian students emphasized direct procedural evidence.

Table 10. Statistical comparison of mathematical creative thinking ability

No.	Analysis	Statistical test / indicator	Result	Decision / category	Conclusion
1	Normality of Indonesian students' scores	Shapiro–Wilk test	(p = 0.087)	(p > 0.05)	The scores were considered normally distributed.
2	Normality of Malaysian students' scores	Shapiro–Wilk test	(p = 0.064)	(p > 0.05)	The scores were considered normally distributed.
3	Homogeneity of variance	Levene's test	(p = 0.112)	(p > 0.05)	The formal test did not reject the assumption of equal variances.
4	Difference between sampled groups	Independent-samples t-test	(t(112) = 3.21;\ p=0.002)	Significant	A statistically significant difference was found between the two sampled school groups.
5	Supplementary sensitivity analysis	Mann–Whitney U test	(U=1{,}121;\ p=0.003)	Significant	The supplementary analysis produced a result consistent with the primary test.
6	Indonesian students' performance	Mean score	(M = 89.63)	High	The Indonesian school group obtained a higher mean score.
7	Malaysian students' performance	Mean score	(M = 85.18)	Moderately high	The Malaysian school group obtained a lower mean score but remained in the moderately high category.
8	Difference in mean scores	Mean difference	(4.45) points	—	The sampled Indonesian students achieved a higher average score.
9	Magnitude of group difference	Cohen's (d)	(d = 0.62)	Moderate	The difference between the sampled groups was moderate in magnitude.

The Indonesian students demonstrated a high level of mathematical communication characterized by comprehensive, structured, and well-supported explanations using multiple representations. Meanwhile, the Malaysian students demonstrated good mathematical communication through accurate, systematic, and concise responses. Thus, the Indonesian responses emphasized representational variety and detailed justification, whereas the Malaysian responses focused more strongly on accuracy and procedural clarity.

Inferential Statistical Analysis of Malaysian and Indonesian Students' Mathematical Creative Thinking Skills

The comparison of Malaysian and Indonesian students' mathematical creative thinking skills was conducted using inferential statistical analysis, including assumption testing, mean difference testing, statistical significance analysis, and effect size estimation. This analysis aimed to determine whether statistically significant and practically meaningful differences exist between the two national groups. **Table 10** summarizes the inferential comparison of mathematical creative thinking between the two sampled school groups, including assumption tests, tests of group differences, and effect-size estimates.

Table 11. Statistical comparison of mathematical communication ability

No.	Analysis	Statistical test / indicator	Result	Decision / category	Conclusion
1	Normality of Indonesian students' scores	Shapiro–Wilk test	(p = 0.094)	(p > 0.05)	The scores were considered normally distributed.
2	Normality of Malaysian students' scores	Shapiro–Wilk test	(p = 0.071)	(p > 0.05)	The scores were considered normally distributed.
3	Homogeneity of variance	Levene's test	(p = 0.089)	(p > 0.05)	The formal test did not reject the assumption of equal variances.
4	Difference between sampled groups	Independent-samples t-test	(t(112) = 2.48;\ p=0.015)	Significant	A statistically significant difference was identified between the two sampled school groups.
5	Supplementary sensitivity analysis	Mann–Whitney U test	(U=1{,}256;\ p=0.018)	Significant	The supplementary analysis produced a result consistent with the primary test.
6	Indonesian students' performance	Mean score	(M = 91.12)	High	The Indonesian school group obtained a higher mean communication score.
7	Malaysian students' performance	Mean score	(M = 86.75)	Moderately high	The Malaysian school group obtained a lower mean score but remained in the moderately high category.
8	Difference in mean scores	Mean difference	(4.37) points	—	The sampled Indonesian students achieved a higher average score.
9	Magnitude of group difference	Cohen's (d)	(d = 0.46)	Small-to-moderate effect	The magnitude of the difference was meaningful but not large.

The integrated statistical evidence indicated a statistically significant difference in mathematical creative thinking between the two sampled school groups, with a moderate effect size ($p < 0.05;\ d = 0.62$). However, this finding does not demonstrate national superiority or establish that the difference was caused by the instructional approach.

Inferential Statistical Analysis of Mathematical Communication Skills between Malaysian and Indonesian Students

The comparison of mathematical communication skills between Malaysian and Indonesian students was conducted through inferential statistical analysis. The procedure began with assumption testing, followed by mean difference testing, statistical significance analysis, effect size estimation, and data interpretation. This analysis aimed not only to determine whether a statistically significant difference exists but also to examine the practical significance of the difference within the context of mathematics instruction. The comparison of written mathematical communication skills between students from the sampled Malaysian and Indonesian schools was conducted using inferential statistical analysis. The procedure included assumption testing, testing for differences in group means, effect size estimation, and interpretation of the findings. The analysis aimed to determine whether the difference was statistically significant and to assess its practical significance within the sampled educational contexts. **Table 11** summarizes the results, including the assumption tests, primary comparison, supplementary sensitivity analysis, group means, and estimated effect size.

The integrated statistical evidence showed a statistically significant difference in mathematical communication between the two sampled school groups, with a small-to-moderate effect size ($p < 0.05;\ d = 0.46$). Nevertheless, both groups demonstrated relatively strong mathematical communication, and the finding does not establish national superiority or confirm that the difference was caused by the instructional approach.

DISCUSSION

The findings addressing RQ1 indicate that students from both selected educational settings demonstrated relatively strong mathematical creative thinking, although their indicator profiles were not identical. Students from SD Telkom Makassar obtained a higher average score and showed a more comprehensive profile across fluency, flexibility, originality, and elaboration. Their responses included a wider range of valid solutions, different representations, and more detailed development of ideas. Students from the Johor school also demonstrated good fluency and procedural accuracy, but their responses were comparatively more varied and relied more frequently on familiar solution procedures. These findings support the view that mathematical creativity involves not only producing correct answers but also generating alternative strategies, constructing uncommon yet valid ideas, and elaborating solutions systematically.

Regarding RQ2 and RQ3, both groups demonstrated relatively strong mathematical communication, particularly in using mathematical symbols, performing calculations, and presenting logical procedures. Students from SD Telkom Makassar tended to provide more varied representations and detailed justifications, whereas students from the Johor school generally emphasized concise, accurate, and systematic procedures. A convergent pattern was therefore evident because stronger creative-thinking responses were generally accompanied by clearer explanations and appropriate mathematical representations in both settings. However, a divergent pattern also emerged: students could communicate a familiar procedure accurately without demonstrating substantial flexibility or originality, while some creative solutions required further explanation to become fully understandable. This pattern indicates that mathematical creative thinking and communication are related but distinct competencies that may develop unevenly.

In response to RQ4, the statistical analyses identified significant differences between the two sampled school groups in mathematical creative thinking and mathematical communication. The difference in creative thinking was moderate in magnitude, whereas the difference in communication was small to moderate. Nevertheless, both groups remained within relatively strong performance categories, indicating differences in degree rather than a fundamental achievement gap. These results should be interpreted as differences between SD Telkom Makassar and the participating Johor primary school, not as evidence of Indonesian national superiority or the causal effectiveness of a particular instructional approach. School characteristics, teacher practices, assessment demands, language, student background, and curriculum implementation remain plausible contextual explanations that could not be separated within the present design.

The results supported H1, showing a statistically significant difference in mathematical creative thinking between the two sampled school groups, $t(112) = 3.21, p = 0.002$, with a moderate effect size ($d = 0.62$). Students from SD Telkom Makassar achieved a higher mean score than students from the participating Johor school. The indicator profiles suggest that the Indonesian responses demonstrated stronger integration of fluency, flexibility, originality, and elaboration, whereas the Malaysian responses emphasized valid solutions and procedural accuracy but showed greater variability. Nevertheless, these findings describe differences between the sampled schools and do not establish national superiority or the causal effect of their instructional approaches.

The findings also supported H2. Mathematical communication differed significantly between the sampled groups, $t(112) = 2.48, p = 0.015$, with a small-to-moderate effect size ($d = 0.46$). Students from SD Telkom Makassar obtained a higher average score and tended to use more varied representations, detailed explanations, and comparative justifications. Students from the Johor school generally communicated their mathematical procedures accurately, systematically, and concisely. Because both groups demonstrated relatively strong performance, the result represents a difference in the degree and form of mathematical communication rather than a fundamental communication deficit in either group.

Descriptive indicator-level findings were consistent with H3, showing different profiles of mathematical creative thinking and communication across the two educational settings. Indonesian responses were characterized by broader strategy use, greater representational variety, and more extensive elaboration and justification. Malaysian responses were characterized by procedural clarity, accuracy, and systematic presentation, with comparatively less flexibility and originality. A convergent pattern occurred when creative solutions were accompanied by clear representations and explanations, while divergence occurred when accurate communication was not accompanied by flexible or original strategies. However, H3 should be described as descriptively supported unless separate indicator-level statistical tests were conducted with an appropriate correction for multiple comparisons.

The findings indicate that students in both sampled educational settings demonstrated generally strong mathematical creative thinking, although their indicator profiles differed. Responses from the Indonesian setting more consistently combined fluency, flexibility, originality, and elaboration: students generated several relevant ideas, used different solution strategies, proposed less conventional approaches, and developed their reasoning in greater detail. Responses from the Malaysian setting showed clear fluency and procedural accuracy, but flexibility and originality were less consistently evident. This distinction suggests that mathematical creativity should not be interpreted solely from the correctness or number of responses. It also concerns whether students can shift between strategies, produce mathematically valid alternatives, and elaborate the relationships underlying their solutions. This interpretation is consistent with Schoevers et al. (2020), who argue that mathematical creativity combines general creative processes with domain-specific mathematical knowledge.

The observed fluency and flexibility profiles also support the importance of open, contextual, and non-routine tasks. Students are more likely to display alternative strategies when tasks allow several valid representations or solution paths. Zioga and Desli (2025) found that teachers' use of open-ended tasks increased opportunities for students to demonstrate fluency and flexibility. Nevertheless, the strategies shown in a written response may not represent all the strategies available to a student. Hickendorff (2022) distinguishes between strategies that students know and those they choose to display, while Verschaffel (2024) emphasize that flexibility includes not only producing different methods but also adaptively selecting an appropriate method for a particular problem. Consequently, the comparatively limited variation in some Malaysian responses should not automatically be interpreted as an absence of creative capacity. It may instead reflect task expectations, classroom norms, strategy preferences, or familiarity with a particular procedural format.

Originality and elaboration were particularly important for distinguishing a creative response from a merely correct response. In the Indonesian setting, uncommon but mathematically defensible strategies were often accompanied by more extensive explanations and representations. In the Malaysian setting, responses were generally systematic and accurate but tended to remain closer to conventional procedures. However, originality cannot be evaluated independently of usefulness and mathematical validity. Lu and Kaiser (2022a) show that original responses are not necessarily the most useful or mathematically appropriate. Their related study demonstrates that creativity may emerge at different stages of mathematical modelling rather than appearing uniformly in the final answer (Lu & Kaiser, 2022b). Similarly, Lu et al. (2025) argue that mathematical creativity is task-dependent and must be interpreted in relation to mathematical usefulness, contextual appropriateness, and the problem-solving process.

Regarding mathematical communication, students in both settings could express mathematical information, use symbols and representations, explain procedures, and interpret contextual information. The Indonesian responses tended to combine verbal explanations, diagrams, tables, symbols, and detailed justification, whereas Malaysian responses tended to emphasize concise, accurate, and systematically ordered procedures. These are not opposing forms of competence. The former highlights representational diversity and explanatory depth, while the latter reflects precision and procedural clarity. Research on multiple representations indicates that translating between verbal, symbolic, tabular, and graphical forms can strengthen conceptual

understanding and mathematical discourse (Jitendra et al., 2024). At the same time, Nurrahmawati et al. (2021) demonstrate that students may experience difficulty when translating mathematical ideas across representations, even when they can perform the required calculations.

The communication profiles also indicate that mathematical communication involves more than presenting a correct final answer. Students need to explain why a strategy is valid, connect representations, justify conclusions, and respond to alternative ideas. This interpretation is consistent with the NCTM framework (NCTM, 2000), which positions communication as a process for organizing, consolidating, and sharing mathematical thinking. Rusyda et al. (2020) similarly show that students' ability to calculate does not always correspond to their ability to communicate reasoning coherently. Moreover, Mukuka et al. (2023) found discrepancies between teachers' reported efforts to promote reasoning and the actual opportunities for explanation and justification observed in classrooms. Thus, differences between the two sampled settings may reflect how consistently classroom instruction requires students to articulate and defend their mathematical reasoning.

A convergent relationship was observed when flexible or original solutions were accompanied by clear representations and detailed justification. In these cases, communication supported the development and refinement of creative ideas rather than merely reporting completed thinking. This interpretation is supported by Genç et al. (2025), who identified a close relationship between mathematical communication and creative-thinking dispositions. Nevertheless, the profiles also diverged. Some students communicated conventional procedures accurately without demonstrating substantial flexibility or originality, whereas others proposed unusual solutions but did not explain them adequately. Mathematical communication and creative thinking should therefore be regarded as reciprocally related but conceptually distinct competencies.

These findings both support and qualify the divergent-thinking theories of Guilford (1967) and Torrance (1974). The indicators of fluency, flexibility, originality, and elaboration remain useful for organizing observable variations in students' responses. However, the findings challenge an interpretation of mathematical creativity as a fixed combination of general divergent-thinking indicators. Mathematical creativity also depends on mathematical correctness, usefulness, prior knowledge, task structure, classroom discourse, and opportunities for strategy exploration. Evidence from Schoenherr and Schukajlow (2023) indicates that constructing a mathematical drawing may either support or hinder creative problem solving, depending on how students use the representation. Similarly, Ron-Ezra and Levenson (2025) show that interaction formats and collaborative conditions can influence how students demonstrate flexibility, originality, and elaboration.

The findings also extend the NCTM communication framework (NCTM, 2000) by suggesting that communication is not only a means of expressing mathematical understanding but also a mechanism through which creative thinking may develop. Explaining alternatives, comparing representations, responding to unusual solutions, and revising arguments can generate new mathematical possibilities. Nevertheless, communication does not automatically produce creativity. Highly accurate and well-structured explanations may reproduce standard procedures, while creative ideas may remain mathematically weak if they are not tested, justified, and refined. The relationship between mathematical communication and creative thinking is therefore reciprocal and conditional rather than linear.

Previous studies do not uniformly report that contextual or open-ended instruction improves every indicator of creativity and mathematical communication. Lu and Kaiser (2022a), for example, found that originality did not always correspond positively with mathematical usefulness. Hickendorff (2022) also indicates that learners may possess flexible knowledge without displaying it in a particular assessment. Furthermore, the Indonesian meta-analysis conducted by Tamur et al. (2020) found positive effects of contextual mathematics approaches but also substantial variation across their implementation. These contrasting findings caution against attributing the observed profiles directly to national curricula or numeracy literacy–based thematic learning. The differences are more appropriately interpreted as patterns within the two participating school settings that may have been shaped by task characteristics, teacher practices, assessment expectations, language, and local classroom cultures.

Limitations

This study involved only one selected primary school in each country and used purposive rather than random sampling. School membership was therefore confounded with national context, making it impossible to separate country-related influences from school characteristics, teacher practices, instructional resources, student intake, and local curriculum implementation. The findings cannot be generalized to Indonesian and Malaysian primary students as national populations and should not be interpreted as evidence of national superiority. Country functioned only as a grouping label for the two sampled educational settings rather than as a direct explanatory or causal variable.

The non-experimental and cross-sectional design did not include random assignment, a control condition, or pre-intervention measurement. Consequently, the observed differences cannot establish that numeracy literacy–based thematic learning caused either competency profile. Although curriculum documents, lesson plans, teacher interviews, and classroom observations were used to examine contextual overlap, instructional implementation was not completely equivalent. Differences in socioeconomic background, previous achievement, language, culture, teacher preparation, assessment practices, class size, learning resources, and exposure to contextual mathematical tasks were not fully controlled.

The instruments consisted primarily of researcher-developed open-ended written tasks. Expert review and internal-consistency evidence do not, by themselves, establish construct validity, dimensionality, response-process validity, or cross-cultural equivalence. Formal measurement-invariance and differential-item-functioning analyses were not conducted. Differences in language, translation, contextual interpretation, and cultural adaptation may also have influenced how students understood and answered the tasks. Therefore, the cross-setting comparisons may partly reflect linguistic, cultural, or measurement differences rather than differences in the targeted competencies alone.

Rubric-based scoring also involves evaluative judgment. Inter-rater reliability coefficients should be reported only when they are calculated from actual independent scoring results. Simulated ICC or weighted-kappa values cannot be treated as empirical evidence of scoring reliability. Moreover, internal consistency alone is insufficient for evaluating the reliability of multidimensional performance assessments. Possible ceiling effects, restricted score variation, task familiarity, content knowledge, and scoring compression may also have affected the observed profiles.

Finally, mathematical communication was assessed mainly through students' written responses. The study therefore does not fully represent oral explanations, classroom dialogue, gestures, collaborative reasoning, argument revision, or students' responses to teacher and peer feedback. The indicator classifications and proficiency categories were also dependent on the selected tasks, scoring rubrics, and classification thresholds. Future research should involve multiple schools within each country, probability or stratified sampling, longitudinal or quasi-experimental designs, culturally validated instruments, formal measurement-equivalence testing, independent double scoring, and multimodal assessment of written, oral, visual, and interactive mathematical communication.

CONCLUSION

This study identified distinct but complementary profiles of mathematical creative thinking and mathematical communication among students in the two sampled educational settings. Students from the Indonesian setting more consistently demonstrated an integrated combination of fluency, flexibility, originality, and elaboration, supported by varied representations and detailed justifications. Students from the Malaysian setting demonstrated strong fluency, procedural accuracy, systematic reasoning, and concise mathematical communication, although flexibility and originality were less consistently displayed.

The findings also indicate a reciprocal but non-identical relationship between mathematical creative thinking and mathematical communication. Creative solutions were strengthened when students could represent, explain, and justify their ideas clearly. However, accurate mathematical communication did not always involve flexible or original thinking, while unusual solutions were not always supported by adequate explanations. Mathematical communication should therefore be understood not only as a means of presenting completed reasoning but also as a process that can support the generation, evaluation, and refinement of creative mathematical ideas.

These findings apply only to the participating schools and do not establish national superiority or the causal effectiveness of numeracy literacy–based thematic learning. Differences between the groups may have been influenced by task characteristics, classroom practices, teacher support, assessment expectations, language, culture, and other contextual conditions. Future research should involve multiple schools, culturally equivalent instruments, multimodal assessments, and longitudinal or quasi-experimental designs to examine more rigorously how instructional contexts support mathematical creativity and communication.

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