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The Role of Teachers in STEM Integration to Enhance Elementary School Students' Numeracy Skills in Malaysia

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Abstract. Numeracy is a fundamental competency for elementary school students in responding to the demands of 21st-century life; however, numeracy achievement remains a challenge in many countries, including Malaysia. This study explores the role of teachers in integrating Science, Technology, Engineering, and Mathematics (STEM) learning to support elementary students' numeracy development in the Malaysian context. Using a qualitative case study design, this research involved 12 elementary school teachers who had experience or understanding of STEM-based learning and were selected through purposive sampling. Data were collected through in-depth interviews, classroom observations, and document analysis. The findings show that teachers understood numeracy as a functional ability to apply mathematical concepts in real-life contexts, rather than merely as procedural calculation skills. STEM integration was implemented through project-based learning, simple experiments, direct measurement activities, and contextual problem solving. Teachers served as facilitators who guided students in exploration, discussion, collaboration, and reflection. However, the implementation of STEM-based numeracy learning was constrained by limited instructional time, variations in students' numeracy abilities, and inadequate learning resources. The study contributes to the discussion on teacher agency by showing how teachers translate STEM pedagogy into classroom practices that support numeracy development. Overall, the findings suggest that STEM integration can strengthen numeracy learning when supported by continuous teacher professional development, sufficient instructional resources, and appropriate educational policies.

Keywords: STEM; Learning; Numeracy; Teacher's Role; Elementary School

1. Introduction

The development of numeracy skills has become a global educational priority in response to the increasing complexity of social, economic, and technological challenges in the 21st century. Numeracy is no longer understood merely as the ability to perform basic calculations, but as the capacity to interpret, apply, and reason with numerical information in various real-life contexts. International assessments such as the Programme for International Student Assessment (PISA) consistently highlight numeracy as a key competency required for lifelong learning and informed decision-making in modern society (OECD, 2022).

Despite its importance, many countries continue to face challenges in improving students' numeracy performance, particularly at the elementary school level. Malaysia's PISA 2022 mathematics performance remained below the OECD average, indicating persistent challenges in contextual mathematical reasoning. This situation suggests that conventional mathematics instruction, which often emphasizes procedural skills, has not fully supported the development of functional numeracy skills. Consequently, there is an urgent need for more contextual and meaningful learning approaches that can bridge mathematical concepts with students' real-world experiences from an early stage of education.

One instructional approach that has gained increasing attention in recent years is Science, Technology, Engineering, and Mathematics (STEM) education. STEM learning emphasizes interdisciplinary integration, authentic problem-solving, and active student engagement. At the elementary level, STEM provides opportunities for students to experience mathematics as a useful tool for understanding scientific phenomena and solving practical problems. However, the effectiveness of STEM integration largely depends on how teachers conceptualize numeracy and implement STEM-based instruction in classroom practice. Although previous studies have demonstrated the effectiveness of STEM-based learning in improving mathematics achievement, limited research has specifically examined how elementary school teachers enact STEM integration to strengthen numeracy in authentic classroom contexts, particularly in Malaysia. However, limited empirical studies have specifically examined how elementary teachers enact STEM integration to strengthen numeracy in authentic classroom settings.

1.1. Problem Statement

Despite increasing policy support for STEM education, limited evidence explains how teachers integrate STEM pedagogically to improve elementary students' numeracy skills. One major problem is that teachers often have limited guidance on how to meaningfully integrate numeracy within STEM learning activities. As a result, STEM instruction may focus more on hands-on activities without explicitly strengthening students' numeracy skills. This condition reduces the potential impact of STEM learning on numeracy development.

Another problem concerns teachers' pedagogical readiness and understanding of numeracy as a functional competence. Differences in students' numeracy abilities, limited instructional time, and insufficient learning resources further complicate the implementation of STEM-based numeracy instruction. These challenges may lead teachers to revert to traditional teaching methods, thereby limiting opportunities for students to engage in contextual and integrative learning experiences.

Investigating these problems is important because teachers play a central role in designing, facilitating, and evaluating learning processes. Understanding how teachers perceive numeracy, integrate STEM into instruction, and address implementation challenges is essential for improving the quality of STEM-based numeracy learning. Without such understanding, efforts to strengthen numeracy through STEM education may remain fragmented and ineffective, particularly at the elementary school level. This study therefore addresses an important empirical gap by examining teachers' roles from a classroom practice perspective.

1.2. Related Research

Previous studies have highlighted the potential of STEM education to enhance students' mathematical understanding and problem-solving skills. English (2017) and Kelley and Knowles (2016) reported that STEM-based learning supports conceptual understanding by allowing students to apply mathematical ideas in authentic contexts. These studies emphasize the role of interdisciplinary integration in making mathematics learning more meaningful for students.

Research conducted in Malaysia has also examined STEM implementation in schools. Ananthan et al. (2022) found that while teachers generally hold positive attitudes toward STEM education, many still struggle with integrating mathematics meaningfully within STEM activities. Similarly, Yasin et al. (2021) reported that teachers face challenges related to pedagogical preparedness, cross-disciplinary understanding, and limited instructional support when implementing STEM at the elementary level. However, most studies focus on student outcomes rather than teachers' pedagogical roles.

More recent studies in Indonesia have shown that project-based STEM learning can significantly improve students' numeracy and problem-solving skills (Sari, Sutawidjaja, & Susanto, 2022). However, most existing research focuses on instructional models or quantitative learning outcomes, with limited attention to teachers' lived experiences and roles in integrating STEM for numeracy development. Therefore, the novelty of this study lies in its in-depth qualitative analysis of elementary school teachers' roles in integrating STEM to enhance numeracy skills, particularly from the perspective of teachers working in the Malaysian educational context.

This study offers novelty by focusing specifically on teacher agency in numeracy-oriented STEM integration in Malaysian elementary schools.

1.3. Research Objectives

This research aims to explore and analyze the role of elementary school teachers in integrating STEM into learning to enhance students' numeracy skills in Malaysia. Specifically, the study focuses on teachers' understanding of numeracy, instructional strategies used in STEM-based learning, and the challenges encountered during classroom implementation.

The expected outcomes of this research include a comprehensive description of how teachers conceptualize and implement STEM-based numeracy instruction, as well as practical insights that can inform teacher professional development and curriculum design. The findings are expected to contribute empirically to the development of effective STEM learning practices at the elementary school level.

2. Theoretical Framework

2.1. Numeracy in Primary Education

This study is grounded in a theoretical framework that integrates the concepts of numeracy, STEM education, and teachers' pedagogical roles in primary education. Numeracy is conceptualized not merely as the ability to perform arithmetic operations but as a functional and contextual competence that involves understanding, using, and interpreting numerical information in a variety of real-life situations (OECD, 2022). In this sense, numeracy extends beyond basic computation to include reasoning, critical thinking, and the application of mathematical knowledge in authentic contexts.

This perspective positions numeracy as a form of mathematical sense-making, where learners actively construct meaning through engagement with problems that require interpretation, analysis, and decision-making. According to Merrilyn Goos et al. (2014), numeracy involves the capacity to use mathematics confidently across different contexts, including personal, social, and professional domains. Similarly, Organisation for Economic Co-operation and Development emphasizes that numeracy is essential for participation in modern society, particularly in interpreting data, managing finances, and making informed decisions. This aligns with sociocultural perspectives emphasizing contextual mathematical meaning-making.

Recent studies further highlight that numeracy is a foundational competence that supports students' engagement with both everyday and academic problems (Makonye & Moodley, 2023). In primary education, the development of numeracy is particularly crucial, as it lays the groundwork for higher-order mathematical thinking and interdisciplinary learning. Therefore, effective numeracy instruction must emphasize conceptual understanding, contextual application, and meaningful learning experiences.

2.2. STEM Education and Numeracy Integration

STEM education is widely recognized as an interdisciplinary instructional approach that integrates science, technology, engineering, and mathematics through authentic problem-solving, inquiry-based learning, and project-based activities. According to Todd R. Kelley and J. Geoff Knowles (2016), STEM integration involves connecting concepts across disciplines to solve real-world problems, thereby promoting deeper understanding and student engagement.

Within this framework, mathematics—and particularly numeracy—functions as a central cognitive tool that supports scientific reasoning, data interpretation, and engineering design processes. Numeracy enables students to analyze patterns, interpret quantitative data, and make evidence-based decisions, which are essential skills in STEM learning contexts (International Journal of Science and Mathematics Education, 2023). As such, numeracy is not taught in isolation but embedded within interdisciplinary learning experiences.

Research indicates that effective STEM integration enhances students' ability to apply mathematical concepts in meaningful contexts, thereby strengthening both conceptual understanding and motivation (Kaldaras & Wieman, 2025). Furthermore, STEM-based learning environments encourage collaboration, creativity, and critical thinking, all of which contribute to the development of numeracy skills. This aligns with the view that learning becomes more meaningful when students can connect abstract mathematical ideas to real-world applications.

2.3. Teachers' Pedagogical Roles in STEM-Based Numeracy Learning

Teachers play a critical role in the successful implementation of STEM-based numeracy learning. As instructional designers and facilitators, teachers are responsible for creating learning environments that integrate multiple disciplines while maintaining clear learning objectives. Their understanding of numeracy and their perceptions of STEM integration significantly influence how mathematical ideas are presented and developed in the classroom (Margot & Kettler, 2019).

In this context, teachers must be able to design tasks that promote inquiry, problem-solving, and interdisciplinary thinking. They are also responsible for guiding students through the learning process, providing scaffolding, and facilitating meaningful discussions that deepen understanding. According to Jelle Thibaut et al. (2018), effective STEM teaching requires not only content knowledge but also pedagogical skills that support integration across disciplines.

Moreover, sustained professional development is essential to enhance teachers' capacity to implement integrated STEM instruction effectively. Research shows that teachers who participate in continuous training are more confident and competent in designing and facilitating STEM-based learning activities (Boz, 2023; Rimbach-Jones et al., 2025). In primary education, where teachers often teach multiple subjects, this competence becomes even more critical to ensure coherent and meaningful learning experiences.

2.4. Theoretical Framework of the Study

The interaction between teachers' conceptual understanding of numeracy, their pedagogical strategies, and the instructional context forms the foundation of this research framework. These components are interconnected and mutually reinforcing. Teachers' understanding of numeracy influences how they design learning activities, while their pedagogical strategies determine how effectively these activities are implemented in the classroom.

Previous meta-analyses and systematic reviews emphasize that teachers' interdisciplinary teaching competence is a key determinant of successful STEM implementation and improved student learning outcomes (International Journal of STEM Education, 2024). In addition, contextual factors such as school support, curriculum alignment, and availability of resources also play an important role in shaping the effectiveness of STEM-based numeracy learning.

By examining these interconnected components, this study seeks to explain how STEM integration can be optimized to support the development of elementary students' numeracy skills in a meaningful and sustainable manner. This framework provides a comprehensive basis for analyzing the relationship between teachers' roles, instructional practices, and student learning outcomes in STEM-based numeracy education.

3. Method

3.1. Research Design

Data collection was conducted from November to Desember 2025 in three SRITI elementary schools in Malaysia. This study employed a qualitative research approach with a case study design. The qualitative approach was selected to explore in depth teachers' perceptions, experiences, and instructional practices related to the integration of STEM in numeracy learning at the elementary school level. This approach allows for a contextual and holistic understanding of educational phenomena as they occur naturally in school settings (Creswell, 2014).

A case study design was used to examine the phenomenon of STEM integration within a specific educational context, namely elementary schools in Malaysia. The case study enabled the researcher to investigate how teachers conceptualize numeracy, implement STEM-based learning strategies, and address challenges in classroom practice. This design is appropriate because it facilitates an in-depth exploration of complex instructional processes and teacher roles within real-life contexts (Yin, 2018).

3.2. Participant

Twelve participants were considered sufficient because data saturation was achieved at the twelfth interview. Make a detailed description of the characteristics of participants or respondents, including their gender, age, occupation, educational background, and other characteristics relevant to the research objectives. Use the Table to explain the frequency and percentage of participants or respondents.

The participants in this study consisted of elementary school teachers in SRITI Malaysia who teach upper-grade classes and have experience implementing or being exposed to STEM-based learning. Participants were selected using purposive sampling, based on criteria aligned with the research objectives. The inclusion criteria were: (1) having at least five years of teaching experience, (2) teaching mathematics or thematic subjects containing STEM elements, and (3) willingness to participate in in-depth interviews.

A total of 12 teachers participated in the study. Their characteristics include gender, age range, teaching experience, educational background, and subject specialization. A detailed description of the participants is presented in Table 1.

Table 1. Characteristics of Research Participants

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	4	33.3
	Female	8	66.7
Age	30–39 years	5	41.7
	40–49 years	7	58.3
Teaching Experience	5–10 years	4	33.3
	>10 years	8	66.7
Educational Background	Bachelor’s degree	9	75.0
	Master’s degree	3	25.0
Teaching Subject	Mathematics	6	50.0
	Thematic/STEM-related	6	50.0

The diversity of participant characteristics supports the richness of perspectives and enhances the depth of qualitative analysis related to STEM integration and numeracy learning.

3.3. Data Collection

Data were primarily collected through semi-structured in-depth interviews as the main data source. Each participant participated in two interview sessions. A total of 24 interviews were conducted. Six classroom observations were conducted using an observation checklist. Documents analyzed included lesson plans, worksheets, and students’ numeracy score records. The interviews were conducted face-to-face over four days, with three teachers interviewed each day on a rotating basis. Each interview session lasted approximately 45–60 minutes and followed a pre-developed interview guide. The interview guide was designed based on the research focus, including teachers’ understanding of numeracy, their perceptions of STEM-based learning, their experiences in integrating STEM into classroom instruction, the instructional strategies employed, and the challenges encountered during implementation. The instrument consisted of 10–12 open-ended questions that allowed for in-depth exploration. The interview process began with an explanation of the research objectives and obtaining participants’ consent, followed by in-depth questioning supported by probing and follow-up questions based on participants’ responses. All interviews were audio-recorded and supported by field notes, then transcribed verbatim to ensure data accuracy.

In addition to the main interviews, follow-up interviews were conducted to clarify and deepen incomplete or ambiguous data. Classroom observations were carried out to directly examine the implementation of STEM-based learning, including teaching practices, instructional strategies, and student engagement. Observations were guided by an observation checklist and supported by field notes. Furthermore, document analysis was conducted on instructional materials such as lesson plans, teaching modules, and students' work to complement and validate the data obtained from interviews and observations. The use of multiple data collection techniques aimed to enhance data credibility through source and method triangulation

3.4. Data Analysis

Data analysis was conducted using thematic analysis, following the procedures proposed by Braun and Clarke (2006). The analysis process began with familiarization with the data through repeated reading of interview transcripts. Initial codes were then generated to identify meaningful segments related to the research focus.

The codes were subsequently grouped into broader themes, such as teachers' conceptualization of numeracy, forms of STEM integration, teacher roles in instruction, and implementation challenges. Data reduction, data display, and conclusion drawing were conducted iteratively to ensure coherence and depth of interpretation. This systematic process enabled the identification of patterns and relationships among themes that address the research objectives.

3.5. Validity and Reliability

To ensure the trustworthiness of the qualitative data, several strategies were employed. Credibility was enhanced through member checking, in which preliminary findings were shared with selected participants to confirm the accuracy of interpretations. Triangulation of sources was also applied by comparing data obtained from different participants to identify consistent patterns and variations.

Dependability was supported through detailed documentation of the research procedures, including data collection and analysis steps, allowing the research process to be transparent and auditable. Confirmability was addressed by maintaining reflective notes and ensuring that findings were grounded in participants' statements rather than researcher assumptions. These strategies align with established criteria for ensuring validity and reliability in qualitative research (Lincoln & Guba, 1985).

4. Findings

This section presents the findings of the study on the role of elementary school teachers in integrating STEM to enhance students' numeracy skills. The findings are derived from in-depth interviews, follow-up interviews, classroom observations, and document analysis. The results are organized into themes that emerged from the qualitative data analysis.

4.1. Teachers' Understanding of Numeracy in STEM-Based Learning

The findings indicate that elementary school teachers conceptualize numeracy as a functional ability that involves understanding, applying, and interpreting mathematical concepts in real-life contexts. Teachers emphasized that numeracy goes beyond procedural calculation and includes mathematical reasoning, decision-making, and contextual problem-solving.

One teacher stated, "*Numeracy is not only about calculation, but about how students use mathematics in everyday life, such as measuring or comparing*" (G1). This view was reinforced by another teacher who explained, "*If it is only about calculation, students quickly forget, but when it is connected to real-life situations, they understand better*" (G3).

Classroom observations showed that teachers actively linked numeracy concepts to contextual activities, such as asking students to measure objects in the classroom and compare the results across groups. Students were observed engaging in discussions to ensure the accuracy of their measurements and to draw simple conclusions based on the data obtained.

In addition, document analysis of lesson plans and teaching modules revealed that learning objectives included integrated numeracy indicators, such as measuring, comparing, and interpreting simple data. This indicates that teachers' understanding of numeracy is not only conceptual but has also been implemented in STEM-based instructional planning. The findings are presented in Table 2 below.

Table 2. Teachers' Understanding of Numeracy in STEM-Based Learning

Aspect of Numeracy	Description from Teachers' Perspectives
Conceptual meaning	Ability to understand and apply mathematics in daily life
Learning orientation	Contextual and functional rather than procedural
Key emphasis	Reasoning, interpretation, and problem-solving
Role in STEM	Foundational skill supporting science and technology learning

4.2. Forms of STEM Integration in Numeracy Instruction

The findings reveal that teachers employed various instructional strategies to integrate STEM into numeracy learning. These strategies included project-based learning, simple experiments, hands-on measurement activities, and contextual problem-solving tasks. Through these approaches, students were encouraged to apply numeracy skills in authentic and meaningful situations.

One teacher stated, *"I usually ask students to work on simple projects, such as creating measuring tools or building simple models, so they can directly apply measurement and estimation"* (G2). Another teacher explained, *"Through experiments, students understand why they need to calculate and measure, not just follow formulas"* (G5).

Classroom observations showed that STEM-based activities allowed students to experience the direct application of numeracy concepts. For example, during a simple experiment, students measured the volume of water using measuring cups, recorded the results, and compared them across groups. Students were actively engaged in calculating measurements and analyzing simple data obtained from their observations.

In addition, document analysis of lesson plans and teaching modules indicated that teachers had incorporated structured STEM learning steps, including exploration, data collection, analysis, and reflection. These documents explicitly integrated numeracy skills, particularly in activities involving measurement, estimation, and data interpretation. This suggests that STEM integration in numeracy learning was not only implemented in classroom practices but also systematically planned in instructional design. This can be seen in Table 3 below.

Table 3. STEM Integration Strategies in Numeracy Learning

Strategy	Description	Numeracy Skills Involved
Project-based learning	Designing or constructing simple products	Measurement, estimation
Simple experiments	Observing scientific phenomena	Data interpretation
Hands-on measurement	Measuring length, volume, or weight	Quantification, comparison
Contextual problem-solving	Solving real-life problems	Reasoning, numerical analysis

4.3. Teachers' Role as Facilitators in STEM-Based Numeracy Learning

Another major finding highlights teachers' roles as facilitators of learning rather than mere transmitters of knowledge. Teachers guided students through processes of exploration, discussion, and reflection during STEM activities. They encouraged students to explain their reasoning and connect mathematical outcomes with scientific observations.

One teacher stated, *"I do not directly give answers, but I guide students by asking questions so they can find the solution themselves"* (G4). Another teacher added, *"My role is to support and direct students' thinking, especially when they are analyzing results from their activities"* (G6).

Classroom observations showed that teachers frequently used open-ended and guiding questions such as *"How did you get that result?"* and *"What happens if the measurement* *changes?"*. These questions encouraged students to articulate their reasoning and engage in deeper thinking. Students were also observed actively participating in group discussions and collaboratively interpreting data obtained from STEM activities.

In addition, document analysis of lesson plans and teaching modules revealed that teachers had incorporated guiding questions and reflection activities into their instructional design. These elements were intended to support students in constructing understanding, connecting empirical findings with numeracy concepts, and drawing meaningful conclusions. This indicates that teachers' facilitative roles were not only evident in classroom practices but also systematically planned in the learning process. As shown in Table 4 below.

Table 4. Teachers' Facilitative Roles in STEM-Based Numeracy Learning

Teacher Role	Description
Learning designer	Planning STEM-based numeracy activities
Facilitator	Guiding exploration and discussion
Questioner	Using probing questions to stimulate reasoning
Reflective guide	Supporting students in drawing conclusions

4.4. Challenges in Implementing STEM Integration to Improve Numeracy

Despite positive perceptions, teachers reported several challenges in implementing STEM-based numeracy learning. The most frequently mentioned challenge was limited instructional time, as STEM activities require extended planning and classroom implementation. Differences in students' numeracy abilities also posed challenges in ensuring equal participation and understanding.

One teacher stated, *"The main challenge is time, because STEM activities take longer than regular lessons"* (G7). Another teacher added, *"Students have different levels of numeracy skills, so it is difficult to ensure that all students understand at the same pace"* (G2).

Classroom observations confirmed these challenges. In several sessions, some student groups were unable to complete all stages of the activities due to time constraints, particularly during the reflection and discussion phases. Additionally, variations in students' abilities were evident, as some students required more guidance to complete measurement and data analysis tasks.

Teachers also reported limited availability of learning resources and supporting facilities. As one teacher explained, *"We sometimes lack materials for experiments, so we have to simplify the activities"* (G5).

Document analysis further supported these findings. Lesson plans and teaching modules showed that while STEM activities were well-structured, they often required more time than allocated in standard lesson schedules. Moreover, the documents indicated limited inclusion of differentiated instruction strategies, which made it challenging to accommodate diverse student abilities effectively. These constraints affected the consistency and optimal implementation of STEM-based numeracy learning. The findings are presented in Table 5 below.

Table 5. Challenges in STEM-Based Numeracy Implementation

Challenge	Description
Time constraints	Limited class time for STEM activities
Student ability differences	Varied levels of numeracy skills
Resource limitations	Lack of materials and facilities
Instructional complexity	Need for careful planning and management

4.5. Perceived Impact of STEM Integration on Students' Numeracy Skills

The findings indicate that teachers perceived STEM integration as having a positive impact on students' numeracy skills. Teachers observed increased student engagement, improved understanding of numeracy concepts, and greater ability to apply mathematics in practical contexts.

One teacher stated, *"Students become more active and understand better because they learn through direct practice"* (G1). Another teacher added, *"They are more confident in explaining their calculations and reasoning during STEM activities"* (G8).

Classroom observations supported these perceptions, showing that students were more actively involved in discussions, collaborative problem-solving, and hands-on activities during STEM-based numeracy lessons. Students were observed measuring, recording data, and discussing results within groups, which encouraged deeper engagement and interaction.

In addition, document analysis of students' work and assessment records revealed improvements in numeracy performance. Students demonstrated better ability in measurement tasks, data representation, and solving contextual problems. Quantitative data from students' numeracy assessments also indicated an increase in average scores from 68 (pre-implementation) to 82 (post-implementation). Furthermore, the percentage of students achieving the minimum mastery criterion (KKM) increased from 55% to 85%, suggesting a significant improvement in learning outcomes. These numeracy data were obtained through document analysis of school assessment records, including students' mathematics scores and numeracy-related performance reports before and after the implementation of STEM-based learning. The assessed numeracy indicators included measurement accuracy, data interpretation, estimation, and contextual problem-solving ability.

These findings indicate that STEM integration not only enhances students' engagement and learning experiences but also contributes to measurable improvements in their numeracy skills.As shown in Table 6 below.

Table 6. Perceived Impact of STEM Integration on Numeracy Skills

Aspect	Observed Impact
Student engagement	Increased participation and motivation
Conceptual understanding	Better grasp of numeracy concepts
Practical application	Improved ability to apply mathematics
Learning atmosphere	More active and collaborative

Tabel 7. Students' Numeracy Learning Outcomes Based on School Documentation

Indicator	Before STEM	After STEM
Mean score	68	82
Students meeting KKM	55%	85%
Measurement skill	Moderate	High
Data interpretation	Moderate	High

As presented in Table 7 above, these documentary findings support the qualitative evidence from interviews and classroom observations, which showed increased student engagement, active participation, and stronger confidence in applying numeracy concepts during STEM-based learning activities.

5. Discussion

This study aimed to explore the role of elementary school teachers in integrating STEM-based learning as a strategy to enhance students' numeracy skills in Malaysia. The findings indicate that teachers play a central and strategic role in shaping how numeracy is conceptualized, implemented, and experienced by students within STEM learning environments. This discussion connects the empirical findings with relevant theoretical perspectives and recent international research, highlighting both consistencies with prior studies and the unique contribution of the present study. This confirms the centrality of teacher agency in STEM implementation.

First, the findings reveal that teachers conceptualize numeracy as a functional and contextual competence rather than merely procedural calculation skills. This understanding aligns with the framework proposed by Organisation for Economic Co-operation and Development, which defines numeracy as the capacity to apply mathematical knowledge to solve real-world problems and make informed decisions (Organisation for Economic Co-operation and Development, 2023). This perspective is consistent with recent scholarship emphasizing that numeracy should be understood as a socially situated and context-dependent competence rather than a narrow computational skill (Goos et al., 2023). In this study, teachers demonstrated this understanding by intentionally embedding numeracy concepts into authentic STEM tasks, suggesting that teachers' conceptual understanding strongly influences instructional design and learning experiences. These findings strengthen constructivist arguments on contextual mathematical learning.

Second, the findings show that project-based learning, contextual problem-solving, and hands-on inquiry were the dominant approaches used by teachers to support numeracy development. These findings are consistent with constructivist learning theory, which emphasizes active knowledge construction through experience and social interaction (Jean Piaget, 1972; Lev Vygotsky, 1978). Recent empirical studies also confirm that integrated STEM learning through project-based approaches improves students' mathematical reasoning, engagement, and transfer of knowledge to real-life contexts (Dare et al., 2021; Çevik, 2023). Furthermore, Forde et al. (2023) found that embedding cognitively demanding mathematical tasks within STEM activities significantly strengthens students' conceptual numeracy understanding. These findings support the argument that STEM integration can reposition numeracy as an applied reasoning tool rather than an isolated subject.

Third, the role of teachers as facilitators emerged as a dominant theme in this study. Teachers guided students through questioning, collaborative exploration, and reflective thinking rather than relying solely on direct instruction. This finding supports learner-centered pedagogical frameworks and aligns with 21st-century learning principles emphasizing critical thinking, creativity, and problem-solving (Trilling and Fadel, 2009). Recent studies have similarly shown that teachers' facilitative practices are essential in successful integrated STEM classrooms because they help students connect disciplinary knowledge and develop deeper conceptual understanding (Thibaut et al., 2021; Galanti and Holincheck, 2022). The present study extends this literature by demonstrating how Malaysian elementary teachers operationalize this facilitative role specifically to strengthen students' numeracy development. This indicates that systemic barriers may outweigh individual teacher limitations.

Despite these positive instructional practices, the study also identified several implementation challenges, particularly related to limited instructional time, diverse student numeracy abilities, and insufficient learning resources. These findings are consistent with previous studies reporting that effective STEM implementation often requires substantial institutional support, curriculum flexibility, and adequate teaching resources (Herro et al., 2022). Similarly, Margot and Kettler (2019) emphasized that structural barriers including time constraints and curriculum demands remain significant obstacles in classroom-level STEM implementation. Interestingly, unlike some previous studies that identified teachers' limited STEM knowledge as the primary challenge, this study found that systemic and structural constraints played a more dominant role. This finding suggests that improving STEM-based numeracy learning requires not only teacher competence development but also broader institutional and policy support.

Overall, this study highlights that successful STEM integration to improve numeracy learning depends not only on teachers' pedagogical competence but also on the availability of supportive educational ecosystems. Continuous professional development, curriculum flexibility, administrative support, and access to quality learning resources are essential to sustain effective STEM-based numeracy instruction. This study contributes to the growing international literature on STEM education by providing empirical evidence from the Malaysian elementary school context, which remains underrepresented in current research. More importantly, the novelty of this study lies in explicitly linking teacher agency, STEM pedagogical practices, and numeracy development within one integrated analytical framework, offering new insight into how STEM learning can meaningfully improve numeracy outcomes in primary education.

6. Conclusion

This study concludes that primary school teachers in Malaysia play a central and strategic role in integrating STEM approaches into classroom learning to enhance students' numeracy skills. Teachers' understanding of numeracy as a functional and contextual competence enables them to design learning activities that meaningfully connect mathematics with science, technology, and simple engineering tasks. The integration of STEM is primarily implemented through project-based learning, contextual problem solving, and hands-on activities that actively engage students in applying numeracy concepts to real-life situations. In this process, teachers act not only as content deliverers but also as facilitators who guide exploration, encourage critical thinking, and support students' reflection. The findings also reveal that STEM-based learning contributes to improved student engagement and deeper understanding of numeracy. However, challenges such as limited instructional time, diverse student numeracy levels, and constrained learning resources remain significant barriers to consistent implementation. Overall, the study highlights that strengthening teachers' pedagogical competence and providing systemic support are essential for optimizing STEM integration to improve numeracy learning in primary education. These findings have implications for teacher training and curriculum policy in primary education.

Limitation

This study employed a qualitative case study design; therefore, the findings are contextual and specific to the particular research setting and are not intended to be generalized broadly to all elementary school learning contexts. The participants were limited to elementary school teachers who had prior experience in implementing STEM-based learning, which may not fully represent the perspectives of teachers with limited or no experience in applying STEM approaches in their teaching practices. In addition, although data were collected through in-depth interviews, follow-up interviews, classroom observations, and document analysis, the interpretation of the findings may still be influenced by the subjectivity of both participants and researchers in interpreting the collected data. Data on students' numeracy learning outcomes in this study were obtained through document analysis based on academic records available at the school; therefore, the researchers did not conduct direct measurements or specific interventions related to students' numeracy achievement. As a result, the analysis of the impact of STEM integration on numeracy learning outcomes remains descriptive and does not fully demonstrate a causal relationship. Therefore, future studies are recommended to employ a mixed-methods approach with a larger sample size and combine documentary data with direct measurement using standardized numeracy assessment instruments to provide a more comprehensive understanding of the effectiveness of STEM implementation in elementary school learning.

Recommendation

Based on the research findings, several recommendations are proposed for future researchers and educational stakeholders. Future studies are encouraged to employ quantitative or mixed-method approaches to examine the impact of STEM integration on students' numeracy achievement more comprehensively and to enhance the generalizability of the findings. Expanding the research context to include diverse school settings, student perspectives, and classroom observations would provide a more holistic understanding of STEM-based numeracy instruction.

For educational stakeholders, including school leaders and policymakers, it is recommended to strengthen professional development programs that focus on integrating numeracy within STEM instruction at the primary school level. Schools should also be supported with adequate learning resources, instructional time, and curriculum flexibility to enable teachers to implement STEM-based learning effectively. These efforts are expected to enhance teachers' instructional practices and promote meaningful numeracy development among primary school students.

Conflict of Interest Statement

The author(s) declare(s) that there is no conflict of interest.

Declaration of Generative AI and AI-assisted Technologies

This manuscript was prepared with the assistance of Generative AI ChatGPT. The AI was used to assist in language refinement and content organization). All intellectual contributions, critical analyses, and final revisions were conducted by the authors. The authors take full responsibility for the accuracy, originality, and integrity of the content presented in this work.

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