How to Cite:
Phuong, T. L., Huong, B. T. L., & Anh, H. T. P. (2025). STEM-Based learning and the formation of problem-solving competence in primary students. *Tennessee Community Service International of Empowerment*, *2*(2), 37–48.
https://doi.org/10.53730/tcsie.v2n2.18

STEM-Based learning and the formation of problem-solving competence in primary students

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***Abstract*---**Developing problem-solving competence has become a key objective in primary education in response to the demands of twenty-first-century skills. STEM-based learning, which integrates Science, Technology, Engineering, and Mathematics, is increasingly recognized as an effective approach to fostering this competence through interdisciplinary, problem-centered, and experiential learning activities. This study investigates the role of STEM-based learning in the formation of problem-solving competence among primary students in Hanoi, Vietnam. The research was conducted at three public primary schools and employed a mixed-methods design. Data were collected from 35 school administrators and teachers through questionnaires, classroom observations, and semi-structured interviews. Quantitative data were analyzed using descriptive statistics, while qualitative data were examined thematically to capture patterns in teaching practices and student learning behaviors. The findings indicate that STEM-based learning supports multiple dimensions of problem-solving competence at the primary level, including problem recognition, interdisciplinary knowledge application, persistence through iterative testing and revision, and collaborative learning. Classroom observations and interview data further reveal that real-life problem contexts, hands-on activities, and reflective discussion play an important role in shaping students' problem-solving processes. At the same time, challenges related to instructional time, assessment practices, and teacher workload were identified as factors influencing implementation. Overall, the study

ISSN 2998-3193 (Online)
Publisher: Smoky Mountain Publishing
Manuscript submitted: 15 Oct 2025, Manuscript revised: 27 Nov 2025, Accepted for publication: 16 Dec 2025

provides context-specific evidence from Vietnamese primary schools, highlighting both the potential and practical considerations of STEM-based learning. The findings contribute to the literature on STEM education and offer implications for curriculum design, instructional strategies, and teacher professional development in primary education.

***Keywords*---**STEM-based learning, problem-solving competence, primary education, interdisciplinary learning, Vietnam.

1. Introduction

In contemporary education, developing students' problem-solving competence has become a central objective, particularly in response to rapid technological change and the growing demand for twenty-first-century skills. Problem-solving competence enables learners to identify problems, analyze information, apply interdisciplinary knowledge, and generate effective solutions in both academic and real-world contexts (Zeeshan et al., 2021; Tan et al., 2023). For primary education, fostering this competence at an early stage is especially important, as it provides a cognitive foundation for higher-order thinking and lifelong learning.

STEM-based learning, which integrates Science, Technology, Engineering, and Mathematics, has been widely recognized as an effective pedagogical approach for promoting problem-solving competence. By emphasizing inquiry, design, and real-world problem contexts, STEM-based learning encourages active student engagement and supports the development of analytical and creative thinking skills (Sheth & Pathak, 2023). Research has shown that STEM learning environments enable students to work collaboratively, apply concepts across disciplines, and reflect on problem-solving processes, all of which are essential components of problem-solving competence (Amalina & Vidákovich, 2022; Lin et al., 2015).

A growing body of international research highlights the positive impact of STEM-based learning on students' problem-solving abilities. Interdisciplinary STEM activities and problem-based STEM instruction have been found to enhance creative problem-solving, critical thinking, and students' perceptions of their own problem-solving skills (Güven & Alpaslan, 2022; Topsakal et al., 2022). Project-based STEM learning in elementary schools also contributes to improved problem-solving performance by engaging students in authentic tasks that require planning, experimentation, and evaluation (Rasyid et al., 2023). Moreover, technology-enhanced STEM experiences, such as informal STEM activities and digital learning tools, further strengthen students' engagement and problem-solving outcomes (Bicer et al., 2017; Siregar, 2025).

In the context of Vietnam, STEM education has gained increasing attention as part of national educational reforms aimed at improving educational quality and aligning learning outcomes with global standards. Previous studies suggest that STEM-oriented programs positively influence students' critical thinking and problem-solving skills and contribute to greater awareness of STEM-related

learning and career pathways (Chen et al., 2021; Linh et al., 2019). However, most existing research in Vietnam has focused on secondary or higher education, while empirical studies examining the effectiveness of STEM-based learning at the primary level remain limited. In addition, there is a need for school-based research that captures how STEM-based learning is implemented in primary classrooms and how it contributes to the formation of problem-solving competence among young learners.

Given these gaps, this study aims to investigate the role of STEM-based learning in the formation of problem-solving competence among primary school students in Hanoi, Vietnam. By employing a mixed-methods approach across three public primary schools, the study seeks to provide empirical evidence on both the outcomes and processes of STEM-based learning at the primary level. The findings are expected to contribute to the literature on STEM education and offer practical implications for curriculum design, instructional strategies, and teacher professional development in primary education (Perels et al., 2005).

2. Theoretical Framework

2.1. Concept and Characteristics of STEM-Based Learning

STEM-based learning is an interdisciplinary educational approach that integrates Science, Technology, Engineering, and Mathematics to engage learners in solving authentic, real-world problems. Rather than focusing on isolated subject knowledge, STEM-based learning emphasizes the interconnectedness of disciplines and the application of knowledge through inquiry, experimentation, and design processes (Sheth & Pathak, 2023). This approach is grounded in constructivist and experiential learning theories, which view learning as an active process in which students construct understanding by interacting with their environment and reflecting on their experiences.

A key characteristic of STEM-based learning is its emphasis on problem-centered instruction. Learning activities are typically organized around complex problems or challenges that do not have predetermined solutions, encouraging students to explore multiple strategies and develop flexible thinking (Tan et al., 2023). In addition, STEM-based learning promotes hands-on and minds-on engagement, allowing students to manipulate materials, test ideas, and learn from failure. These features are particularly suitable for primary students, who benefit from concrete experiences and exploratory learning (Rasyid et al., 2023).

At the primary level, STEM-based learning is often implemented through project-based or problem-based activities that are closely connected to students' everyday lives. Such activities help young learners build early scientific and mathematical understanding while simultaneously developing creativity, collaboration, and communication skills (Güven & Alpaslan, 2022). By engaging in interdisciplinary tasks, primary students begin to see learning as meaningful and relevant, which enhances motivation and supports deeper conceptual understanding.

2.2. Theoretical Perspectives on Problem-Solving Competence

Problem-solving competence is widely regarded as a fundamental learning outcome in modern education and a key component of twenty-first-century skills. It involves a set of cognitive, metacognitive, and behavioral processes, including problem identification, information analysis, solution generation, implementation, and evaluation (Zeeshan et al., 2021). From an educational perspective, problem-solving competence is not a static ability but a developmental construct that evolves through practice and guided learning experiences.

For primary students, problem-solving competence encompasses both domain-specific skills and general cognitive strategies. Young learners gradually develop the ability to reason logically, make predictions, test hypotheses, and reflect on their thinking processes. Research highlights that these skills are best nurtured in learning environments that encourage exploration, questioning, and collaboration rather than rote memorization (Amalina & Vidákovich, 2022). Furthermore, formative assessment plays an important role in supporting the development of problem-solving competence by providing feedback on students' strategies and learning processes (Lin et al., 2015).

In the context of STEM education, problem-solving competence is often conceptualized as an iterative process that mirrors scientific inquiry and engineering design cycles. Students are expected to define problems, propose solutions, test and refine ideas, and communicate their findings. This process-oriented view aligns with contemporary assessment approaches that emphasize performance, reasoning, and reflection over simple content recall (Tan et al., 2023).

2.3. The Role of STEM-Based Learning in Developing Problem-Solving Competence

STEM-based learning provides a rich pedagogical context for developing problem-solving competence by immersing students in interdisciplinary problem situations that require active engagement and higher-order thinking. Through STEM activities, students are encouraged to integrate knowledge from multiple disciplines, collaborate with peers, and apply concepts in meaningful contexts, thereby strengthening their problem-solving abilities (Lansiquot et al., 2011).

Empirical studies have consistently shown that problem-based and project-based STEM approaches have a positive impact on students' problem-solving skills and related competencies. For instance, interdisciplinary STEM learning has been found to enhance creative problem-solving and critical thinking by exposing students to open-ended challenges and collaborative learning environments (Topsakal et al., 2022; Bicer et al., 2017). At the elementary level, project-based STEM activities help students develop planning skills, persistence, and the ability to evaluate solutions, which are essential components of problem-solving competence (Rasyid et al., 2023).

Moreover, STEM-based learning encourages metacognitive development by prompting students to reflect on their thinking and learning strategies. Reflection

activities, such as discussing solution processes and evaluating outcomes, help students become more aware of how they approach problems and how they can improve their strategies in future tasks (McCrum, 2017). These reflective practices are particularly important in primary education, where students are still developing self-regulation and learning awareness.

2.4. Assessment of Problem-Solving Competence in STEM Education

Assessment plays a critical role in understanding and supporting the development of problem-solving competence within STEM-based learning environments. Traditional assessment methods that focus solely on correct answers may fail to capture the complexity of problem-solving processes. Therefore, contemporary STEM assessment emphasizes performance-based and process-oriented approaches that evaluate students' reasoning, collaboration, and reflection (Amalina & Vidákovich, 2022).

Assessment frameworks in STEM education often include multiple dimensions, such as problem understanding, strategy use, solution quality, and communication. Collaborative problem-solving assessment systems have been developed to capture both individual and group performance in STEM tasks, providing a more comprehensive picture of students' learning (Lin et al., 2015). These approaches are particularly relevant for primary education, where social interaction and guided support play an important role in learning.

2.5. STEM-Based Learning and Problem-Solving Competence in the Vietnamese Context

In Vietnam, STEM education has increasingly been promoted as part of educational reforms aimed at improving teaching quality and fostering key competencies among students. Research indicates that STEM-oriented programs contribute positively to students' critical thinking, problem-solving skills, and engagement in learning (Chen et al., 2021; Linh et al., 2019). However, most existing studies have focused on secondary or higher education, and there is limited empirical evidence on how STEM-based learning is implemented at the primary level.

Given the characteristics of Vietnamese primary education, including curriculum requirements and classroom conditions, there is a need for context-specific research that examines how STEM-based learning can be effectively designed and implemented for young learners. This study adopts a theoretical framework that views STEM-based learning as a catalyst for developing problem-solving competence through interdisciplinary integration, hands-on activities, collaborative learning, and reflective practice. This framework provides the foundation for the research design, data collection, and analysis presented in the subsequent sections of the article.

3. Methodology

The study was conducted at three public primary schools in Hanoi: Kim Dong Primary School (Giang Vo Ward), Ba Dinh Primary School (Ngoc Ha Ward), and

Thanh Tri Primary School (Vinh Hung Ward). These schools were selected because STEM-based learning activities had been regularly implemented in classroom teaching, creating suitable conditions for observing their impact on students' problem-solving competence.

A mixed-methods approach was employed to reflect both practical implementation and observed outcomes. STEM-based learning activities were integrated into regular lessons and organized around problem-based and project-oriented tasks appropriate for primary students. During these activities, students worked collaboratively to identify problems, design solutions, test ideas, and discuss results under teachers' guidance (Sicherl-Kafol & Denac, 2010).

Data were collected from a total of 35 school administrators and teachers, who participated in questionnaires and interviews. The questionnaire focused on their evaluations of students' problem-solving competence and the effectiveness of STEM-based learning in classroom practice. In addition, classroom observations were conducted to capture students' engagement, collaboration, and problem-solving behaviors during STEM activities. Semi-structured interviews with selected administrators and teachers provided further insights into instructional experiences, perceived outcomes, and implementation challenges (Hainey et al., 2016).

Quantitative data were summarized using descriptive statistics to identify general trends across the three schools. Qualitative data from observations and interviews were analyzed thematically, allowing recurring patterns related to teaching practices and student learning processes to be identified. The integration of these data sources supported a more comprehensive understanding of how STEM-based learning contributed to the formation of problem-solving competence among primary students.

4. Findings

4.1. Quantitative Findings

Survey data were collected from 35 school administrators and teachers across three primary schools to examine their perceptions of changes in students' problem-solving competence following the implementation of STEM-based learning activities.

Regarding students' ability to recognize and understand problems, a large majority of respondents reported positive changes. Specifically, 27 out of 35 respondents (77.1%) indicated that students were better able to identify task requirements and constraints when learning activities were designed as practical or real-life problems. Six respondents (17.1%) perceived moderate improvement, while two respondents (5.8%) reported little or no noticeable change.

In terms of solution planning and interdisciplinary knowledge application, 25 respondents (71.4%) agreed that students increasingly combined knowledge from different subjects during STEM activities, particularly mathematics and science.

Eight respondents (22.9%) reported occasional integration depending on lesson design, and two respondents (5.8%) noted limited interdisciplinary application.

Concerning testing, revision, and persistence, 29 respondents (82.9%) observed that students were more willing to test ideas repeatedly and revise their solutions after unsuccessful attempts. Five respondents (14.3%) reported moderate improvement, while one respondent (2.8%) perceived no clear change in students' persistence.

With respect to collaboration during problem solving, 26 respondents (74.3%) indicated that STEM-based learning promoted more active peer discussion and idea sharing. Seven respondents (20.0%) reported uneven participation within groups, and two respondents (5.8%) considered collaboration effects to be minimal.

Respondents also identified several constraints affecting implementation. 21 respondents (60.0%) cited limited instructional time as a major challenge, 18 respondents (51.4%) mentioned uneven student participation, and 15 respondents (42.9%) reported increased preparation workload for teachers.
These results are summarized in Table 1.

Table 1. Survey results on perceived changes in students' problem-solving competence (n = 35)

Aspect	Positive	Moderate	Limited or none
Problem recognition	27 (77.1%)	6 (17.1%)	2 (5.8%)
Interdisciplinary application	25 (71.4%)	8 (22.9%)	2 (5.8%)
Testing and persistence	29 (82.9%)	5 (14.3%)	1 (2.8%)
Collaboration	26 (74.3%)	7 (20.0%)	2 (5.8%)

4.2. Qualitative Findings

4.2.1. Classroom Observation Results
Classroom observations confirmed patterns reported in the survey. During STEM-based lessons, students were observed actively discussing task requirements, particularly when teachers introduced activities as practical challenges. In classrooms where teachers guided students to clarify constraints at the beginning of lessons, students demonstrated more purposeful planning and task engagement.

Figure 1. Primary students working collaboratively during STEM-based learning activities

Students frequently engaged in hands-on testing and revision. Observations showed repeated cycles of assembling, testing, and modifying solutions, indicating an iterative problem-solving process. Reflection quality varied across classes and was strongly influenced by time allocation and teacher guidance. Observable indicators of problem-solving competence are presented in Table 2.

Table 2. Observed indicators of problem-solving competence in STEM lessons

Stage	Observable behaviors
Problem identification	Clarifying task goals and constraints
Planning	Proposing ideas and assigning roles
Testing	Experimenting and comparing results
Revision	Modifying solutions based on feedback
Reflection	Explaining reasoning and outcomes

4.2.2. Interview Findings from Administrators and Teachers

Interview data provided explanatory depth to the quantitative findings. Interviewees were coded as QL for administrators and GV for teachers. Several teachers described a shift in instructional practice. One teacher explained that facilitating rather than explaining allowed students' problem-solving processes to become more visible in class (GV.3). Another teacher noted that students who were usually passive showed greater engagement during STEM activities because tasks required concrete action (GV.7).

Administrators emphasized the motivational role of real-life contexts. One administrator observed that students were more persistent when they understood the purpose of the task (QL.2). Another administrator highlighted that STEM-based learning encouraged students to focus on reasoning rather than memorizing answers (QL.4).

Collaboration emerged as both a benefit and a challenge. Teachers reported improved peer interaction but noted uneven participation in some groups. Assigning clear roles was identified as an effective strategy to address this issue (GV.10).

Time constraints and assessment difficulties were also discussed. One teacher expressed uncertainty about evaluating problem-solving competence consistently without clear criteria (GV.12), while an administrator emphasized the need for professional support in STEM lesson design (QL.5). Key interview themes are summarized in Table 3.

Table 3. Themes identified from interviews

Theme	Description	Codes
Teacher role	Shift from instruction to facilitation	GV.3, GV.7
Student motivation	Engagement through real-life tasks	QL.2, QL.4
Collaboration	Benefits and participation challenges	GV.10
Constraints	Time, materials, assessment	GV.12, QL.5

Figure 2. Students presenting outcomes and reflecting on problem-solving processes

5. Discussion

One important insight concerns the role of authentic problem contexts in shaping students' engagement with learning tasks. When problems were embedded in familiar or practical situations, students were perceived to demonstrate clearer understanding of task requirements and constraints. This supports the view that meaningful problem contexts function as cognitive anchors, enabling young learners to connect new tasks with prior experiences and thereby engage more purposefully in problem-solving activities (Tan et al., 2023; Zeeshan et al., 2021). From a constructivist perspective, this finding reinforces the idea that understanding in STEM education is actively constructed through interaction

with meaningful tasks rather than transmitted through direct explanation (Sheth & Pathak, 2023).

The findings also contribute to ongoing discussions on interdisciplinary learning at the primary level. Teachers' observations that students combined mathematical reasoning, scientific explanations, and basic engineering decisions suggest that interdisciplinary thinking is achievable even among younger learners when learning environments are carefully designed. This aligns with prior research arguing that interdisciplinary STEM tasks promote flexible knowledge use and support deeper conceptual understanding (Lansiquot et al., 2011; Güven & Alpaslan, 2022). The present study extends this literature by showing that such integration does not require advanced content but can emerge through simple design and problem-based activities.

Another key contribution of the study lies in highlighting persistence and iterative thinking as central elements of problem-solving competence. The acceptance of trial and error observed in STEM-based lessons reflects a shift away from answer-focused learning toward process-oriented engagement. This finding is consistent with studies suggesting that problem-based STEM instruction encourages resilience and iterative improvement, which are essential for effective problem solving (Topsakal et al., 2022; McCrum, 2017). Importantly, the results indicate that these dispositions can be fostered at the primary level when classroom norms support experimentation and revision.

Collaboration, while widely recognized as a strength of STEM education, emerged as a more complex dimension in this study. Increased peer interaction and idea sharing were commonly reported, supporting research on collaborative problem solving in STEM contexts (Lin et al., 2015; Amalina & Vidákovich, 2022). At the same time, variations in collaboration quality highlight the importance of intentional group organization and teacher facilitation. This suggests that collaboration should be treated not as an automatic outcome of group work but as a competence that requires instructional support.

Finally, the constraints identified by participants provide important context for interpreting the findings. Issues related to time, materials, assessment, and teacher workload echo challenges reported in previous studies on STEM implementation in Vietnam and similar educational contexts (Chen et al., 2021; Linh et al., 2019). These constraints do not diminish the value of STEM-based learning but underscore the need to view it as a systemic innovation that depends on professional development, curricular alignment, and institutional support.

6. Conclusion

This study explored the role of STEM-based learning in the formation of problem-solving competence among primary students in Hanoi, Vietnam. Through a mixed methods design involving surveys, classroom observations, and interviews with administrators and teachers, the study provided evidence grounded in everyday classroom practice.

The results indicate that STEM-based learning creates favorable conditions for the development of problem-solving competence by engaging students in meaningful tasks, supporting interdisciplinary thinking, encouraging persistence through iterative processes, and promoting collaborative learning. Rather than focusing on isolated skills, STEM-based learning appears to shape how students approach problems, interact with peers, and reflect on their learning.

Beyond documenting these outcomes, the study highlights important implications for practice. Effective implementation of STEM-based learning at the primary level requires thoughtful lesson design, active teacher facilitation, and adequate time and resources. Attention to assessment practices is also necessary to ensure that problem-solving competence is recognized and supported systematically.

By providing context-specific evidence from Vietnamese primary schools, this study contributes to the broader literature on STEM education and competency-based learning. It suggests that introducing STEM-based learning early in schooling can play a meaningful role in preparing students for more complex learning challenges in later stages. Future research may build on these findings by examining long-term impacts, student perspectives, and scalable models of STEM implementation in primary education.

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