Indonesian Primary School Teachers' Perceptions of STEMPreneur for Supporting Computational Thinking in Science Learning

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Abstract
The increasing emphasis on computational thinking (CT) in primary education has encouraged the exploration of innovative pedagogical approaches that integrate scientific inquiry with authentic problem solving. One emerging approach is STEMPreneur, which combines STEM education with entrepreneurial thinking to foster innovation and value creation. This study explored Indonesian primary school teachers' perceptions of STEMPreneur for promoting computational thinking in Primary Science (IPAS) learning. A sequential explanatory mixed-methods design was employed involving 50 primary school teachers from Jakarta and Bekasi, followed by semi-structured interviews with five purposively selected participants. Quantitative data were analyzed using descriptive statistics, while qualitative data were examined through thematic analysis. The findings revealed that teachers perceived STEMPreneur as a relevant and pedagogically valuable approach that supports the development of decomposition, pattern recognition, abstraction, algorithmic thinking, and evaluation. However, teachers also identified challenges related to pedagogical knowledge, instructional resources, computational thinking assessment, and curriculum time. To address these challenges, participants recommended continuous professional development, practical instructional resources, explicit computational thinking assessment, and authentic project-based learning. The study proposes a pedagogical ecosystem for STEMPreneur implementation that provides a conceptual framework for integrating computational thinking into primary science education.

1. Introduction

The rapid advancement of artificial intelligence (AI), automation, and digital technologies has fundamentally transformed the competencies required for future generations (Setiawan et al., 2025). Rather than emphasizing content acquisition alone, contemporary education systems are increasingly expected to cultivate higher-order thinking skills, creativity, innovation, problem-solving, and computational thinking (CT) to prepare learners for complex and uncertain future challenges. International organizations such as the OECD, UNESCO, and the World Economic Forum consistently identify computational thinking as one of the essential competencies for twenty-first-century learning because it enables learners to formulate problems systematically, develop logical solutions, evaluate multiple alternatives, and transfer knowledge across disciplines (OECD, 2023; Unesco, 2020; World Economic Forum, 2023). Consequently, many countries have begun integrating Consequently, many countries have begun integrating computational thinking not only into computer science education but also across broader curriculum areas, including science education at the primary level.

Within primary education, science learning plays a strategic role in developing students' scientific reasoning through inquiry, observation, experimentation, and evidence-based problem solving. In Indonesia, the implementation of Primary Science and Social Studies (IPAS) under the Merdeka Curriculum provides opportunities to integrate interdisciplinary learning that connects scientific concepts with authentic problems encountered in everyday life (Ramadhani, 2023; Surul & Septiliana, 2023). Such learning environments provide meaningful contexts for developing computational thinking through decomposition, pattern recognition,

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abstraction, algorithmic thinking, and evaluation (Kong, 2016; Mills et al., 2025; Weng et al., 2024; Yeni et al., 2024). Previous studies further indicate that many primary school teachers experience difficulties in translating computational thinking into classroom activities because of insufficient pedagogical guidance, limited instructional resources, and uncertainty regarding appropriate teaching strategies (Feng & Yang, 2022; Israel et al., 2022; Kite & Park, 2023). These findings indicate that, despite the growing recognition of computational thinking as an essential competency, its successful integration into primary science classrooms remains a considerable challenge for many teachers.

To address these challenges, STEM education has been widely promoted as an interdisciplinary approach that integrates science, technology, engineering, and mathematics through authentic problem-solving experiences. Numerous studies have demonstrated that STEM-based learning contributes positively to students' critical thinking, creativity, collaboration, engineering design skills, and computational thinking (Abanoz & Kalelioğlu, 2025; Abu Khurma et al., 2023). However, conventional STEM education has also been criticized for emphasizing technological innovation more than value creation, entrepreneurial competence, and students' capacity to transform scientific ideas into meaningful innovations that address societal needs (Hynes et al., 2023; Mapanga & Faleni, 2025; Ng et al., 2024). To address these limitations, researchers have increasingly extended STEM education by incorporating entrepreneurial perspectives, giving rise to Entrepreneurial STEM. Entrepreneurial STEM encourages learners not only to solve scientific and technological problems but also to recognize opportunities, create innovative solutions, evaluate their feasibility, and generate products or services that provide value for society.

Building upon this perspective, STEMPreneur has emerged as a pedagogical approach that integrates STEM learning with entrepreneurial thinking in authentic educational contexts. Unlike traditional entrepreneurship education, which primarily focuses on business creation, STEMPreneur embeds entrepreneurial competencies within STEM learning to promote innovation, creativity, opportunity recognition, risk awareness, decision making, and value creation through scientific inquiry (Fawaida et al., 2023). From this perspective, entrepreneurship is not treated as a separate learning objective but as a pedagogical context that enriches STEM learning. Through project-based investigations addressing real societal problems, students are expected not only to acquire scientific knowledge but also to develop entrepreneurial mindsets that support innovation and sustainable problem solving. Furthermore, entrepreneurial problem-solving processes naturally involve decomposition, analytical reasoning, iterative solution design, evaluation, optimization, and evidence-based decision making, which correspond to the core dimensions of computational thinking (Wang et al., 2022). Therefore, STEMPreneur represents a promising pedagogical approach for supporting computational thinking in primary science education.

Despite the growing interest in STEM education, computational thinking, and STEMPreneur, empirical evidence regarding teachers' perceptions of STEMPreneur remains limited, particularly in primary education. Existing studies have predominantly focused on students' learning outcomes, while comparatively little attention has been devoted to teachers, who play a central role in translating curriculum innovations into classroom practice (Hynes et al., 2023; Kaya-Capocci et al., 2025; Soomro & Shah, 2022; Yu et al., 2025). This gap is particularly evident in the Indonesian context, where the Merdeka Curriculum promotes contextual, interdisciplinary, and project-based learning but provides limited pedagogical guidance for integrating computational thinking through entrepreneurship-oriented STEM activities (Iwata et al., 2020). Consequently, little is known about how Indonesian primary school teachers perceive STEMPreneur, how prepared they are to implement it, and what pedagogical challenges they encounter in supporting computational thinking within Primary Science and Social Studies (IPAS) learning.

Responding to these gaps, this study explores Indonesian primary school teachers' perceptions of STEMPreneur as a pedagogical approach for supporting computational thinking in Primary Science and Social Studies (IPAS) learning through a sequential explanatory mixed-methods design. Specifically, the study investigates teachers' perceptions of STEMPreneur implementation, examines its perceived potential for fostering computational thinking, identifies the pedagogical challenges teachers encounter during implementation, and explores the strategies they recommend for effective classroom adoption. This study contributes to the literature in three ways. First, it extends the emerging discussion on STEMPreneur by examining teachers' perspectives rather than focusing solely on student outcomes. Second, it provides empirical evidence regarding Indonesian primary school teachers' perceptions and implementation readiness toward STEMPreneur. Third, it proposes an evidence-informed Pedagogical Ecosystem for STEMPreneur Implementation that may guide curriculum developers, teacher educators, and policymakers in designing sustainable computational thinking-oriented learning environments for primary schools.

Accordingly, this study addresses four interrelated research questions concerning Indonesian primary school teachers' perceptions of STEMPreneur in Primary Science and Social Studies (IPAS). It examines how teachers perceive the implementation of STEMPreneur, how they perceive its potential to foster computational thinking, the pedagogical challenges they encounter during implementation, and the pedagogical strategies they recommend for effectively integrating STEMPreneur into primary science learning.

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2. Method

2.1. Research Design

This study employed a sequential explanatory mixed-methods design, in which quantitative data were collected and analyzed during the first phase, followed by qualitative interviews to provide deeper explanations of the quantitative findings. This design was selected because it enables researchers to obtain both broad patterns of teachers' perceptions and rich contextual insights regarding the implementation of STEMPreneur in primary science education (Creswell & Creswell, 2020; Fraenkel et al., 2012). The integration of quantitative and qualitative findings offers a comprehensive understanding of teachers' readiness, perceived benefits, implementation challenges, and pedagogical recommendations related to STEMPreneur and computational thinking. The sequential explanatory design has been widely adopted in studies exploring teachers' perceptions of STEM education and computational thinking because it combines the generalizability of survey findings with the explanatory power of qualitative evidence.

2.2. Participants

The participants were 50 elementary school teachers teaching Grades 4–6 Primary Science and Social Studies (IPAS) in public and private schools in Jakarta and Bekasi, Indonesia. These two regions were selected because they represent urban educational settings that have actively implemented the Merdeka Curriculum and have relatively diverse school characteristics. Participants were selected using purposive sampling. To be eligible for participation, teachers were required to be currently teaching Grades 4–6 Primary Science and Social Studies (IPAS), have at least one year of teaching experience, and be willing to participate voluntarily in the study. Following the quantitative phase, five teachers were purposively selected for semi-structured interviews. The interview participants represented different teaching experiences and varying levels of perceptions toward the STEMPreneur approach, enabling the researchers to obtain diverse perspectives regarding its implementation in primary science classrooms.

2.3. Research Instruments

Quantitative data were collected using a questionnaire consisting of 25 items distributed across five dimensions: (1) perceived usefulness of STEMPreneur, (2) curriculum compatibility, (3) teacher self-efficacy, (4) perceived contribution to computational thinking, and (5) implementation readiness. Responses were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Qualitative data were obtained through semi-structured interviews with five selected teachers. The interview protocol explored teachers' understanding of STEMPreneur, its potential to foster computational thinking, perceived implementation challenges, and recommendations for classroom practice. Prior to data collection, the questionnaire was reviewed by experts in science education and educational research to ensure content validity. The internal consistency of the questionnaire was evaluated using Cronbach's alpha.

2.4. Data Collection

Data were collected from May to June 2026. The questionnaire was distributed online to teachers in Jakarta and Bekasi using Google Forms. After the survey results were analyzed, five teachers were invited to participate in individual semi-structured interviews. Each interview lasted approximately 10-15 minutes and was conducted online or face-to-face, depending on participants' availability. All interviews were audio-recorded with participants' consent and transcribed for analysis.

2.5. Data Analysis

Quantitative data were analyzed using descriptive statistics, including frequency, percentage, mean, and standard deviation, to describe teachers' perceptions of STEMPreneur. The reliability of the questionnaire was assessed using Cronbach's alpha. Qualitative interview data were analyzed using thematic analysis following Braun and Clarke's six-step procedure: familiarization, coding, generating themes, reviewing themes, defining themes, and reporting the findings. Finally, the quantitative and qualitative findings were integrated to provide a comprehensive interpretation of teachers' perceptions regarding the implementation of STEMPreneur for fostering computational thinking in Primary Science learning.

2.6. Integration of Quantitative and Qualitative Findings

Following the sequential explanatory mixed-methods design, integration occurred during the interpretation stage. Quantitative findings provided an overall picture of teachers' perceptions toward STEMPreneur, while qualitative findings were used to explain the underlying reasons behind those perceptions, clarify contextual implementation challenges, and identify pedagogical considerations. This triangulation strengthened the credibility of the findings and enabled the development of evidence-based design principles for integrating STEMPreneur into primary science instruction to foster computational thinking.

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3. Results and Discussion

3.1. Results

3.1.1. Teachers' Perceptions of STEMPreneur Implementation in Primary Science Learning (RQ1)

The first research question sought to explore how Indonesian primary school teachers perceive the implementation of STEMPreneur in Primary Science (IPAS) learning. This aspect was examined through three dimensions: perceived usefulness, curriculum compatibility, and implementation readiness. Descriptive statistical analysis indicated that teachers generally held positive perceptions toward the implementation of the STEMPreneur approach in primary science classrooms.

As presented in Table 1, the overall mean score across the three dimensions was 4.20 (SD = 0.55), indicating a high level of agreement among respondents regarding the feasibility and educational value of STEMPreneur. Among the dimensions, perceived usefulness obtained the highest mean score (M = 4.32, SD = 0.51), followed by implementation readiness (M = 4.17, SD = 0.58) and curriculum compatibility (M = 4.11, SD = 0.55).

Table 1. Teachers' Perceptions of STEMPreneur Implementation in Primary Science Learning (n = 50)

Dimension	Mean	SD	Interpretation
Perceived usefulness	4.32	0.51	Very Positive
Curriculum compatibility	4.11	0.55	Positive
Implementation readiness	4.17	0.58	Positive
Overall	4.20	0.55	Positive

Further analysis of the questionnaire responses revealed that 92% of teachers agreed or strongly agreed that STEMPreneur could make science learning more meaningful by connecting scientific concepts with authentic problems encountered in students' daily lives. In addition, 88% of respondents believed that the approach encourages students to become more active through project-based and inquiry-oriented learning activities.

Regarding curriculum alignment, 86% of teachers perceived that STEMPreneur is compatible with the objectives of the Merdeka Curriculum, particularly its emphasis on contextual learning, interdisciplinary integration, project-based learning, and the development of twenty-first-century competencies. Teachers considered entrepreneurial activities to provide authentic contexts that enable students to apply scientific knowledge while simultaneously developing creativity, collaboration, and problem-solving skills.

Teachers also expressed relatively high levels of readiness to implement STEMPreneur in their classrooms. Approximately 84% of respondents indicated their willingness to adopt the approach in future science lessons, provided that adequate instructional resources, teaching examples, and professional development opportunities are available. However, several respondents expressed moderate confidence in designing entrepreneurship-oriented science activities independently, suggesting that practical instructional guidance remains necessary.

These findings indicate that Indonesian primary school teachers perceive STEMPreneur as a relevant, feasible, and pedagogically valuable approach for IPAS learning. Teachers recognized its potential to enrich inquiry-based science instruction by integrating authentic entrepreneurial experiences with scientific investigation, while maintaining alignment with the learning principles promoted by the Merdeka Curriculum. Nevertheless, the findings also suggest that successful classroom implementation requires sufficient pedagogical support to strengthen teachers' confidence and instructional competence.

3.1.2. Teachers' Perceptions of STEMPreneur for Fostering Computational Thinking (RQ2)

The second research question examined how teachers perceive the potential of STEMPreneur to foster students' computational thinking (CT) in primary science (IPAS) learning. Teachers were asked to evaluate the extent to which STEMPreneur learning activities could support the development of the five core dimensions of computational thinking: decomposition, pattern recognition, abstraction, algorithmic thinking, and evaluation.

Teachers expressed very positive perceptions regarding the contribution of STEMPreneur to computational thinking development. The overall mean score for this dimension was 4.36 (SD = 0.49), indicating that respondents strongly believed that integrating entrepreneurial challenges into science learning creates

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meaningful opportunities for students to develop computational thinking skills. Table 2 presents teachers' perceptions across the five dimensions of computational thinking.

Table 2. Teachers' Perceptions of STEMPreneur in Fostering Computational Thinking (n = 50)

Computational Thinking Dimension	Mean	SD	Interpretation
Decomposition	4.41	0.48	Very Positive
Pattern Recognition	4.29	0.53	Very Positive
Abstraction	4.30	0.51	Very Positive
Algorithmic Thinking	4.38	0.50	Very Positive
Evaluation	4.42	0.47	Very Positive
Overall	4.36	0.49	Very Positive

Among the five dimensions, evaluation obtained the highest mean score (M = 4.42), followed closely by decomposition (M = 4.41) and algorithmic thinking (M = 4.38). These findings suggest that teachers perceive STEMPreneur activities as particularly effective in encouraging students to evaluate alternative solutions, identify appropriate strategies, and develop systematic procedures for solving authentic problems. Although pattern recognition recorded the lowest mean score (M = 4.29), the result still fell within the "very positive" category, indicating consistently favorable perceptions across all computational thinking dimensions.

Further examination of individual questionnaire responses showed that 94% of teachers agreed or strongly agreed that entrepreneurial projects encourage students to break complex real-world problems into smaller and more manageable components, reflecting the process of decomposition. Likewise, 92% of respondents believed that students naturally engage in algorithmic thinking when planning sequential procedures for designing, testing, and improving products or solutions during STEMPreneur activities.

Teachers also perceived that entrepreneurial problem-solving contexts facilitate abstraction by encouraging students to identify essential information while ignoring irrelevant details. Approximately 90% of respondents agreed that students learn to simplify complex situations by focusing on key variables before proposing scientific solutions. Furthermore, 88% of teachers reported that students frequently compare different cases and identify similarities across problems, supporting the development of pattern recognition.

The highest level of agreement emerged in relation to the evaluation dimension. Nearly 96% of teachers agreed that STEMPreneur learning provides opportunities for students to reflect on the effectiveness of their solutions, revise product designs based on evidence, and justify their decisions using scientific reasoning. Teachers perceived this iterative process as one of the most valuable characteristics of STEMPreneur because it encourages continuous improvement rather than simply producing a final answer.

These findings indicate that teachers view STEMPreneur as more than an entrepreneurship-oriented instructional approach. Instead, they perceive it as a pedagogical framework that systematically supports the development of computational thinking through authentic scientific inquiry, iterative design processes, collaborative problem solving, and evidence-based decision making. According to respondents, integrating entrepreneurial challenges into primary science learning enables students to engage in multiple computational thinking processes simultaneously, making STEMPreneur a promising approach for cultivating higher-order thinking skills in elementary education.

3.1.3. Challenges in Implementing STEMPreneur in Primary Science Classrooms (RQ3)

The third research question explored the challenges encountered by teachers in implementing STEMPreneur within primary science (IPAS) classrooms. While the quantitative findings indicated that teachers generally demonstrated positive implementation readiness (M = 4.17, SD = 0.58), the follow-up interviews revealed several practical challenges that may hinder the successful integration of STEMPreneur into everyday classroom practice. Thematic analysis of the interview data identified four major themes: (1) limited pedagogical knowledge, (2) insufficient instructional resources, (3) difficulties in assessing computational thinking, and (4) time constraints within the curriculum. Hierarchical relationships between the four major themes was shown in figure 1.

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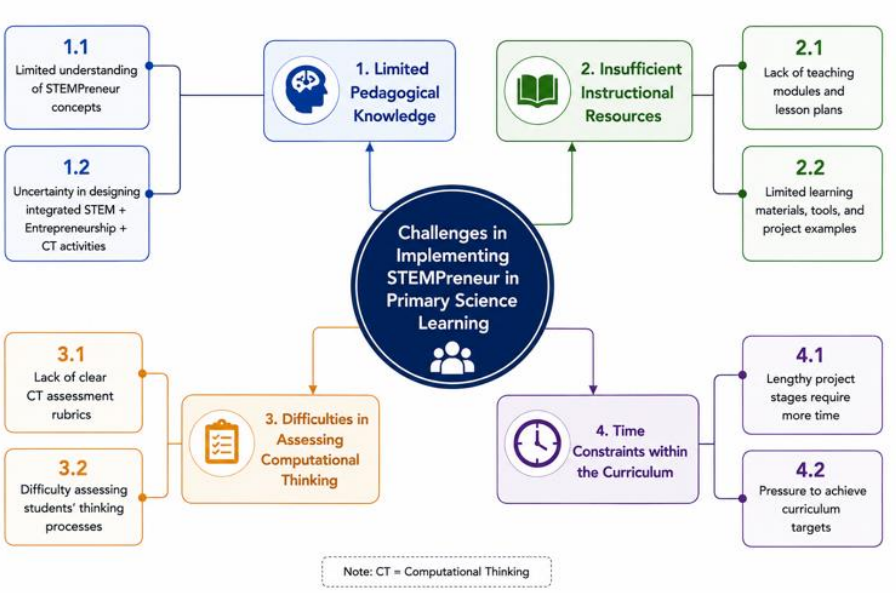


Figure. 1. Thematic Map Illustrating the Major Challenges Identified by Teachers During the Implementation of STEMPreneur in Primary Science Learning

3.1.3.1. Theme 1. Limited Pedagogical Knowledge

Although teachers expressed positive attitudes toward STEMPreneur, most participants admitted that they were still unfamiliar with the pedagogical principles underlying the approach. The concept of integrating STEM, entrepreneurship, and computational thinking was considered relatively new, and several teachers indicated that they lacked practical experience in designing learning activities that combine these components.

One participant explained:

> "We understand the idea of connecting science with entrepreneurship, but we are still unsure how to organize the learning activities so that students also develop computational thinking." (Teacher 2)

Similarly, another teacher stated:

> "Most of us have implemented project-based learning, but STEMPreneur requires a different way of planning lessons because the entrepreneurial element must be integrated naturally into science learning." (Teacher 5)

These responses suggest that teachers require clearer pedagogical guidance before implementing the approach independently.

3.1.3.2. Theme 2. Insufficient Instructional Resources

The second challenge concerned the availability of instructional materials and supporting resources. Teachers reported that existing science textbooks and teaching materials provide limited examples of entrepreneurship-oriented STEM activities suitable for elementary school students.

One participant commented:

> "There are very few teaching materials that combine science, entrepreneurship, and computational thinking. Usually, we have to prepare everything ourselves." (Teacher 1)

Another teacher added:

> "It would be easier if there were lesson plans, worksheets, and examples of projects that have already been tested in elementary schools." (Teacher 4)

The findings indicate that practical teaching resources remain an important prerequisite for wider implementation.

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3.1.3.3. Theme 3. Difficulties in Assessing Computational Thinking

Teachers also highlighted assessment as one of the most challenging aspects of implementing STEMPreneur. Although they believed that students demonstrated computational thinking during project activities, many participants were uncertain about how to measure these skills systematically.

As expressed by one teacher:

> "Students clearly show problem-solving skills during projects, but we do not yet have clear assessment criteria to evaluate computational thinking." (Teacher 3)

Another participant stated:

> "Assessing the final product is relatively easy, but evaluating students' thinking processes is much more difficult." (Teacher 5)

These findings suggest that teachers need assessment frameworks capable of capturing students' computational thinking processes throughout entrepreneurial science projects.

3.1.3.4. Theme 4. Time Constraints within the Curriculum

The final challenge identified by participants related to limited instructional time. Teachers explained that entrepreneurship-oriented projects often require multiple stages, including problem identification, planning, investigation, product development, testing, reflection, and presentation. Consequently, completing all activities within the allocated IPAS instructional hours was considered difficult.

One teacher explained:

> "Students need sufficient time to investigate problems and improve their products. Unfortunately, classroom schedules often limit these activities." (Teacher 1)

Another participant remarked:

> "The approach is very interesting, but teachers must also complete curriculum targets within a limited number of instructional hours." (Teacher 4)

These comments indicate that curriculum flexibility is an important consideration for the successful implementation of STEMPreneur.

3.1.4. Teachers' Recommended Pedagogical Strategies for Integrating STEMPreneur (RQ4)

The fourth research question explored teachers' recommendations for effectively integrating STEMPreneur into primary science (IPAS) learning to foster students' computational thinking. Analysis of the interview data revealed that teachers proposed several pedagogical strategies to facilitate successful implementation. Unlike the challenges presented in the previous section, these findings emphasize practical solutions that teachers believe are necessary to strengthen classroom implementation. The thematic analysis generated four major pedagogical strategies: (1) continuous professional development, (2) development of practical instructional resources, (3) integration of computational thinking assessment, and (4) implementation of authentic project-based learning. The framework of thematic relationships was shown in figure 2.

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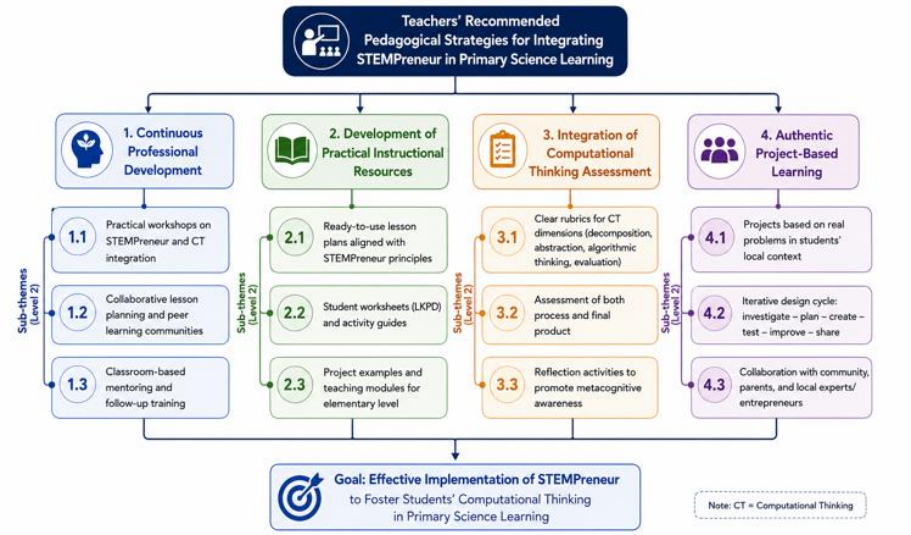


Figure 2. Thematic Map of Teachers' Recommended Pedagogical Strategies for Integrating STEMPreneur in Primary Science Learning

3.1.4.1. Theme 1. Continuous Professional Development

The majority of participants emphasized that teachers require continuous professional development before implementing STEMPreneur effectively. Rather than introducing the concept through theoretical seminars alone, participants recommended practical workshops that demonstrate classroom implementation, lesson planning, and project facilitation.

One participant explained:

> "Training should focus on classroom practice. Teachers need to experience how STEMPreneur works rather than only learning the theory." (Teacher 2)

Another teacher added:

> "Collaborative workshops where teachers design lesson plans together would help us feel more confident." (Teacher 5)

These findings indicate that experiential professional learning is considered essential for improving teachers' pedagogical competence.

3.1.4.2. Theme 2. Development of Practical Instructional Resources

Teachers consistently recommended the development of comprehensive instructional resources to support classroom implementation. These resources include lesson plans, student worksheets (LKPD), project examples, teaching modules, and digital learning materials specifically designed for elementary science learning.

One participant stated:

> "If practical teaching modules are available, teachers can adapt them more easily to their own classrooms." (Teacher 1)

Another participant explained:

> "Examples of successful classroom projects would provide teachers with confidence when implementing STEMPreneur for the first time." (Teacher 4)

Participants believed that accessible instructional resources would reduce teachers' preparation time and encourage wider adoption.

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3.1.4.3. Theme 3. Integration of Computational Thinking Assessment

Teachers also recommended that computational thinking should be explicitly incorporated into classroom assessment. Participants suggested that assessment should evaluate not only students' final products but also their reasoning processes throughout project implementation.

One participant commented:

> "Students should be assessed based on how they analyze problems, develop solutions, and improve their ideas, not only on the final product." (Teacher 3)

Another teacher suggested:

> "Clear rubrics for decomposition, abstraction, and algorithmic thinking would help teachers evaluate students more consistently." (Teacher 5)

These findings indicate that teachers prefer process-oriented assessment aligned with the core dimensions of computational thinking.

3.1.4.4. Theme 4. Authentic Project-Based Learning

Participants emphasized that STEMPreneur should be implemented through authentic projects addressing real problems within students' local communities. Teachers believed that contextual learning encourages students to connect scientific concepts with entrepreneurial thinking while simultaneously engaging in computational thinking processes.

One participant explained:

> "Students become more motivated when the project solves problems they encounter in their own environment." (Teacher 2)

Similarly, another teacher remarked:

> "Community-based projects allow students to investigate, design solutions, test ideas, and evaluate the results in meaningful ways." (Teacher 4)

Teachers viewed authentic project-based learning as the most effective context for integrating science, entrepreneurship, and computational thinking simultaneously.

3.2. Discussion

3.2.1. STEMPreneur as an Emerging Pedagogical Approach for Supporting Computational Thinking in Primary Science

The present study found that Indonesian primary school teachers generally perceive STEMPreneur as a promising pedagogical approach for supporting computational thinking in Primary Science learning. Teachers expressed positive perceptions regarding the usefulness, curriculum compatibility, implementation readiness, and perceived potential of STEMPreneur to support computational thinking. The qualitative findings further showed that teachers viewed entrepreneurial projects as meaningful learning experiences that encourage students to investigate authentic problems, generate innovative ideas, evaluate alternative solutions, and refine their products through iterative processes. Rather than associating computational thinking solely with programming or digital technologies, teachers perceived it as a cognitive process embedded within scientific inquiry and entrepreneurial problem solving. These findings suggest that teachers recognize STEMPreneur as an instructional approach capable of integrating scientific inquiry, entrepreneurial thinking, and computational reasoning within authentic learning contexts.

These findings indicate that, from teachers' perspectives, computational thinking is not limited to computer programming but can also be fostered through authentic learning experiences requiring students to analyze problems, generate solutions, evaluate alternatives, and reflect on the effectiveness of their decisions. Teachers therefore perceived entrepreneurship as providing meaningful contexts in which computational thinking processes may naturally occur during scientific inquiry. Rather than viewing entrepreneurial activities as separate learning objectives, respondents considered them complementary to science learning because they encourage students to engage in systematic problem solving while considering the usefulness and value of their solutions.

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This interpretation is consistent with contemporary perspectives that conceptualize computational thinking as a domain-general cognitive process rather than a purely technological competence (Kafai & Proctor, 2022; Kakavas & Ugolini, 2019; Kerimbayev et al., 2023). Likewise, the dimensions identified by teachers, including decomposition, pattern recognition, abstraction, algorithmic thinking, and evaluation, are consistent with widely accepted computational thinking frameworks ((Kite & Park, 2023; Kong, 2016; Weng et al., 2024; Yeni et al., 2024). The present findings also complement previous studies reporting that STEM-based learning provides opportunities for developing higher-order thinking skills through authentic problem-solving activities (Abanoz & Kalelioğlu, 2025; Abu Khurma et al., 2023). However, unlike earlier studies that primarily focused on students' learning outcomes, the present study contributes by demonstrating how teachers perceive the pedagogical value of STEMPreneur for supporting computational thinking within Primary Science learning.

A possible explanation for these perceptions lies in the pedagogical characteristics of STEMPreneur itself. Entrepreneurial science projects require learners to identify authentic problems, generate ideas, evaluate alternative solutions, test their feasibility, and improve products through iterative refinement. Such learning activities correspond closely with constructivist perspectives, which emphasize that knowledge is actively constructed through engagement with authentic experiences and social interaction (Bransford et al., 2004; Piaget, 1970; Vygotsky, 1978). Within this context, entrepreneurship functions not merely as an additional curriculum component but as a meaningful pedagogical context that enriches scientific inquiry by encouraging innovation, evidence-based decision making, and reflective problem solving. Consequently, teachers perceived STEMPreneur as a pedagogical approach that naturally accommodates the cognitive processes commonly associated with computational thinking.

Nevertheless, these findings should be interpreted with appropriate caution. The present study explored teachers' perceptions rather than directly examining students' computational thinking development or evaluating the effectiveness of STEMPreneur through classroom intervention. Therefore, the findings should not be interpreted as evidence that STEMPreneur improves or causes improvements in computational thinking. Instead, they indicate that Indonesian primary school teachers perceive STEMPreneur as a promising pedagogical approach that has the potential to support computational thinking within authentic Primary Science learning. Future intervention studies are needed to examine whether these positive perceptions are reflected in measurable improvements in students' computational thinking performance.

3.2.2. Toward a Pedagogical Ecosystem for Implementing STEMPreneur in Primary Education

One of the most important findings of this study is that teachers perceived the successful implementation of STEMPreneur as depending on more than positive attitudes toward the approach itself. Both the quantitative and qualitative findings indicate that teachers viewed effective implementation as requiring the interaction of several complementary pedagogical components. Specifically, participants consistently highlighted the importance of teacher professional development, practical instructional resources, computational thinking assessment, and authentic project-based learning. Based on these findings, this study proposes a Pedagogical Ecosystem for STEMPreneur Implementation, which conceptualizes these four components as mutually reinforcing elements that support the integration of STEMPreneur into Primary Science learning.

These findings suggest that teachers do not perceive STEMPreneur simply as an instructional model that can be adopted independently. Instead, they view its implementation as requiring a supportive educational environment in which teachers possess adequate pedagogical competence, have access to appropriate instructional resources, apply assessment practices that capture students' thinking processes, and engage students in authentic community-based projects. From this perspective, the implementation of STEMPreneur is viewed as a systemic process rather than the application of a single teaching strategy. Such perceptions emphasize that sustainable curriculum innovation depends not only on instructional design but also on the availability of institutional and pedagogical support.

This interpretation is consistent with previous studies emphasizing that educational innovation is more sustainable when supported by interconnected pedagogical and organizational factors rather than isolated instructional interventions (Bronfenbrenner, 2009; Fullan et al., 2017). Similarly, the importance of continuous professional development identified by teachers aligns with research demonstrating that effective implementation of innovative pedagogies requires collaborative professional learning, mentoring, and opportunities for reflective practice (Cirkony et al., 2024; Darling-Hammond et al., 2017). Teachers' emphasis on practical instructional resources is also consistent with studies highlighting lesson plans, teaching modules, and instructional guides as important pedagogical scaffolds for implementing interdisciplinary learning (Li et al., 2022; Oved & Alt, 2025). Furthermore, participants' recommendations regarding process-oriented computational thinking assessment correspond with recent literature advocating assessment approaches that capture students' reasoning processes rather than focusing exclusively on learning products (Jeltova et al., 2007; Xu et al., 2023).

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The fourth component is authentic project-based learning, which functions as the context in which the previous three components converge. Teachers perceived authentic community-based projects as the most effective learning environment for integrating scientific inquiry, entrepreneurial thinking, and computational reasoning simultaneously. Through iterative cycles of problem identification, investigation, solution design, testing, reflection, and product refinement, students engage naturally in computational thinking while creating solutions that are relevant to their local communities. Authentic projects therefore serve as the operational core through which STEMPreneur is enacted in classroom practice (Almazroui, 2023; Cian & Brasili, 2025).

From a theoretical perspective, these findings extend current discussions of STEMPreneur by positioning it as a pedagogical ecosystem rather than merely an extension of STEM education. Teachers' perceptions indicate that effective implementation depends on the dynamic interaction among professional learning, instructional resources, assessment practices, and authentic project-based learning. These four components function as complementary elements that collectively create conditions supporting meaningful implementation. In this conceptualization, authentic projects provide the learning context, teacher professional development strengthens instructional capacity, instructional resources facilitate classroom practice, and assessment supports reflection on students' reasoning processes. Consequently, this ecosystem offers a conceptual framework for understanding the pedagogical conditions that teachers perceive as necessary for implementing STEMPreneur within Primary Science classrooms.

Nevertheless, this proposed Pedagogical Ecosystem should be interpreted as a conceptual framework derived from teachers' perceptions, rather than as a validated implementation model. Although participants consistently identified these four components as important for successful implementation, the present study did not examine how the ecosystem operates in actual classroom practice or evaluate its effectiveness in improving students' learning outcomes. Therefore, the proposed framework should be regarded as an evidence-informed conceptual model that requires further validation through classroom intervention studies, design-based research, and implementation studies conducted in diverse educational contexts.

3.3. Implications for Theory, Practice, and Future Research

The findings of this study provide several important implications for educational theory, practice, and future research. From a theoretical perspective, the findings suggest that teachers perceive entrepreneurship as more than an additional component of STEM education. Instead, they view entrepreneurial activities as meaningful pedagogical contexts that may support computational thinking through authentic scientific inquiry, innovation, and problem solving. These perceptions broaden current discussions of computational thinking by positioning it as a cognitive process that teachers believe can be integrated into interdisciplinary science learning rather than being confined to programming or computer science education.

This interpretation is consistent with recent perspectives that conceptualize computational thinking as a domain-general cognitive competence applicable across multiple disciplinary contexts rather than as an exclusively technological skill. Previous studies have primarily discussed computational thinking in relation to programming, robotics, engineering design, and digital technologies. In contrast, the present findings indicate that teachers also perceive entrepreneurial inquiry as providing meaningful opportunities for students to engage in decomposition, abstraction, algorithmic thinking, evaluation, and iterative decision making during authentic science learning. Accordingly, this study extends existing discussions by highlighting teachers' perceptions regarding the pedagogical relevance of STEMPreneur for supporting computational thinking within Primary Science education.

From a practical perspective, the proposed Pedagogical Ecosystem for STEMPreneur Implementation provides a conceptual reference for curriculum developers, teacher educators, school leaders, and policymakers seeking to integrate computational thinking into Primary Science learning. Teachers consistently emphasized that successful implementation requires continuous professional development, practical instructional resources, process-oriented computational thinking assessment, and authentic project-based learning. These findings suggest that educational initiatives designed to introduce STEMPreneur should consider these components collectively rather than treating them as separate interventions. Such an integrated approach may contribute to more coherent and sustainable implementation within school settings.

3.4. Limitations

Several limitations should be considered when interpreting these findings. First, this study involved a relatively small sample of 50 primary school teachers from two urban regions in Indonesia, namely Jakarta and Bekasi, which may limit the transferability of the findings to other educational contexts. Second, the study explored teachers' perceptions and implementation readiness rather than directly observing classroom practices or measuring students' computational thinking. Consequently, the findings should be interpreted as evidence of teachers' perspectives toward the potential of STEMPreneur rather than evidence of its instructional effectiveness. Third, although the sequential explanatory mixed-methods design enabled a more comprehensive

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understanding by integrating quantitative and qualitative findings, the qualitative phase involved only five interview participants.

These limitations also provide directions for future research. Further studies should validate the proposed Pedagogical Ecosystem for STEMPreneur Implementation through classroom intervention studies, longitudinal investigations, and design-based research involving larger and more diverse samples. Such studies are needed to examine how STEMPreneur is enacted in classroom practice and to investigate its relationship with students' computational thinking, scientific literacy, entrepreneurial competence, and other twenty-first-century learning outcomes.

4. Conclusion

This study investigated Indonesian primary school teachers' perceptions of STEMPreneur as an instructional approach for fostering computational thinking in Primary Science (IPAS) learning. The findings indicate that teachers perceive STEMPreneur as a relevant, feasible, and pedagogically valuable approach capable of promoting computational thinking through authentic entrepreneurial inquiry, despite challenges related to pedagogical knowledge, instructional resources, computational thinking assessment, and curriculum time. First, this study provides empirical evidence of Indonesian primary school teachers' perceptions and implementation readiness toward STEMPreneur, an area that has received limited attention in the existing literature. Second, the findings demonstrate how teachers conceptualize the relationship between STEMPreneur and computational thinking by recognizing entrepreneurial inquiry as an authentic context for developing decomposition, abstraction, pattern recognition, algorithmic thinking, and evaluation. Third, this study proposes a Pedagogical Ecosystem for STEMPreneur Implementation that integrates teacher professional development, instructional resources, computational thinking assessment, and authentic project-based learning to support sustainable implementation in Primary Science education. Future research should validate the proposed pedagogical ecosystem through classroom intervention studies involving more diverse educational contexts and larger samples. Longitudinal and design-based research is also recommended to examine its impact on students' computational thinking, scientific literacy, creativity, and entrepreneurial competencies. Overall, this study positions STEMPreneur as an emerging pedagogical approach that extends STEM education by embedding computational thinking within authentic, innovation-oriented Primary Science learning.

Author Contributions

All authors contributed equally to this paper. All authors have read and approved the final manuscript.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics and Consent Declarations

This study adhered to established ethical standards for educational research. Participants received detailed information regarding the objectives of the study, voluntary participation, confidentiality, and their right to withdraw at any stage without consequence. Written informed consent was obtained prior to data collection. Personal identities were anonymized through participant codes, and all research data were securely stored and used exclusively for academic purposes.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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