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Research article

STEM misconceptions among preschool children and teacher scaffolding in Vietnam: A classroom-based qualitative analysis

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Abstract: In this study, we examined STEM-related misconceptions among preschool children and how teachers scaffold these during classroom activities in Vietnamese early childhood settings. Forty-two narrative reports written by in-service teachers after STEM lessons with children aged 3–6 were analyzed using inductive thematic analysis. Line-by-line coding generated 132 misconception codes and 103 scaffolding codes, which were organized into nine themes. Our findings indicated four major clusters of misconceptions: rule-based perceptual reasoning, misunderstandings of invisible mechanisms, overgeneralization of everyday experience, and strong emotional reactions when outcomes contradict predictions. Teachers mainly responded through procedural guidance, with inquiry-oriented prompts used only sporadically and emotional reassurance prioritized when children showed frustration or fear, leading to frequent missed opportunities to address misconceptions explicitly. We identified key pedagogical challenges in the early implementation of STEM education in Vietnam, notably an emphasis on product completion and emotional comfort over conceptual understanding. This advocates for STEM-focused teacher education that enables practitioners to elicit children's ideas, balance emotional support with cognitive challenge, and design classroom tasks that prioritize inquiry and conceptual reasoning over the production of neat final products.

Keywords: STEM education, misconceptions, teacher scaffolding, early childhood education, qualitative thematic analysis, Vietnam

1. Introduction

Early STEM education has become a global priority as researchers increasingly recognize that young children are capable of sophisticated scientific and engineering thinking when provided with opportunities for hands-on inquiry and guided exploration. Studies show that preschoolers naturally engage in processes foundational to STEM—such as observation, prediction, comparison, and causal reasoning, long before formal instruction begins [1–3]. When supported through responsive teaching, these experiences contribute to long-term interest, persistence, and conceptual understanding in science-related domains [4]. Consequently, many early childhood systems worldwide have sought to strengthen inquiry-based STEM approaches in the preschool years.

Furthermore, a growing body of research highlights persistent difficulties in implementing high-quality STEM pedagogy in early childhood classrooms. Teachers frequently report limited confidence in facilitating science and engineering learning, insufficient pedagogical content knowledge, and uncertainty when supporting children's explanations or reasoning [2,3,5]. These challenges often result in a reliance on directive instruction, procedural assistance, or activity management rather than inquiry-oriented approaches that foreground children's thinking. Studies further indicate that teachers may notice children's ideas but struggle to interpret or scaffold them in ways that promote conceptual growth [1,6,7].

These challenges are evident in emerging STEM contexts such as Vietnam. Although national reforms have encouraged experiential and competency-based learning, the early implementation of STEM remains shaped by long-standing pedagogical norms that emphasize orderliness, correct products, and teacher authority. Analyses of STEM initiatives in Vietnam and the surrounding region have shown that classroom activities often prioritize aesthetics, compliance, or task completion over open-ended inquiry [8–11]. Teachers commonly work with large class sizes, limited materials, and uneven access to professional development; structural factors that constrain children's opportunities for experimentation, risk-taking, and hypothesis testing [12,13]. Cultural norms of deference and group harmony further influence interaction patterns, such that children may be reluctant to voice alternative ideas or challenge explanations [14,15].

Within this instructional ecology, little is known about how Vietnamese preschool children articulate their emergent STEM ideas during actual classroom activity, or how teachers respond to these ideas as they arise. Although misconceptions in primary and secondary science have been extensively documented internationally [16], research on the early manifestations of such misconceptions among preschoolers engaged in hands-on STEM activities remains scarce. Even less is understood about how teachers in Vietnam, working within culturally shaped norms of care, authority, and product-oriented practice, interpret or scaffold these misconceptions. Studies on early STEM education in Vietnam have largely concentrated on teacher readiness, systemic constraints, and broader implementation challenges [13,17,18]. They have given limited attention to the micro-level cognitive and pedagogical interactions through which misconceptions emerge and conceptual learning unfolds.

To address this gap, we analyze 42 narrative classroom reports produced by Vietnamese teachers following STEM lessons for children aged 3–6. These reports provide retrospective teacher-generated accounts of children's predictions, explanations, and emotional responses to STEM-related phenomena, together with teachers' descriptions of their instructional responses during inquiry activities. By examining children's misconceptions alongside teachers' scaffolding moves, we seek to illuminate the cognitive, pedagogical, and cultural dynamics that shape early STEM reasoning in Vietnamese preschool classrooms.

Two questions guide the research:

- (RQ1) What types of STEM-related misconceptions do preschool children display during hands-on STEM activities?
- (RQ2) How do teachers scaffold children's thinking in response to these misconceptions during classroom STEM instruction?

By exploring these questions, the study contributes to the global literature on early STEM learning, offering contextually grounded insights into the opportunities and constraints that shape conceptual engagement in Vietnam's early childhood education system.

2. Literature review

Research in early childhood STEM education has expanded rapidly over the past decade, driven by a global recognition that early experiences form the foundation for later scientific thinking, engineering literacy, and problem-solving competence. A substantial body of work demonstrates that preschool-aged children possess rich intuitive resources for engaging with scientific and engineering phenomena, even before formal schooling begins. Studies across contexts, including those in Europe, North America, Australia, and Asia, show that young children spontaneously generate predictions, compare outcomes, observe causal patterns, and engage in elementary engineering design when given opportunities for hands-on inquiry [3,4,19–21]. Large-scale empirical reviews similarly emphasize that early STEM engagement predicts positive dispositions toward science, creativity, and persistence in problem-solving [22,23]. However, young children's sense-making is often grounded in perceptual cues, everyday experiences, and affect-laden associations, resulting in intuitive explanations that may deviate systematically from canonical scientific accounts [24,25].

2.1. Early STEM reasoning and misconceptions in young children

Across domains, including mechanics, floating and sinking, shadows and light, plant growth, and chemical reactions, research has consistently documented relatively stable patterns of misconceptions among preschool and early primary learners. Children often rely on "intuitive rules" such as "heavier objects sink," "bigger objects move faster," "shadows come from the light being strong," or "a red volcano must be hot" [24,26,27]. These rules reflect structured, experience-based mental models that children construct from their prior interactions with the physical and natural world, rather than merely random answers.

Empirical evidence also points to domain-specific patterns of misconception. In physical science, children frequently predict force, motion, and buoyancy outcomes primarily on the basis of perceived heaviness, size, or shape [28,29]. In the natural sciences, many misconceptions involve invisible mechanisms, such as plant growth, evaporation, weather phenomena, and chemical reactions, that are difficult to observe directly [25]. In engineering contexts, young learners often carry everyday assumptions, such as "more glue makes a structure stronger", into design tasks while paying limited attention to principles of balance, stability, and load distribution [2,4]. Furthermore, some studies show that during early STEM learning, children may experience negative emotions such as anxiety, frustration, or low self-confidence; when such emotions persist in science activities, they can hinder the formation and revision of children's scientific understanding [30].

A set of studies shows that scientific misconceptions in early childhood are widespread and systematically patterned rather than random errors. In the domain of force and gravity, de Freitas and Palmer [31] found that instead of conceiving Newtonian force as an abstract law, children blend bodily sensations of falling, flying, and height with sounds and imaginative narratives; from a narrow right–wrong perspective, these rich embodied interpretations are easily labelled as "misunderstandings" of force. In floating and sinking, Kallery [29] documented persistent naïve rules such as "heavy things sink, light things float," "big things float, small things sink," or "objects with holes sink," and showed that only through carefully structured predict–observe–explain sequences with controlled variables do children gradually shift toward explanations based on material kind and the role of trapped air. Using causal reasoning tasks about the invisible property of weight, Wang, Williamson, and Meltzoff [32] reported that 2- to 3-year-olds often perform at chance level on more complex tasks and can use only weight reliably in very simple contexts, whereas 4- to 5-year-olds show a more stable use of weight as a causal variable across different tasks. For shadow formation, Herakleioti and Pantidos [33] found that children frequently misidentify the location and mechanism of shadows, fail to relate shadow size to distance from the light source, and sometimes provide verbally "correct" explanations while their gestures imply, for example, that light passes through the obstacle. Taken together, these studies suggest that young children's scientific misconceptions arise from embodied, perceptual experiences and specific activity settings, rather than being isolated, random mistakes. Despite the ubiquity of these misconceptions, relatively few studies examine how they arise within authentic classroom interactions or how teachers respond moment by moment as children express naive ideas.

2.2. Teacher scaffolding, pedagogical content knowledge, and responsiveness

In early childhood science education, children's misconceptions are increasingly viewed not merely as "wrong answers" but as starting points for pedagogical intervention. Drawing on a Vygotskian perspective, scaffolding is understood as calibrated support that enables children to move from their intuitive rules toward more scientifically grounded explanations [34]. In their study on floating and sinking, Hsin and Wu [34] demonstrated that preschoolers' reasoning is constrained by limited domain knowledge and emerging metacognitive abilities, leading them to rely heavily on everyday experiences. The authors propose using higher-order questioning, encouraging manipulation and shared discussion of materials, and systematically comparing predictions with experimental outcomes as ways to surface and gradually revise the naïve rules children are using.

The effectiveness of such scaffolding depends strongly on teachers' pedagogical content knowledge (PCK) and their teaching beliefs. Schmitt [22] reports that in everyday STEM activities, diagnostic and conceptually oriented scaffolding moves are relatively rare; teachers often prioritize organizing play environments over deliberately working with children's "incorrect ideas." Higher PCK is associated with a greater self-reported willingness to diagnose and scaffold, but co-constructivist beliefs must be translated into concrete strategies within classroom contexts before they can have a meaningful influence on practice [22]. In a study on scientific literacy, Roy et al. [35] characterized teachers as "play partners" who closely observe children and intervene at opportune moments—for example, helping children trace the shadow of a box outdoors by positioning it in sunlight and suggesting where and how to outline the shadow. Annisa [36] similarly emphasized that scaffolding should be distinguished from intrusive interference: Teachers provide just enough support to sustain interest, reduce negative experiences with science, and open opportunities for children to reconsider their initial conceptions. Taken together, these studies suggest that scaffolding, PCK, and responsiveness in everyday interactions are critical conditions that determine whether children's misconceptions are ignored, superficially corrected, or transformed into stepping stones toward deeper scientific understanding.

2.3. Cultural and contextual conditions for early childhood STEM education in Vietnam

Early childhood STEM education in Vietnam is developing within a context that combines cultural and institutional constraints with growing opportunities for innovation. Traditions that emphasize respect for teachers, hierarchy, and children being "good" and "correct" continue to shape classroom organization: Teachers tend to occupy a central role and often prioritize neat, aesthetically pleasing, and requirement-compliant products over debate, trial-and-error, or open questioning [11,12,15]. Nevertheless, studies indicate that teachers and school leaders increasingly view STEM as an important avenue for fostering children's thinking, creativity, and problem-solving skills, and that many are willing to experiment with more flexible forms of organization within their local constraints [11,37].

At the policy level, STEM has been highlighted in national education strategies and is increasingly appearing in project work, clubs, and special STEM days in kindergartens. Despite ongoing challenges, such as large class sizes, limited physical space, constrained materials, and uneven STEM competence among teachers, research suggests that educators hold STEM in high regard, actively make use of available materials, and deliberately "weave" scientific and technological elements into learning corners and everyday experiential activities [13,38,39]. Moreover, the broader Vietnamese educational context, which places strong value on visible achievement and "beautiful" end products, also influences early childhood practice by subtly encouraging a focus on outcomes rather than on exploratory processes. Recognizing these characteristics enables in-service and pre-service programs for early childhood teachers to design forms of support that are better aligned with teachers' everyday realities, thereby gradually building a more robust foundation for implementing STEM in Vietnamese preschools [37,38].

2.4. Gaps in the literature and the contribution of this study

Although international research has made significant progress in documenting early misconceptions and examining teacher scaffolding, critical gaps remain. Few researchers examine misconceptions within integrated STEM activities, where the blending of science, technology, engineering, and mathematics creates unique reasoning challenges, or within art-integrated STEM (STEAM) activities, where additional representational and aesthetic demands are introduced. Even fewer researchers analyze micro-level teacher–child interactions in naturalistic classroom settings, particularly in non-Western educational systems. In Vietnam, research primarily entails teacher beliefs, readiness for STEM, or systemic barriers to STEM adoption. To date, no researchers has systematically documented the actual misconceptions expressed by preschool children during STEM activities or the moment-to-moment scaffolding provided by teachers.

Given these gaps, there is a need for empirical work that captures how young children articulate emergent STEM ideas, how misconceptions surface in the flow of classroom activity, and how teachers' real-time pedagogical decisions mediate these moments. In this study, we address this need by analyzing 42 narrative reports written by Vietnamese teachers immediately following hands-on

STEM lessons. These reports provide rich, teacher-generated reflective-narrative data on children's predictions, explanations, affective responses, and spontaneous reasoning, as well as teachers' instructional moves in the context.

This literature review, therefore, sets the stage for the conceptual framework that follows, which integrates developmental, cognitive, and sociocultural theories to explain why misconceptions emerge, how they are structured, and how teacher scaffolding mediates conceptual change in early STEM learning.

3. Conceptual framework

The conceptual framework guiding this study integrates three complementary theoretical traditions that collectively explain why STEM misconceptions arise in early childhood, how they are cognitively structured, and how teachers can support their revision in classroom contexts. These traditions, constructivist developmental theory, conceptual change research, and sociocultural theory of scaffolding, are consistent with the international evidence synthesized in the literature review and reflect the specific pedagogical and cultural characteristics of Vietnamese early childhood education.

3.1. Constructivist developmental theory: Why preschoolers generate intuitive but inaccurate explanations

From a constructivist developmental perspective, young children are not passive recipients of scientific facts but active builders of their own explanatory schemes. In the Piagetian tradition, cognitive development is described as a sequence of qualitatively different structures, with preoperational thought strongly constrained by perceptual salience and centration. As summarized by Hsin and Wu [34], Piaget argued that children do not fully master the concept of floating and sinking until around nine years of age; at earlier ages, they rely mainly on direct manipulation of objects and simple perceptual cues rather than on abstract reasoning about density or compensating variables. This classic account helps explain why preschoolers often prioritize what appears heavier, bigger, or more active when attempting to explain physical phenomena.

Contemporary constructivist work refines this picture by making more explicit the limits of children's processing resources and the nature of the informal "theories" they construct. Arsalidou and Pascual-Leone [40] characterized constructivist developmental theory as charting growth in "effective complexity": With limited working memory and attentional control, young children default to simple, habitual schemas that cannot accommodate multiple interacting variables or non-obvious mechanisms, especially in misleading situations. Within a rational constructivist framework, Xu [41] proposed that children begin with proto-conceptual primitives and gradually construct domain-specific intuitive theories, such as intuitive physics, through language, Bayesian learning from evidence, and active hypothesis revision. Kelemen [42] showed that these intuitive frameworks integrate direct experience and testimony but often embody causal assumptions and category structures that are "profoundly at odds" with canonical science, thereby giving rise to robust, systematic misconceptions rather than random errors. In sum, constructivist developmental theory explains preschoolers' inaccurate explanations as developmentally rational constructions built from limited cognitive resources and everyday experience, which makes them coherent and persistent, but also misaligned with scientific models.

3.2. Conceptual change theory: How misconceptions are structured and how they shift

From a conceptual change perspective, learners' misconceptions are not isolated "errors" but parts of relatively coherent mental models. The framework theory approach proposes that children construct a commonsense or naive physics based on everyday observations and cultural experiences; this system constitutes a framework theory, an organized conceptual structure used to explain and predict phenomena [43]. Özdemir and Clark's [44] review distinguishes two major perspectives: A knowledge-as-theory view, which emphasizes the systematic, ontological–epistemological underpinnings of everyday conceptions, and a knowledge-as-elements view, which treats understanding as composed of many small units that are contextually activated. Both perspectives converge on the idea that misconceptions are robust because they are anchored in explanatory structures that function well in everyday life, rather than arising simply from a lack of "correct information" [44].

In terms of dynamics, classic models of conceptual change (e.g., Posner et al., as summarized by [44]) argue that conceptual restructuring occurs only when learners become dissatisfied with their current conception and perceive the new conception as intelligible, plausible, and more fruitful. In early childhood science education, sociocognitive studies demonstrate that effective conceptual change is typically supported through sequences of predict–observe–explain activities, utilizing deliberately designed situations to destabilize initial representations and help children construct precursor models that are more compatible with scientific ideas [45]. These precursor models do not require children to "leap" immediately to the full scientific model; instead, they function as intermediate steps that enable misconceptions to be gradually restructured. In their study of floating and sinking, Hsin and Wu [34] demonstrated that carefully sequenced hands-on tasks, combined with prompting questions and systematic comparison between predictions and outcomes, are crucial conditions for children to shift from intuitive rules (e.g., "heavy things sink") to more mechanistic explanations involving material type and the role of air.

3.3. Sociocultural theory: How teacher scaffolding mediates conceptual change

From a sociocultural perspective, conceptual change happens through guided participation in shared activity rather than through individual discovery alone. Drawing on Vygotskian ideas about the zone of proximal development, several studies describe scaffolding as contingent support that links children's everyday experiences with culturally valued scientific concepts [34,35]. In preschool STEM settings, this support includes asking children to predict and compare outcomes, structuring cycles of exploration–representation–discussion, and modeling or revoicing scientific language so that children can inspect and refine their own ideas [19,34]. Studies also show that such responsive scaffolding can sustain interest and deepen causal reasoning when it is attuned to children's prior conceptions and emotions [35,36].

Furthermore, the quality of scaffolding is closely tied to teachers' pedagogical content knowledge and confidence. Schmitt [22] found that early childhood teachers with stronger diagnostic knowledge were more likely to elicit and work with children's ideas, whereas others focused mainly on managing activities or offering generic encouragement, rarely addressing underlying conceptions. Similar patterns emerge in broader STEM and science-literacy work, where scaffolding ranges from rich, dialogic support to largely procedural guidance, depending on how secure teachers feel with the content [35,46].

In Vietnam, these issues are further shaped by institutional and cultural conditions. Research indicates that early childhood classrooms continue to be predominantly teacher-led and product-oriented, with limited opportunities for open-ended STEM inquiry, despite policies encouraging more child-centered approaches [11,13]. Teachers report low confidence and uneven preparation for STEM, and professional development has often been theoretical rather than practice-focused [11]. Within this context, scaffolding tends to emphasize organizing activities, ensuring safety, and maintaining harmony more than deliberately surfacing and working through children's misconceptions. A sociocultural view of scaffolding thus highlights its potential to mediate conceptual change and its vulnerability to wider pedagogical traditions and system-level constraints.

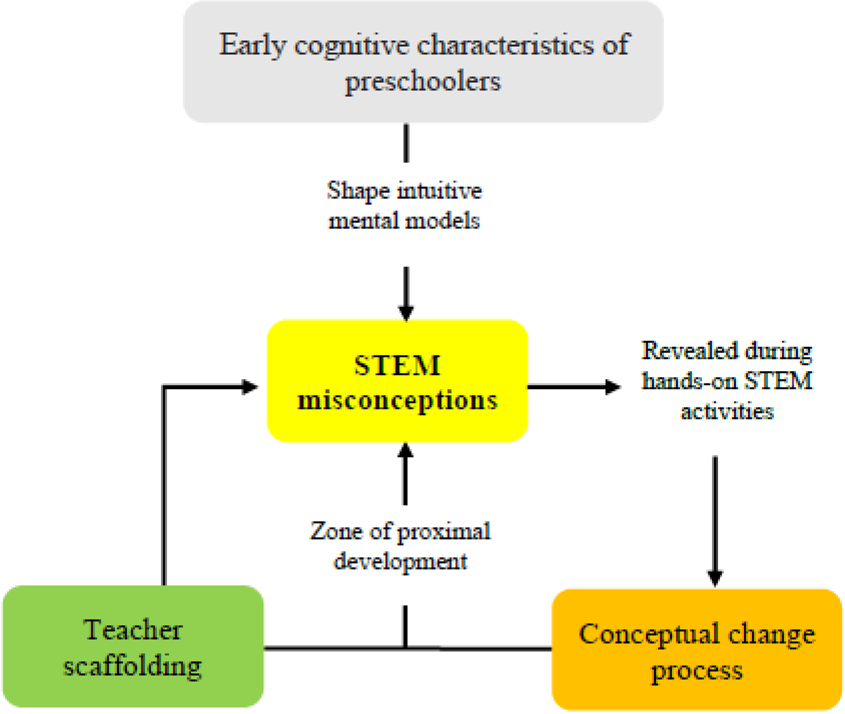

Figure 1. Conceptual framework of STEM misconceptions and teacher scaffolding in early childhood education.

3.4. Integrated framework for this study

By bringing together these three theoretical perspectives, the framework conceptualizes STEM misconceptions as developmentally grounded, cognitively structured, and socioculturally mediated. Developmentally, misconceptions arise from young children's intuitive, perception-based reasoning, which reflects the characteristic modes of thought in early childhood. Cognitively, these misconceptions are embedded within coherent mental models that organize children's expectations about how phenomena work and that often resist revision in the absence of targeted instructional support. Socioculturally, the expression and transformation of these ideas are shaped by teachers' scaffolding practices and by the local norms governing classroom interactions.

This integrated framework informs the analytic approach of this study. It anticipates that the misconceptions identified in the Vietnamese dataset will mirror children's intuitive explanatory frameworks, that conceptual change will require explicit and sustained scaffolding, and that teachers' responses will be influenced by their disciplinary knowledge and the cultural and institutional dynamics of Vietnamese early childhood education. As such, the framework provides a robust theoretical basis for examining the forms of STEM misconceptions expressed by young children and the scaffolding strategies, or missed opportunities, through which teachers respond to these misconceptions during hands-on STEM activities.

4. Methodology

4.1. Research design

We employed an exploratory qualitative design to investigate the forms of STEM-related misconceptions displayed by preschool children and how teachers responded to these conceptual difficulties during classroom activities. We relied on written narrative reports produced by preschool teachers and teachers immediately after conducting STEM lessons. These reports provided teachers' retrospective accounts of instances in which children expressed reasoning, misconceptions, or emotional reactions during STEM activities. Because our aim was to identify patterns that emerged from authentic classroom practice, we adopted an inductive, data-driven approach to thematic analysis.

4.2. Data collection

The narrative reports were generated by in-service preschool teachers enrolled in a professional development program on early childhood STEM education organized by a teacher education university in Vietnam. As part of the program, participating teachers were asked to design and implement a STEM activity in their own classrooms and to submit a written reflective report immediately afterward. Reports were expected to describe the activity context, children's responses, STEM-related misconceptions or incorrect explanations identified during the activity, the ways teachers responded to these moments, and their own pedagogical reflections. A total of 58 reports were submitted. Following an initial screening, 42 reports were retained for analysis. Reports were excluded when: (a) The activity was primarily craft-based or decorative with limited identifiable STEM inquiry content; (b) no child reasoning, predictions, or misconceptions were described; or (c) the report lacked sufficiently specific and detailed descriptions of children's statements, behaviors, or teacher responses to permit reliable coding. The final dataset, therefore, consisted of reports containing analyzable evidence of children's emerging STEM thinking and teacher responses.

Each narrative report typically included the lesson objective, the title of the STEM activity, the number and age of children participating, the materials and equipment used, and the sequence of procedures implemented during the session. Notably, the reports provided detailed descriptions of the moments when children expressed misconceptions, through predictions, explanations, comments, or observable behavior, and the corresponding teacher responses. Teachers were encouraged to include verbatim statements from children when possible, especially statements reflecting incorrect reasoning or emotional reactions to unexpected outcomes. Reports also documented the forms of scaffolding teachers employed, such as procedural guidance, prompting questions, or emotional reassurance. When available, teachers attached photographs to illustrate key moments in the activity, such as children's engagement with materials, experimental setups, or finished products. These visual materials were treated as contextual information that enriched the written descriptions.

Data were collected immediately after the lesson to ensure accuracy and minimize the potential for retrospective distortion. Teachers were instructed to focus on the specific episodes in which children displayed confusion, incorrect reasoning, or persistent intuitive beliefs, and to describe how they responded in the moment. This approach provided teachers' retrospective representations of how children's emerging STEM thinking and teachers' pedagogical responses unfolded during classroom activities. The analysis included 42 narrative reports written by preschool teachers. The demographic and professional characteristics of the participating teachers are summarized in Table 1. The reports were collected from public (n = 19, 45.2%) and private (n = 23, 54.8%) preschools in urban (n = 29, 69.0%) and rural (n = 13, 31.0%) settings. Teachers represented all three preschool age groups and had an average of 5.4 years of teaching experience (range = 2–12 years). The mean class size was 17.8 children (range = 10–32).

Table 1. Demographic and professional characteristics of the participating preschool teachers (N = 42).

Characteristic	Category	n (%) / Mean (Range)
School type	Public	19 (45.2)
	Private	23 (54.8)
Teaching area	Urban	29 (69.0)
	Rural	13 (31.0)
Children's age group	3–4 years	13 (31.0)
	4–5 years	14 (33.3)
	5–6 years	15 (35.7)
Teaching experience (years)	Mean (Range)	5.4 (2–12)
Class size (children)	Mean (Range)	17.8 (10–32)

4.3. Context of data collection

The STEM activities were conducted in typical early childhood classrooms in Vietnam, which generally enroll 25–30 children and operate within a structured daily routine. Activities took place in small groups or whole-class formats, depending on the topic and materials. Lessons were typically 25–35 minutes in duration and followed a standard sequence, which included an introduction, prediction, experimentation, observation, and a brief discussion. Materials ranged from simple household objects (e.g., fruits, water containers, and cardboard wheels) to basic science kits used for demonstrations and experiments. The reports covered a wide range of STEM topics, including floating and sinking, saltwater density, volcano reactions, shadow formation, capillary action in plants, and simple engineering design.

4.4. Ethical considerations

The data were obtained from teacher-generated narrative reports documenting routine classroom activities. No child was directly approached or interacted with for research purposes, and no additional procedures were introduced beyond everyday teaching practice. Teachers provided informed consent to share their written reports for research use. The study was approved by the Research Ethics Committee of Hanoi National University of Education (Approval No. 134/GCN-ĐHSPHN).

To ensure anonymity, all identifying information was removed, and any accompanying photographs were cropped or blurred so that no child could be recognized. Children's verbal expressions included in the dataset were anonymized and presented without names or identifiable details. In accordance with international ethical standards for research involving young children, parental consent was not required because no identifiable information about children was collected or disseminated.

5. Findings

5.1. Descriptive overview of the dataset

A total of 58 teacher-generated STEM narrative reports were collected, of which 42 were retained for analysis because they contained explicit descriptions of children's reasoning and teacher responses to difficulties. Across these 42 reports, coders identified 132 misconception events, with an average of just over three misconception events per report (range 1–6). Additionally, 103 scaffolding episodes were coded, corresponding to an average of approximately 2.45 episodes per report. Procedural forms of scaffolding, such as guiding children through the steps of an activity or adjusting materials to ensure a successful outcome, were more frequent than conceptually focused interventions.

Table 3 summarizes the distribution of misconception events across STEM domains. Misconceptions were most common in physical science activities (46.21% of all coded misconceptions), particularly in lessons involving floating and sinking, volcano experiments, motion, and color mixing. Natural science contexts, including plant growth, water phenomena, and capillary action, accounted for 28.79% of misconceptions, while basic engineering tasks such as bridge and tower construction and vehicle design accounted for 15.91%. A smaller proportion of misconceptions (9.09%) emerged in art-integrated STEM activities, and these were coded only when children's reasoning was explicitly expressed.

Table 2. Dataset overview and quantitative summary.

Variable	**Value**	**Notes**
Total reports collected	58	All teacher-generated STEM narratives
Reports included (with misconceptions)	42	72.41% of total dataset
Reports excluded	16	Art/craft only, no scientific reasoning
Total misconception events	132	Identified across 42 reports
Mean misconception events per report	3.14	Range: 1–6 events
Total scaffolding episodes	103	Teacher responses to difficulties
Mean scaffolding episodes per report	2.45	Procedural most frequent

Table 3. Distribution of misconceptions by STEM domain.

STEM Domain	Number of Reports	% of total misconceptions	Examples of Misconceptions
Physical Science Floating and sinking Shadows and light Volcano (acid–base reaction) Color mixing Moving objects/motion	61	46.21	*"Heavy objects always sink. "Big objects move faster."*
Natural Science Plant growth Water vapor and rain formation Color absorption/capillary action (cabbage experiment) Observation of changes over time	38	28.79	*"Water climbs up the cabbage.", "Volcano is hot because of its red color."*
Engineering Bridge building Tower construction Car-making/vehicle design Train model construction Structural stability	21	15.91	*"Tall structures are stronger. "Decorations make it stable."*
Art-integrated STEM Product decoration Exploration of musical instruments	12	9.09	*Only included when reasoning appeared*

5.2. Qualitative analysis of the narrative reports

The analysis followed an inductive, exploratory qualitative approach that aimed to identify recurring patterns in children's STEM thinking and in teachers' scaffolding practices. As noted above, 58 narrative reports were collected, and 42 reports that contained analyzable descriptions of children's predictions, verbal explanations, behavioral reactions, and teacher responses during STEM activities were retained. These 42 reports constituted the dataset for thematic analysis. The procedure adhered to Braun and Clarke's [47] reflexive thematic analysis, with an emphasis on data-driven coding, iterative refinement, and transparent documentation of analytic decisions. Although the analysis was primarily inductive and grounded in the narrative reports, the conceptual framework presented in Section 3 informed the researchers' attention to issues related to children's intuitive reasoning, conceptual change, and teacher scaffolding. The framework therefore served as a sensitizing device during the coding process rather than as a predetermined coding structure. Initial codes were generated directly from the data through repeated reading and line-by-line coding without imposing predefined categories. Themes were subsequently refined through constant comparison across reports and were then interpreted in relation to the developmental, conceptual change, and sociocultural perspectives outlined in the conceptual framework.

In the familiarization phase, all reports were read repeatedly to gain an initial understanding of the structure of the activities, the embedded reasoning episodes, and the scaffolding strategies reported by teachers. Analytical memos were written to capture early impressions of recurring misconceptions (for example, weight–sink rules, size–strength assumptions, and misunderstandings of invisible mechanisms) and teaching patterns (for example, procedural guidance, emotional reassurance, and inquiry prompts). These memos provided a first sketch of how children's intuitive STEM ideas and teachers' responses unfolded during classroom activities.

In the initial coding phase, a line-by-line coding process was applied across all 42 reports. Coding remained semantic, focusing on explicit statements and described behaviors, but was sensitive to patterns of meaning, such as frustration when predictions failed or withdrawal after being corrected. Two parallel streams of code were developed. One stream captured child reasoning, for example, "heavy things must sink," "tall structures are stronger," "add more powder to increase the explosion," and "the car is broken if it does not move." These were instances of withdrawal following an incorrect answer. The second stream captured teacher scaffolding, for example, step procedural guidance, prediction prompts, emotional reassurance, correction of children's products, and missed follow-up after a misconception was voiced. This process generated 132 misconception-related codes and 103 scaffolding-related codes, which formed the basis for subsequent analytic development.

During category development, initial codes with similar meanings were compared and collapsed into broader descriptive categories. For example, codes such as *"The heavy one has to sink," "big ones sink," and "big objects are stronger"* were grouped into a category representing rules like reasoning from salient features. Similarly, teacher actions such as correcting technique, giving step-by-step instructions, and adjusting materials for children were grouped under procedural scaffolding. This stage clarified conceptual distinctions between types of reasoning and scaffolding while preserving the diversity of expressions found in the raw data.

Based on these categories, themes were then constructed through iterative comparison within and across reports. Nine inductively derived themes were developed: four themes captured patterns in children's misconceptions, and five themes captured patterns in teacher scaffolding. Themes were refined to ensure internal coherence and clear distinction from one another. The analytic structure that links sample initial codes, intermediate descriptive categories, and the final emergent themes is summarized in Table 4, which functions as a coding matrix for the study.

To assess inter-coder reliability, two researchers independently coded 66 coding decisions derived from the dataset. Initial agreement was achieved for 53 of the 66 coding decisions (80.3%). To account for chance agreement, Cohen's kappa was calculated, yielding a value of $\kappa = 0.788$, indicating substantial agreement between coders. Discrepancies were subsequently discussed and resolved through consensus. An audit trail was maintained by retaining coding memos, code lists, and records of category and theme development. Thick description was supported by incorporating verbatim excerpts from teacher reports into the Results section to ground interpretations in the data. Negative case analysis was conducted by revisiting codes and themes when contradictory instances appeared. Together, these procedures enhanced the transparency of the analytic process and strengthened the credibility of the interpretations derived from the coding matrix presented in Table 4.

Table 4. Coding matrix linking initial codes, descriptive categories, and emergent themes.

Initial codes (from raw reports)	Descriptive categories	Emergent themes
“Whatever is heavy must sink” (roared, upset) *“Bigger things are stronger. “Taller means stronger.”*	Rule-like predictions based on salient features Size/height-based assumptions	Theme 1: Rule-based perceptual reasoning
“Not right, I am not playing anymore!”	Emotional reactions to incorrect predictions	Theme 4: Emotional responses to prediction failure
“Add more powder so the volcano gets stronger.” *“The shadow is big because my hand is big.”*	Misattributions derived from visible cues Surface-level explanations of light/shadow	Theme 2: Misinterpreting invisible mechanisms
“My car is not moving, it must be broken!” *Attaching wheels without understanding the axle function*	Everyday reasoning applied to engineering tasks Functional misconceptions	Theme 3: Everyday overgeneralization
Teacher: “Try each object one by one…” *The teacher adjusts materials or corrects the product.*	Stepwise procedural guidance Product-oriented correction	Theme 5: Procedural scaffolding
Teacher: “Let us compare the results with your predictions.” *Teacher asks, “What do you think?”*	Prediction–outcome comparison prompts Encouraging explanation	Theme 6: Inquiry-oriented scaffolding
The teacher sits at eye level to reassure the child *Teacher reassures fearful children during light/volcano activities*	Emotional reassurance and soothing Relationship-focused support	Theme 7: Emotional scaffolding
The teacher moves on without revisiting the misconception. *“No follow-up after incorrect reasoning (teacher does not ask ‘Why does the orange float?’).”*	Absence of reported conceptual elaboration Absence of reported conceptual elaboration	Theme 8: Limited conceptual follow-up in teachers’ accounts
Teacher: “I will help you finish this toy train, okay?” *“The teacher provided a sample car and instructed the children: ‘Let us make it like this model so that your car will look nice and correct.’”*	Teacher takeover of children’s products Product-oriented intervention	Theme 9: Product-oriented intervention and teacher control over children’s work

5.3. Children’s STEM misconceptions

Theme 1: Rule-based explanations grounded in perceptual features

A dominant misconception across reports was the reliance on simple, rule-like explanations, particularly around weight, size, and height, when predicting physical phenomena. Children frequently asserted that all heavy objects sink, all light objects float, and taller structures are inherently stronger.

In a floating–sinking activity, one child insisted: "*No, that is not right, anything heavy must sink!"* followed by the reaction: *"Not right, I am not playing anymore!"*

Similar reasoning appeared across engineering tasks, where construction was guided by assumptions such as *"the taller bridge will be stronger"* or *"more glue means better movement."* These accounts demonstrated that children often draw direct conclusions from salient physical attributes, regardless of the underlying mechanisms that govern these conclusions.

Theme 2: Misinterpretation of non-visible processes in scientific phenomena

When scientific outcomes involved invisible mechanisms, such as gas expansion, density differences, or light propagation, children often explained their observations using visually salient or familiar cues.

In several volcano demonstrations, children interpreted the reaction through real-world associations rather than understanding the underlying causal mechanisms. One child refused to come near the experiment, stating that it was *"hot and dangerous"*, even though the mixture was cold and safe, indicating that the child's explanation was derived from visual resemblance to real volcanic eruptions rather than from observable evidence.

This illustrates how children often relied on affective–perceptual cues (color, eruption shape, prior knowledge from media) rather than reasoning about the actual physical process (gas expansion from a chemical reaction). In shadow experiments, children reacted primarily to the appearance of size changes: *"Children shouted with excitement when the shadows became larger or smaller."* These examples suggested that interpretations were grounded in observable transformations, while the underlying processes remained unclear to the children.

Figure 2. Children's emotional responses during a volcano experiment: a) A preschool boy showing fear as peers trigger the eruption; b) a preschool girl showing fear as peers trigger the eruption.

Theme 3: Overgeneralization of everyday experiences in engineering tasks

Across reports, children transferred familiar everyday expectations directly into STEM contexts. For example, children assumed that vehicles "must" move once wheels were attached, regardless of axle alignment or friction.

One child expressed disappointment when the handmade vehicle did not move:

"My car is not moving; maybe it is broken!"

Overgeneralization also occurred for light experiments: Placing a hand closer to a flashlight was seen as a guaranteed way to *"make the shadow big"* without considering other factors such as distance from the projection surface.

Theme 4: Emotional reactions when predictions are disconfirmed

Several reports documented strong affective responses when children's predictions were incorrect. Emotional reactions included frustration, withdrawal, crying, and refusal to continue participating.

One report described:

"The child lowered their head, stayed silent, and did not want to answer further."

Another report documented a child becoming upset and refusing to join the activity after an unexpected floating outcome contradicted her prior assertion about heaviness. These records highlighted that misconceptions were not only cognitive errors but also moments that triggered notable emotional responses. Taken together, these four themes address RQ1 by showing that preschoolers' STEM misconceptions cluster around perceptual rules, invisible mechanisms, everyday overgeneralizations, and affect-laden responses.

5.4. Teacher Scaffolding in response to misconceptions

Theme 5: Predominance of procedural scaffolding

Procedural scaffolding, defined as teacher actions that guide how to perform a task, manipulate materials, or follow a sequence of steps without addressing the underlying scientific mechanisms, was the most prevalent form of support across the dataset. This form of scaffolding ensured that activities were executed smoothly and correctly from a technical standpoint, but did little to support conceptual reasoning. Teachers frequently centered their interventions on demonstrating or correcting specific manipulations, such as how to pour, mix, hold, attach, or arrange materials.

For example, in a volcano experiment, the teacher guided children through each procedural step:

"Pour the vinegar slowly… now add the color… now put in the baking soda",

which was often accompanied by hand-over-hand adjustments to guarantee a visually successful eruption. Similarly, during the floating–sinking task, teachers provided directives aimed at procedural clarity rather than conceptual engagement, such as:

"Let us test one object at a time so we can see clearly. If you drop everything together, we will not know which one floats and which one sinks."

Such procedural scaffolding supported task completion and maintained behavioral order, yet shifted the instructional focus toward executing the activity "correctly" rather than examining the scientific ideas underlying children's predictions and misconceptions. As a result, procedural guidance frequently replaced opportunities for deeper inquiry, limiting children's chances to confront contradictions between their expectations and observed outcomes.

Figure 3. Teacher procedural guidance during a volcano eruption experiment in response to children's misconceptions: a) The teacher instructs the child to pour the vinegar slowly; b) the teacher instructs the child to add the baking soda.

Theme 6: Occasional inquiry-oriented scaffolding

Alongside predominantly procedural and affective support, several reports included episodes in which teachers briefly adopted a more inquiry-oriented stance. In these moments, teachers used open-ended questions or prompts to elicit children's predictions, invite comparison, or encourage them to justify their ideas. For example, before placing objects in water, some teachers asked questions such as *"Do you think this ball will float or sink?"* or *"Which object do you think will sink first?",* thereby positioning children's initial ideas as something to be articulated and tested.

After the activity, a few reports described teachers asking children to revisit their earlier thinking, for instance, by saying, *"Try comparing the result with your initial prediction"* or *"Was your guess the same as what happened?"* In a smaller number of cases, teachers explicitly probed children's reasoning with follow-up questions such as *"Why do you think it floated?"* or *"What made you change your mind?"*

These inquiry-oriented moves created short-lived opportunities for deeper engagement with the phenomena, as children were invited not only to act but also to explain, compare outcomes with expectations, and reflect on their own thinking. However, such episodes appeared inconsistently across the dataset and were typically brief. They often occurred as isolated turns embedded within otherwise procedural guidance (for example, in the middle of giving step-by-step instructions). They were not always followed by further probing or collective discussion. As a result, while Theme 6 shows that teachers were capable of adopting inquiry-oriented scaffolding, this practice emerged only sporadically and did not constitute a dominant pattern of interaction in the observed STEM activities.

Theme 7: Strong emphasis on emotional scaffolding

Across the reports, teachers frequently responded to children's distress, hesitation, or uncertainty with forms of emotional support. When children appeared frightened by dramatic phenomena, embarrassed after an incorrect prediction, or reluctant to participate, teachers' first moves typically focused on restoring emotional comfort rather than probing the underlying ideas. In one report, for example, a child stepped back from the "volcano" experiment and refused to come closer. The teacher:

"Approached, sat at eye level to create a sense of safety, gently explained that the mixture was not hot, and comforted and acknowledged the child's feelings"

before inviting the child to watch from a distance. Similar patterns occurred in activities involving sinking objects or noisy reactions, where teachers reassured children that *"nothing will hurt you"* or *"this is just a game"* and allowed them to opt out if they still felt afraid.

Emotional scaffolding was also evident in more routine STEM-related tasks, such as plant-growing projects or simple engineering challenges. When children forgot steps or made mistakes, teachers often used soft, non-judgemental reminders:

"It is okay if you forgot this time… Would you like to water the plant now?"
or
"Never mind, we can try again together."

These responses validated children's feelings, protected their sense of competence, and helped them re-engage with the task without shame. In several reports, teachers explicitly praised effort and perseverance *("You tried very hard, that is great")* even when the product did not match the intended design, signaling that emotional well-being was a central priority.

Overall, emotional scaffolding represented a substantial proportion of teachers' responses when misconceptions triggered frustration, disappointment, or fear. Such support contributed to maintaining a caring classroom climate and sustaining children's willingness to participate. Furthermore, the predominance of affective over conceptual follow-up meant that once a child appeared calm, teachers often moved the activity forward without returning to the original misconception or inviting the child to reconsider their explanation.

Theme 8: Limited conceptual follow-up for teachers' accounts

Across several reports, teachers' narratives provided limited evidence of conceptual follow-up after children expressed misconceptions or incorrect predictions. In several accounts, activities appeared to proceed to completion once an immediate practical issue had been resolved, with little further description of questioning, comparison, prediction testing, or revisiting of children's initial explanations. In other cases, teacher responses focused primarily on behavioral guidance, reassurance, or task completion rather than conceptual elaboration. Because the dataset consisted of retrospective teacher narratives, this theme should be interpreted as limited documentation of conceptual follow-up in teachers' accounts, rather than definitive evidence that such follow-up did not occur during classroom practice.

Theme 9: Product-oriented intervention and teacher control over children's work

A recurring pattern across the 42 analyzed reports was teachers' direct intervention in children's constructions to ensure that the final product appeared *"correct," "beautiful,"* or closely matched an intended model. These product-oriented practices frequently shifted activities from open-ended engineering exploration toward replicating a predetermined design, thereby limiting opportunities for children to experiment, make mistakes, or reveal emerging misconceptions.

In one train-building activity, the teacher reorganized the structural elements, attached the wheels, and adjusted the decorative components so that the model would appear *"more complete."* The accompanying photograph in the report shows a highly polished train with balanced compartments and neatly aligned wheels, features that reflected the teacher's corrections rather than the child's independent problem-solving. The narrative contained little evidence of the child's design attempts or reasoning processes, focusing instead on the teacher's efforts to refine the final product.

A similar pattern appeared in a car-making task. Instead of encouraging children to explore axle alignment, friction, or alternative wheel placements, the teacher instructed them to *"make it like the sample."* As a result, children focused on copying the ready-made template rather than generating or testing their own designs. The completed cars closely resembled the teacher's model, with minimal variation across children's products, indicating reduced opportunities for authentic engineering thinking.

Overall, these reports suggested that product-oriented intervention was not incidental but a consistent instructional pattern. By prioritizing neatness and accuracy, teachers unintentionally constrained children's agency, limited the emergence of productive errors, and reduced opportunities to surface or address engineering-related misconceptions. This theme highlighted how product-focused expectations can shift STEM activities toward craft-making rather than inquiry-based design. These patterns respond to RQ2 by demonstrating that scaffolding is dominated by procedural and emotional forms, with inquiry-oriented support and conceptual engagement appearing more sporadically.

Figure 4. Product-oriented intervention during engineering activities: a) A train model completed and refined by the teacher to appear more "finished"; b) children's cars closely copied from the teacher's sample template, with minimal variation across products.

6. Discussion

Our findings of this study revealed several important patterns in how STEM misconceptions emerge and how teachers respond to them in Vietnamese early childhood classrooms. Consistent with the constructivist developmental perspective, children's ideas were typically rooted in intuitive, perception-based reasoning. For example, they tended to explain buoyancy purely in terms of weight or to interpret mechanical failure as simple "breakdown", rather than invoking non-obvious mechanisms such as density, force, or stability. This finding aligns with prior work, which demonstrates that young children tend to prioritize salient surface features over underlying structures and construct intuitive yet systematically inaccurate explanatory frameworks [29,31–33]. We extend this literature by documenting a repertoire of such intuitive rules within authentic Vietnamese STEM lessons and by showing how they arise in the continuous flow of classroom activity, rather than in isolated, researcher-designed tasks.

From a conceptual change standpoint, a striking pattern was that many of the misconceptions recorded in the narrative reports did not become focal points for targeted conceptual work. Misconceptions were often acknowledged or noted but not revisited, probed, or used as anchors for comparing evidence and making predictions. Instead, teachers tended to move the activity forward once behavioral order or emotional comfort had been restored. This pattern is consistent with models of conceptual change which argue that, in the absence of cognitive conflict and explicit support for restructuring, learners' framework theories and intuitive models remain largely intact [43–45]. This study contributes a more fine-grained picture of how opportunities for conceptual follow-up were represented in teachers' reflective accounts. Across many reports, teachers described responding to misconceptions through brief corrections or acknowledgements while providing limited documentation of subsequent predict–observe–explain sequences, counterexample construction, or other forms of conceptual elaboration.

The data also corroborate and deepen sociocultural accounts of scaffolding. In line with Hsin and Wu's [34] and Schmitt's [22] findings, conceptually rich scaffolding, such as questioning that elicits children's reasoning, connecting ideas across tasks, or modeling mechanistic explanations, was relatively rare, whereas procedural and organizational support was common. Teachers often corrected products, demonstrated the "right way," or adjusted materials so that the outcome appeared successful, rather than working with children's faulty explanations through talk, comparison, and re-representation. This confirms earlier concerns that when pedagogical content knowledge is limited, early childhood teachers tend to default to activity management and affective support instead of conceptual probing [19,22]. This study adds micro-level evidence that, under these conditions, hands-on STEM activities risk becoming procedural rather than conceptual, with little direct impact on children's underlying mental models.

A recurring theme throughout the reports was the prevalence of teacher-directed interaction patterns and product-oriented enactments of STEM. Many teachers described prioritizing neatness, visual appeal, and completing predetermined products. When instruction shifted in this direction, explorations of causal mechanisms were truncated, and unexpected results were treated as errors to be corrected rather than as resources for inquiry. These findings align with Vietnamese and regional studies that document strong traditions of teacher authority and product-oriented practices in early childhood education [11,15]. They also give empirical specificity to critiques in the STEM literature that warn against craft-based or decorative implementations that marginalize scientific reasoning [13,23]. More importantly, these three theoretical perspectives appear to operate not separately, but interact with one another. Children engaged in activities with developmentally typical, intuitive explanations based on salient perceptual features (e.g., weight, size, or visible effects). However, within product-oriented classroom routines, teachers often prioritized completing neat and successful products, reducing failure, and quickly restoring emotional comfort when children became frustrated. As a result, outcomes that contradicted children's predictions and could have created productive cognitive conflict were often softened, overlooked, or corrected immediately. This reduced the disequilibrium needed for children to reconsider their initial explanations and develop more adequate conceptual understandings. In this sense, sociocultural norms related to product completion and emotional harmony did not simply coexist with children's misconceptions; they also shaped the conditions under which conceptual change was more or less likely to occur.

The findings also underscore the central role of teacher knowledge and confidence, as anticipated by the integrated framework. Across the reports, teachers often appeared unsure about the mechanisms underlying buoyancy, capillary action, chemical change, or structural stability, and at times offered scientifically inaccurate explanations or avoided the conceptual dimension entirely. This aligns with earlier work documenting limited science preparation and uneven STEM-related PCK in early childhood teacher education, in Vietnam and internationally [3,5,19]. We extend this evidence by showing how content-knowledge gaps shape moment-to-moment pedagogical decisions: They influence which misconceptions are recognized as significant, which are overlooked, and which are inadvertently reinforced through oversimplified explanations or premature demonstrations.

Another important contribution concerns the interplay between emotional and cognitive scaffolding. The reports revealed that teachers frequently provided strong emotional support, comforting children who were nervous or startled by dramatic phenomena such as "volcanoes" or sinking objects, and often moved on once the child appeared calm. While this nurturing orientation is consistent with Vietnamese early childhood philosophy and with findings that interest and positive affect are crucial for sustained engagement [35,36], the data suggest that emotional harmony sometimes takes precedence over cognitive struggle. From a conceptual change perspective, this is consequential: If confusion, surprise, and mild dissatisfaction are quickly smoothed over, opportunities for productive cognitive conflict, the mechanism that drives conceptual restructuring, may be curtailed [42,45]. A similar tension between emotional support and task-focused engagement has been reported in Vietnamese kindergarten classrooms [12]. The study, therefore, refines sociocultural accounts of scaffolding by illustrating how emotional labor, in this context, can inadvertently dampen the very processes that developmental and conceptual change theories identify as necessary for revising intuitive frameworks.

Within this integrative perspective, children's fear of "dangerous" volcano experiments, their discomfort when predictions fail, and their pride in producing neat, correct products can be understood not as separate from cognition but as affective dimensions of their evolving intuitive models and of the conceptual change process [42,43,45]. Likewise, the product-oriented enactments and interactional norms documented in the reports, emphasis on neat, visually appealing products, deference to teacher authority, and tight time constraints [11,15,38], —can be read as sociocultural conditions that shape teachers' scaffolding moves [19,22,34]. These conditions appear to channel teachers toward procedural guidance, emotional reassurance, and partial or complete takeover of children's work, while limiting opportunities for learners to articulate their own explanations, experience manageable cognitive conflict, and revise their STEM conceptions [43,45].

Finally, the study highlights how structural and material conditions in Vietnamese preschools become cognitive conditions for STEM learning. Large class sizes, constrained physical spaces, and reliance on low-cost or recycled materials have been noted in prior Vietnamese research [11,39]; however, their implications for conceptual interaction have rarely been explored in detail. The narrative reports show how these constraints channel activity toward tightly managed whole-group routines, limit the range of possible designs and trials, and encourage convergence on a single "correct" product. These contextual factors interact with developmental tendencies and teachers' PCK to shape the forms of misconceptions that arise and the kinds of scaffolding that are feasible in practice.

Taken together, these findings confirm and extend the integrated framework proposed in this study. Developmentally, they reaffirm that Vietnamese preschoolers' misconceptions are grounded in intuitive, perception-based reasoning, in which salient features such as weight, size, or visible effects are often treated as sufficient explanations. Cognitively, they show that these misconceptions are organized and resilient in precisely the ways conceptual change theories predict, especially when not confronted through carefully designed opportunities for prediction, comparison, and productive cognitive conflict. Socioculturally, they demonstrate how teachers' scaffolding practices. shaped by cultural norms of authority, care, classroom order, and product orientation, as well as by content knowledge and institutional constraints, mediate whether misconceptions are ignored, superficially corrected, or used as stepping stones toward more profound understanding. In the Vietnamese early childhood context, where teachers are often expected to maintain harmony and guide children toward correct and orderly outcomes, contradictory results may be resolved quickly rather than explored dialogically. As a result, the very moments most likely to stimulate conceptual change may be reduced or bypassed.

At a theoretical level, the study offers a context-sensitive elaboration of how constructivist developmental, conceptual change, and sociocultural mechanisms intertwine in early STEM learning in Vietnam. Empirically, it provides:

- A grounded classification of recurring STEM-related misconceptions expressed by young children in hands-on activities and
- Detailed insights into specific scaffolding limitations and patterns of limited conceptual follow-up documented in Vietnamese preschool teachers' reflective accounts.

Together, these contributions inform the refinement of conceptual frameworks for early STEM learning and point to concrete directions for strengthening STEM-focused teacher education and classroom practice in similar cultural and institutional contexts.

7. Conclusions

This study presents one of the first classroom-based qualitative analyses of STEM misconceptions among preschool children in Vietnam, examining how teachers respond to these emerging ideas during hands-on activities. Drawing on 42 narrative reports written immediately after STEM lessons, it documents the naturalistic ways in which young children generate intuitive but scientifically inaccurate explanations, often grounded in perceptual cues, everyday experiences, or affective associations. These findings reaffirm developmental accounts of early scientific reasoning while highlighting culturally shaped patterns of participation that influence how misconceptions are expressed and interpreted in Vietnamese early childhood settings.

A central contribution of this study is the identification of a persistent misalignment between children's intuitive reasoning and the types of scaffolding teachers provide. Moreover, while teachers frequently offered procedural and emotional assistance, conceptual scaffolding, such as prompting comparison, revisiting explanations, or designing cognitive conflict, occurred far less consistently. As a result, many misconceptions remained unexamined and unaddressed, even when activities provided clear opportunities for conceptual growth. The analysis further reveals that multiple contextual factors, including teacher-directed pedagogical norms, limited scientific content knowledge, craft-oriented enactments of STEM, and cultural expectations of compliance, harmony, and emotional safety, contribute to this pattern.

These findings deepen international research by illustrating how local cultural, institutional, and material conditions shape the mechanisms through which misconceptions persist or change in early STEM learning. They underscore the need to strengthen teachers' disciplinary understanding, inquiry-based pedagogical content knowledge, and strategies for balancing emotional support with cognitive challenge. Designing professional development that helps teachers recognize, elicit, and productively engage with children’s intuitive ideas is essential for fostering early scientific reasoning.

Several methodological limitations should be noted. We relied exclusively on retrospective narrative reports written by teachers after STEM lessons rather than on direct classroom observations or video-recorded interactions. Although reports were completed immediately after the activities, they may reflect selective recall, reconstruction of events, or the tendency to emphasize successful practices. In addition, the dataset captured teachers’ interpretations of children’s thinking rather than children’s perspectives directly. These limitations should be considered when interpreting the findings. Researchers should extend this work through direct classroom observations, longitudinal tracking of conceptual change, and intervention studies that examine how specific scaffolding strategies influence children’s emerging understanding of STEM. Additional studies across Vietnamese regions and school types would also help clarify how cultural and institutional variations shape early STEM learning. By illuminating how young children think and how teachers respond to their ideas, this study contributes to the foundational knowledge needed to advance culturally responsive, conceptually rich STEM education in Vietnamese early childhood classrooms.

Author contributions

Manh-Tuan Nguyen: Conceptualization, Methodology, Formal analysis, Investigation, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; Huyen-Anh Mai: Methodology, Formal analysis, Validation, Writing – review & editing; Doan Phuong Lam Khuat: Investigation, Data curation, Validation, Writing – review & editing; Lien Kim Thi Tran: Resources, Validation, Writing – review & editing; Thi-Huyen Nong: Investigation, Data curation, Validation, Writing – review & editing.

Use of Generative-AI tools declaration

The authors declare that generative AI tools (including ChatGPT by OpenAI) were used during the preparation of this manuscript to improve the readability and language of selected passages, assist in restructuring draft sections, and support language editing. All AI-assisted content was critically reviewed, verified, and substantially revised by the authors where necessary. The authors retain full responsibility for the accuracy, integrity, originality, and interpretation of the work. No AI tool was used in data collection, coding, data analysis, interpretation of findings, or formulation of the study's conclusions.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

Ethics declaration

The authors ensure that this research paper was done in compliance with Ethical Standards.

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Appendix

Teacher reflection report template

Teacher background information

Teaching experience: ______ years
Age group/class: ______
Number of children in the class: ______
Type of preschool: Public / Private
Location: Urban / Rural

Instructions

Teachers were invited to complete the following written reflection after implementing a STEM activity in their classroom. The template was designed to elicit information regarding the activity context, children's responses, STEM-related misconceptions, teachers' instructional responses, and pedagogical reflections.

Reflection report

1. Please briefly describe a STEM activity that you implemented with preschool children during the past week. Include the activity title, learning objectives, materials and resources used, and the main implementation procedures.
2. During the activity, did you observe any STEM-related misconceptions? Please describe any notable statements, explanations, predictions, ideas, or behaviors demonstrated by the children that reflected misconceptions.
3. How did you respond to these misconceptions, and what did you learn from the experience? Please describe the instructional strategies or scaffolding approaches you used and any pedagogical insights you gained.
4. If available, please provide photographs or other illustrative evidence related to the STEM activity.