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STEAM Education in Early Childhood Education: Research Trends, Approaches, and Research Gaps

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ABSTRACT

This review synthesizes research trends, pedagogical approaches, and research gaps in STEAM education in early childhood settings. Nineteen eligible Scopus-indexed studies published between 2020 and 2026 were examined through a descriptive review and thematic analysis. Data were extracted on publication characteristics, contexts, participants, objectives, methods, forms of STEAM implementation, and major findings; recurring patterns were then coded and compared across studies. The results show that early childhood STEAM is implemented through diverse, developmentally situated approaches, including project-based and hands-on activities, science-arts integration, storytelling and coding, digital tools, outdoor education for sustainability, and food-based learning. These approaches offer different pedagogical strengths, but the evidence is too heterogeneous to rank their effectiveness across contexts. Teacher-related research constitutes a major strand, addressing readiness, beliefs, competence, professional development, implementation conditions, and intentions to sustain practice. However, these variables are usually investigated separately rather than as a connected pathway from preparation to high-quality and sustained implementation. Important gaps concern the degree of integration among STEAM domains, longitudinal evidence on the sustainability of professional development, comparable measures of child outcomes, cross-context influences, and the participation of families and other stakeholders. The review contributes an integrative account linking teacher preparation, implementation quality, sustainability, and child outcomes. It highlights the need for practice-based teacher education, continuing institutional support, context-sensitive implementation, and longitudinal, multi-level research.

1. Introduction

STEAM education, integrating Science, Technology, Engineering, Arts, and Mathematics, has been investigated in early childhood education as an interdisciplinary approach in which children participate in exploration, problem solving, creativity, and product creation. Recent studies show that STEAM at this educational level has been implemented in various forms, including project-based activities (Başaran & Bay, 2023), outdoor education linked to sustainable development (Zdybel et al., 2024), food-based learning integrating science, language, and nutrition (Stage et al., 2025), storytelling to introduce initial concepts of coding (Çabuk et al., 2022), and the integration of science and arts in early childhood educational practice (Areljung, 2020). This diversity indicates that STEAM in early childhood education is not implemented according to a single model but is applied through multiple pedagogical approaches and forms of learning content.

One notable research direction focuses on designing and organizing STEAM activities to create integrated learning experiences for children. Başaran and Bay (2023) investigated project-based STEAM activities and examined children's development in product creation, teamwork, presentation, and technical skills. In another approach, Zdybel et al. (2024) developed the “STEAM Outdoor Education for Sustainability” curriculum, connecting STEAM as a teaching method with education for sustainable development in outdoor environments. Stage et al. (2025) integrated food-based learning with science to simultaneously support science learning, language development, and children's dietary quality. Areljung (2020), in contrast, approached STEAM through the integration of science and arts in early childhood practice, while Çabuk et al. (2022) showed that storytelling and unplugged coding activities can be used to introduce concepts related to coding and computational thinking to young children. These studies reflect the potential of STEAM to connect multiple learning domains with concrete experiences appropriate to early childhood education contexts.

Alongside studies focusing on children, another prominent line of research considers preschool teachers to be important actors in STEAM implementation. Bui et al. (2023), through a survey dataset of 754 preschool teachers in Vietnam, emphasized issues related to teachers' understanding, competence, and readiness to organize STEAM activities and projects. Nguyen et al. (2025a) further examined factors affecting the STEAM practices of Vietnamese preschool teachers, while Pransiska et al. (2025) investigated teachers' readiness and acceptance of STEAM-oriented interactive e-books for English vocabulary instruction. In Hanoi, Vu (2023) focused on teachers' beliefs about the STEAM learning environment and challenges encountered in teaching. In Estonia, Haugas et al. (2023) also indicated that teachers recognized the significance of incorporating technology, creativity, and environmental issues into early childhood education but experienced difficulties integrating engineering and technology. These findings suggest that STEAM implementation in practice is closely associated with teachers' perceptions, preparation, competencies, and working conditions.

Training and professional development have therefore become an important research direction. Chang (2023) investigated the impact of a STEAM training program on the professional preparedness and confidence of preschool teachers in Taiwan. Before the training, teachers recognized the importance and expected outcomes of STEAM but had limited teaching experience and self-efficacy; accordingly, the training program included general STEAM knowledge, STEAM learning in early childhood, teaching methods, and curriculum design. In the study by Başaran and Bay (2023), teachers also received practical training before implementing a series of project-based STEAM activities with children. Similarly, the More PEAS Please! program developed by Stage et al. (2025) combined STEAM curriculum development with teacher professional development to support the integration of food-based learning and science. These findings suggest that professional development can help teachers translate STEAM knowledge into concrete educational practice.

However, receiving training or holding positive perceptions of STEAM does not necessarily mean that teachers will sustain its implementation over time. Nguyen et al. (2025b) directly addressed factors affecting Vietnamese preschool teachers' intention to continue implementing STEM/STEAMactivities and noted that some teachers, despite participating in training and support programs to develop STEM/STEAM knowledge, still did not intend to sustain these practices. In addition, Dinh (2021) identified difficulties in implementing STEAM in preschools in the northern mountainous region of Vietnam, where implementation of the model needs to be considered in relation to teachers' qualifications and material conditions. Haugas et al. (2023) likewise reported difficulties among Estonian teachers in integrating engineering and technology into educational activities. More recently, Kandır and Çağlak (2026) approached the issue through an analysis of teachers' needs regarding the applicability of STEAM+X in early childhood education, whereas Köchig et al. (2026) analyzed teachers' experiences of integrating STEAM and digital technology into classrooms in Spain and Germany. Thus, STEAM research is expanding from issues of teacher awareness and training toward the conditions affecting practice and the sustainability of STEAM implementation.

The scope of STEAM content in early childhood education is also becoming increasingly diverse across the studies reviewed. Magnusson and Bäckman (2023) questioned the role and capacity of the Arts component in the relationship between STEM and STEAM, while examining teachers' understandings of STEM together with children's art activities involving digital technology. Areljung (2020) explored the relationship between science and arts through "Science-Arts" activities, whereas Huang et al. (2023) used KAPLA construction activities to develop computational thinking among preservice early childhood educators in a STEAM learning context. Studies on coding (Çabuk et al., 2022), digital technology (Köchig et al., 2026), and outdoor education and sustainable development (Zdybel et al., 2024; Haugas et al., 2023) further extend the scope of STEAM applications. This indicates that STEAM in early childhood education is being approached as a space for integrating multiple types of content and modes of learning, although the presence and connections among STEAM components vary across studies.

Beyond children and teachers, some studies have begun to extend attention to other actors and conditions within the educational ecosystem. López and Cabello (2022), in their review of parental involvement in early childhood STEM education, observed that family involvement has not received commensurate attention in STEM/STEAM programs for young children. Awang et al. (2020) approached STEAM implementation through the need to develop clear teaching strategies for preschool teachers, while Kandır and Çağlak (2026) focused on teachers' needs in applying STEAM+X. These research directions indicate that STEAM implementation concerns not only children's activities or individual teacher competence but also professional support, pedagogical strategies, and the participation of other educational stakeholders.

Existing review work represented in the selected corpus has tended to address specific dimensions, such as parental involvement in early childhood STEM, whereas primary studies typically examine individual instructional approaches or separate teacher-related variables. What remains missing is a structured synthesis that maps the range of early childhood STEAM approaches while connecting evidence on teachers' readiness, professional development, implementation, and sustained practice. This review addresses that gap by synthesizing 19 studies to identify research trends, compare major approaches, integrate the teacher-focused evidence, and prioritize unresolved questions for research and practice.

2. Methodology

2.1. Search Strategy and Eligibility Criteria

The search strategy was designed to identify publications addressing both STEAM education and early childhood education. Synonymous and related terms within each conceptual group were combined using the Boolean operator "OR," while the two conceptual groups were connected using "AND." The following search string was applied to the titles, abstracts, and keywords of publications indexed in the Scopus database:

TITLE-ABS-KEY(("STEAM education" OR "STEAM learning" OR "STEAM teaching" OR "STEAM approach*" OR "integrated STEAM") AND ("early childhood education" OR preschool* OR kindergarten* OR "early years education" OR "pre-primary education"))

The search, conducted on 01.08.2026, initially retrieved 157 records. After one duplicate record was removed, 156 records underwent title-and-abstract screening. Of these, 137 were excluded for not meeting the eligibility criteria. The full texts of the remaining 19 publications were assessed, and all 19 were included in the final synthesis. Studies were eligible when they: (1) were indexed in Scopus and published within the stated period; (2) addressed STEAM education in early childhood, preschool, kindergarten, preschool teacher, or preservice early childhood educator contexts, or examined an issue directly relevant to implementation in those contexts; and (3) provided sufficient information on the aims, participants or context, methods, approach, or findings for analysis. Duplicate records and studies not directly relevant to the review focus were excluded. Figure 1 summarizes the selection process.

2.2. Data Extraction

A structured extraction matrix was used to record publication year, country or research context, participants, objectives, research methods, STEAM approach, teacher-related variables, child outcomes, and major findings. These fields supported both the descriptive mapping of the corpus and comparisons within and across thematic groups.

2.3. Descriptive and Thematic Analysis

The analysis proceeded in three stages. First, descriptive review was used to summarize publication years, contexts, participants, and prominent research directions. Second, a primarily inductive thematic analysis was conducted in accordance with the objectives of the review. Study-level findings were coded, recurrent codes were compared, and related codes were grouped into themes concerning STEAM activity design, the role and preparedness of teachers, training and professional development, implementation conditions and challenges, sustainability, and the integration of STEAM components and related content. Third, studies within each theme were compared by objectives, participants, contexts, methods, and findings to identify convergences, differences, and underexamined relationships. Because this was a single-author review, no independent second coder was used; coding decisions and theme boundaries were revisited iteratively against the extraction matrix to improve internal consistency. The conclusions are therefore limited to the 19-study corpus and should not be generalized to the entire international literature.

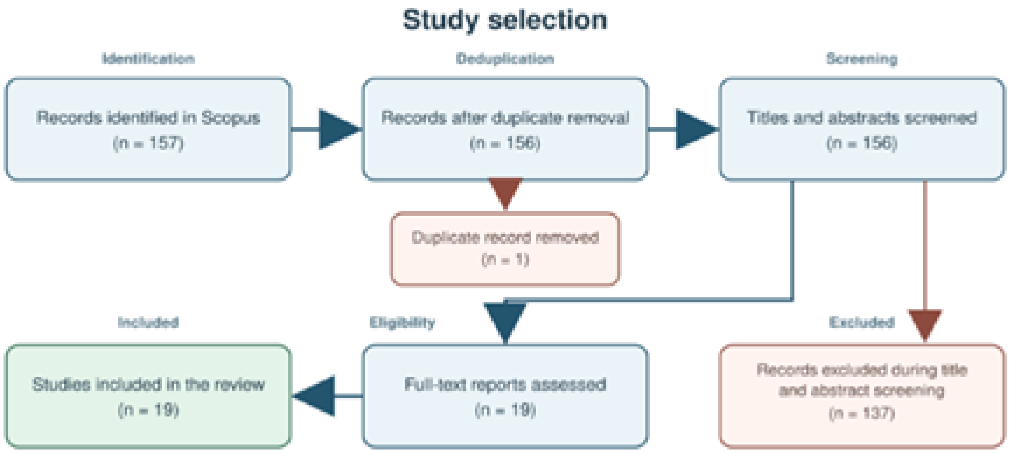

Figure 1. PRISMA-style flow diagram of the study-selection process.

3. Results

3.1. Research Trends in STEAM Education in Early Childhood Education

The 19 included studies were published between 2020 and 2026: 2 studies in 2020, 1 in 2021, 2 in 2022, 7 in 2023, 1 in 2024, 4 in 2025, and 2 in 2026. Publications were more concentrated from 2023 onward, indicating that interest in early childhood STEAM became more visible within the analyzed literature in recent years. Because the dataset was restricted to the selected corpus, however, this distribution should not be interpreted as the growth rate of the entire global field.

Viewed chronologically, earlier studies mainly sought to clarify how STEAM could be interpreted and incorporated into early childhood educational practice. Areljung (2020) investigated the integration of science and arts through "Science-Arts" activities, thereby raising the issue of how fields often considered separately can intersect in children's activities. Also in 2020, Awang et al. (2020) examined the

Fred Rogers approach as a STEAM teaching strategy in preschool contexts. In 2021, Dinh (2021) shifted attention to difficulties in implementing STEAM in preschools in the northern mountainous region of Vietnam, showing that the translation of STEAM into practice is associated with specific conditions related to teachers and facilities. In 2022, the scope of research continued to broaden as Çabuk et al. (2022) examined the use of storytelling and coding activities to introduce initial coding concepts to young children, while López and Cabello (2022) reviewed the role of parents in early childhood STEM education.

The year 2023 included the largest number of studies in the dataset and also displayed clear diversity in research topics. One group of studies focused directly on teachers. Bui et al. (2023) provided data on Vietnamese preschool teachers' understanding, competence, and readiness to implement STEAM activities and projects; Chang (2023) investigated the effects of training on teachers' professional preparedness and confidence; and Vu (2023) examined Hanoi preschool teachers' beliefs about STEAM learning environments and challenges in teaching. In parallel, Başaran and Bay (2023) investigated project-based STEAM activities; Magnusson and Bäckman (2023) questioned the role of Arts in the relationship between STEM and STEAM; Huang et al. (2023) used KAPLA construction activities to develop computational thinking among preservice early childhood educators; and Haugas et al. (2023) examined STEAM in relation to sustainable development and teachers' practices. This diversity indicates that, from 2023 onward within the analyzed corpus, STEAM was no longer considered solely as a way of organizing activities for children but was also approached from the perspectives of teachers, teacher training, technology, arts, and sustainable development.

Studies from 2024 to 2026 continued to extend STEAM research into more specific content areas and issues. Zdybel et al. (2024) developed the STEAM Outdoor Education for Sustainability curriculum, connecting STEAM with outdoor environments and education for sustainable development. Stage et al. (2025) integrated STEAM with food-based learning to target outcomes related to science, language, and dietary quality. Pransiska et al. (2025) extended STEAM into the context of interactive e-books for English vocabulary instruction. Two studies by Nguyen et al. (2025a, 2025b) focused more deeply on Vietnamese preschool teachers, examining respectively the factors affecting STEAM activity implementation and those associated with teachers' intention to continue STEM/STEAM activities. By 2026, Kandır and Çağlak (2026) extended the approach to STEAM+X through a teacher needs analysis, while Köchig et al. (2026) investigated teachers' experiences in Spain and Germany in integrating STEAM and digital technology into early childhood classrooms.

Overall, within the 19 studies, a shift can be observed from the question of how STEAM can be organized in early childhood education toward more diverse questions concerning who implements it, the conditions of implementation, the content being integrated, and the sustainability of STEAM in practice. Children remain an important focus, but teachers are becoming an increasingly prominent research focus. At the same time, the scope of STEAM has expanded through connections with digital technology, coding, computational thinking, sustainable development, outdoor education, food, and language. This trend reflects the flexibility of STEAM in early childhood education but also reveals considerable diversity in how studies define and implement STEAM.

3.2. Major Approaches to STEAM Education in Early Childhood Education

Analysis of the 19 studies shows that STEAM education in early childhood contexts is not implemented through a single uniform method. Instead, studies employ different approaches depending on their objectives, participants, and educational content. A relatively consistent feature is that STEAM is commonly situated within integrated and experiential activities rather than treated as five entirely independent domains. Accordingly, science, technology, engineering, arts, and mathematics are connected to varying degrees as children explore, solve problems, or create products.

One prominent approach is to organize STEAM through projects and hands-on activities. Başaran and Bay (2023) implemented project-based STEAM activities and examined children's skills related to product creation, teamwork, presentation, and technical tasks. In this approach, children do not merely receive content but participate in carrying out tasks and creating products. Awang et al. (2020) approached STEAM through a teaching strategy based on the Fred Rogers approach, while Areljung (2020) established connections between science and arts through “Science-Arts” activities. Although their objectives and forms of organization differ, these studies show that STEAM is introduced into early childhood education through experiences in which knowledge from multiple domains can be mobilized simultaneously.

Arts is a component that has received specific attention in several studies. Areljung (2020) directly investigated the relationship between science and arts in early childhood practice. Magnusson and Bäckman (2023) further questioned the capacity and position of “A” in STEM contexts, examining teachers' understandings of STEM as well as children's art activities involving digital technology. These studies suggest that adding Arts to STEM does not merely mean expanding the label from STEM to STEAM but also raises questions about the nature of integration: whether arts is used as a means to support other domains or becomes a component with its own role in STEAM experiences. This is important because the degree and form of Arts integration may alter how STEAM is interpreted and organized in early childhood classrooms.

Another group of approaches concerns technology, coding, and computational thinking. Çabuk et al. (2022) combined storytelling with plugged or unplugged coding activities to introduce coding-related concepts to young children. The integration of storytelling and coding demonstrates that technological content can be transformed into activities better suited to the developmental characteristics of preschool children rather than being presented in a purely technical form. Huang et al. (2023) used KAPLA in preservice early childhood teacher education to develop computational thinking in a STEAM context, linking design and problem-solving processes with knowledge from multiple domains. Pransiska et al. (2025), in turn, examined STEAM-oriented interactive e-books in English vocabulary instruction, showing that digital technology can be integrated with STEAM to serve a specific learning objective.

The trend of combining STEAM with technology is further reflected in the study by Köchig et al. (2026), which examined teachers' experiences of integrating STEAM and digital technology into early childhood classrooms across two national contexts. Together with Haugas et al. (2023), in which teachers reported difficulties integrating engineering and technology, these findings indicate that Technology and Engineering both expand the possibilities for organizing STEAM activities and create new demands for teachers. This is particularly noteworthy in early childhood education, where technology needs to be selected and organized in ways appropriate to young children's developmental characteristics and modes of learning.

In addition to projects, arts, and technology, another notable approach is the connection between STEAM and sustainable development. Zdybel et al. (2024) developed the STEAM Outdoor Education for Sustainability curriculum, in which STEAM was connected with outdoor education and sustainable development content. Haugas et al. (2023) also examined the relationship between STEAM and sustainable development through the views and practices of Estonian teachers. The emergence of this research direction suggests that STEAM can be used as a way of organizing learning that enables children to engage with issues extending beyond individual domains of science, technology, or arts.

Stage et al. (2025) demonstrated another form of integration by connecting STEAM with food-based learning in the More PEAS Please! program. The study targeted outcomes related to science learning, language development, and children's dietary quality while combining a program for children with professional development for teachers. This case shows that a STEAM activity can simultaneously address multiple developmental and learning objectives. Overall, the diversity of approaches reflects STEAM's adaptability to multiple areas of early childhood education. However, this very diversity also raises questions about the criteria for identifying an activity as STEAM and the degree of integration required among Science, Technology, Engineering, Arts, and Mathematics.

The reviewed evidence does not support a definitive ranking of effectiveness because the studies differ in design, participants, duration, and outcome measures. A comparative reading nevertheless shows distinct strengths and constraints. Project-based and hands-on approaches provide strong opportunities for integration, collaboration, and product creation, but they require substantial teacher facilitation, planning time, and materials. Arts- and storytelling-based approaches are accessible and developmentally appropriate, yet Arts may become merely instrumental and Engineering or Mathematics may remain implicit. Coding and digital approaches can support computational thinking and targeted learning goals, but their suitability depends on teachers' digital competence, infrastructure, and the pedagogical function of technology. Outdoor, sustainability, and food-based approaches connect STEAM with authentic experiences and broader developmental goals, although they are highly context-dependent and their diverse outcomes are difficult to compare. Thus, appropriateness should be judged in relation to children's developmental characteristics, intended outcomes, teacher capacity, and available resources rather than by assuming that one approach is universally superior.

3.3. Teachers as a Central Focus of STEAM Research

One of the most prominent findings of the review is the central role of teachers in a considerable number of studies. While studies of children mainly address how activities are organized and children's learning or developmental outcomes, studies of teachers focus on a broader sequence of issues, ranging from understanding, beliefs, and readiness to training, implementation competence, challenges, and the sustainability of STEAM. This reflects the recognition that translating STEAM from an educational orientation into classroom activities depends substantially on the teachers who directly design and organize learning experiences.

Bui et al. (2023) provided a dataset from 754 Vietnamese preschool teachers concerning readiness to implement STEAM activities and projects, including survey content related to teachers' understanding and competence. This study provides data on teachers' level of preparation in the STEAM context. Vu (2023) approached the issue from the perspective of Hanoi preschool teachers' beliefs about the STEAM learning environment and teaching challenges. These two studies indicate that teacher preparation is related not only to knowledge or skills but also to how teachers perceive and evaluate STEAM in educational practice.

Training and professional development constitute another prominent area. Chang (2023) investigated the impact of a STEAM teacher training program on professional preparedness and confidence. The study found that, before training, teachers recognized the importance and expected outcomes of STEAM but had limited teaching experience and self-efficacy. The training program included STEAM content, children's STEAM learning, teaching methods, and curriculum design. This case suggests that STEAM training needs to go beyond providing conceptual knowledge and build teachers' capacity to design and organize activities in practice.

Teacher training also appears as a supporting component in studies focusing on programs for children. In the study by Başaran and Bay (2023), teachers received practical training before implementing project-based STEAM activities. Stage et al. (2025) combined the More PEAS Please! program with professional development for teachers. Thus, professional development is examined not only as a distinct teacher-related outcome but also as a condition enabling STEAM programs to be implemented with children.

Recent studies move beyond asking whether teachers are ready or trained and instead examine what affects STEAM implementation in practice. Nguyen et al. (2025a) analyzed factors affecting Vietnamese preschool teachers' implementation of STEAM activities. Nguyen et al. (2025b) further examined factors influencing the intention to sustain STEM/STEAM activities. The emergence of the concept of “persistence” extends the focus from initial implementation to the capacity to continue implementation after training or support. This is a notable shift because a professional development program has long-term significance only when knowledge and competencies are translated into sustainable practice.

Studies of teachers' difficulties and needs provide further evidence regarding this issue. Dinh (2021) examined difficulties in implementing STEAM in preschools in the northern mountainous region of Vietnam, where teacher-related conditions and facilities were issues requiring consideration. Haugas et al. (2023) showed that Estonian teachers experienced difficulties integrating Engineering and Technology despite viewing some areas such as creativity, technology, and the environment positively. Kandır and Çağlak (2026) approached the issue from the perspective of teachers' needs regarding the applicability of STEAM+X, while Köchig et al. (2026) analyzed teachers' practical experiences in integrating STEAM and digital technology.

Across these studies, a coherent teacher-focused pathway can be identified: initial readiness and beliefs shape engagement with professional learning; practice-based training supports implementation competence; competence is translated into classroom enactment; and continued support influences whether practice is sustained. Figure 2 presents this synthesis. The pathway should not be interpreted as an established causal model because the reviewed studies generally examined its components separately. Rather, it is a conceptual framework derived from the corpus to guide future testing of the links among readiness, training, implementation quality, and sustainability.

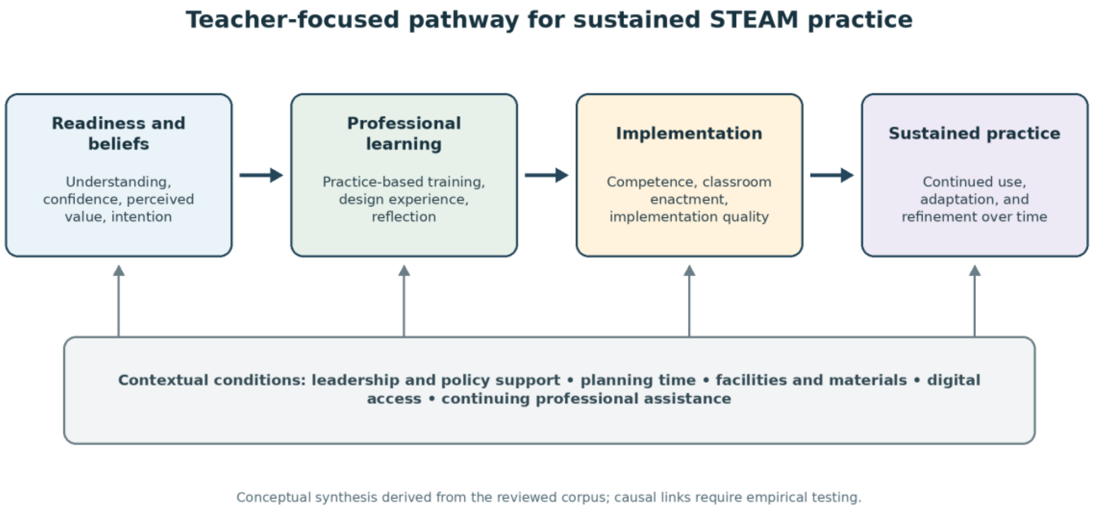

Figure 2. Conceptual pathway linking teacher readiness, professional learning, implementation, and sustainability.

The framework also makes contextual support explicit. Leadership, time, facilities, digital access, curriculum expectations, and continuing professional assistance may enable or constrain each transition. This helps explain why positive beliefs or participation in training alone may not result in high-quality or sustained STEAM practice.

3.4. Contextual Factors Influencing STEAM Implementation

The geographical diversity of the corpus indicates that STEAM implementation is embedded in cultural, institutional, and policy contexts. Studies from Vietnam draw attention to teacher qualifications, material conditions, readiness, and continuation of practice (Dinh, 2021; Bui et al., 2023; Vu, 2023; Nguyen et al., 2025a, 2025b). Evidence from Estonia highlights both interest in creativity, technology, and environmental themes and difficulty integrating Engineering and Technology (Haugas et al., 2023). Research across Spain and Germany further illustrates how teachers' experiences of STEAM and digital integration are situated within different educational environments (Köchig et al., 2026).

Across these settings, context appears to influence implementation through access to materials and digital infrastructure, teacher education and professional support, institutional expectations, curriculum priorities, and opportunities to adapt activities to local environments. However, the studies were not designed for direct cross-national comparison, so the corpus cannot establish that one cultural or policy setting is more effective than another. The evidence instead supports a context-sensitive interpretation: an approach that is feasible in one setting may require adaptation in another, and implementation quality should be evaluated in relation to local resources and educational conditions.

3.5. Research Gaps

Comparison of the 19 studies indicates that the first research gap concerns the nature of STEAM integration. Although STEAM in principle comprises Science, Technology, Engineering, Arts, and Mathematics, the studies in the dataset do not devote equivalent attention to all components. Areljung (2020) and Magnusson and Bäckman (2023) directly addressed Arts and the relationship between arts and science or STEM. Meanwhile, Haugas et al. (2023) showed that Engineering and Technology are areas that teachers find difficult to integrate. Several other studies focus strongly on technology, coding, or computational thinking (Çabuk et al., 2022; Huang et al., 2023; Köchig et al., 2026), but not all five STEAM components are analyzed to the same extent. This suggests a continuing need to clarify the nature of “integration” in early childhood STEAM, including the extent to which each domain is represented and how the domains are connected within the same learning experience.

The second gap concerns the relationship between teacher characteristics and the quality of STEAM practice. Studies have addressed multiple variables, including understanding, competence, and readiness (Bui et al., 2023), beliefs and challenges (Vu, 2023), professional preparedness and confidence (Chang, 2023), factors affecting implementation (Nguyen et al., 2025a), and intention to sustain activities (Nguyen et al., 2025b). However, these issues have largely been examined separately. The corpus does not provide a unified model explaining the process from training and the development of knowledge and competence to actual practice, implementation quality, and the sustainability of STEAM. Future research could therefore examine multiple components simultaneously to clarify the mechanism through which teacher preparation is translated into STEAM practice.

The third gap concerns the sustainability of professional development. Several studies show that teachers received training before or during the implementation of STEAM programs (Başaran & Bay, 2023; Chang, 2023; Stage et al., 2025). However, evidence regarding whether post-training changes are sustained over longer periods remains limited within the corpus. Nguyen et al. (2025b) specifically raised this issue by focusing on teachers' intention to persist in STEM/STEAM implementation. This suggests that future studies need to move beyond immediate post-training assessment and follow teachers' practices over longer periods.

The fourth gap concerns the assessment of outcomes for children. Existing studies assess markedly different sets of outcomes. Başaran and Bay (2023) focused on product creation, teamwork, presentation, and technical skills. Çabuk et al. (2022) addressed content related to coding, problem solving, and computational thinking. Stage et al. (2025) targeted science learning, language development, and dietary quality. This diversity reflects the broad applicability of STEAM but also makes comparisons across studies difficult. Within the corpus, no common system of outcomes or indicators was identified for evaluating the effects of STEAM education on preschool children.

The fifth gap is the shortage of comparative evidence on implementation contexts. Although the corpus includes studies from Vietnam, Estonia, Spain, Germany, and other settings, most analyze contextual factors within a single study. Direct comparisons of how culture, policy, facilities, curriculum expectations, and professional-support systems shape STEAM practice remain limited. Future research should therefore examine contextual mechanisms and adaptation processes rather than assume that one implementation model can be transferred unchanged.

Finally, the role of actors beyond children and teachers has not become a prominent research direction. López and Cabello (2022), in their review of early childhood STEM education, indicated that parental involvement remains insufficiently addressed. Across the remaining studies, teachers and children occupy central positions, whereas families, school leaders, and other support actors are rarely analyzed as components of STEAM implementation. This suggests a research direction based on an ecosystem perspective, in which STEAM is viewed not only as teacher-child interaction in the classroom but also as being influenced by coordination among families, schools, and professional support conditions.

Taken together, these gaps show that research on STEAM in early childhood education is expanding in both content and context, but fragmentation remains across research streams. Some studies focus on children and STEAM activities, others on teachers, training, or implementation conditions, while research on technology, Arts, sustainable development, and families forms relatively separate directions. Future research therefore needs to strengthen connections among three levels: teachers' characteristics and competencies, the quality of STEAM implementation, and outcomes for children. At the same time, these levels need to be examined under specific contextual conditions and over time in order to clarify not only how STEAM can be implemented but also which conditions enable high-quality implementation and its sustainability in early childhood education practice.

4. Discussion

The review findings show that STEAM education in early childhood contexts is becoming increasingly diverse in content, modes of organization, and study populations. What is noteworthy is not only the emergence of multiple forms of implementation but also a change in how STEAM is conceptualized. Rather than being merely a combination of the five domains of Science, Technology, Engineering, Arts, and Mathematics, STEAM is increasingly approached as an orientation for organizing learning experiences in which children have opportunities to explore, design, experiment, and solve interdisciplinary tasks. Studies of science-arts, projects, coding, outdoor education, food, and digital technology demonstrate the flexibility of STEAM when introduced into young children's education (Areljung, 2020; Çabuk et al., 2022; Başaran & Bay, 2023; Zdybel et al., 2024; Stage et al., 2025; Köchig et al., 2026). From this perspective, the value of STEAM in early childhood education appears to lie not in ensuring that every activity fully represents all five components, but in its capacity to create meaningful connections among domains within learning experiences appropriate for children.

However, this very flexibility also raises an issue concerning the conceptual boundaries of STEAM. When studies use highly diverse forms yet place all of them under the STEAM concept, the question arises as to what degree of integration is sufficient for an activity to be considered a STEAM activity. The studies by Areljung (2020) and Magnusson and Bäckman (2023) particularly show that incorporating Arts into STEM is not simply a matter of adding another domain to an existing model, but is related to how the function of arts in the learning process is understood. Similarly, the difficulties teachers experience in integrating Engineering and Technology, reflected in Haugas et al. (2023), show that STEAM components are not easily implemented to an equivalent degree in practice. Therefore, a theoretical challenge for the field is to move from asking "how many STEAM components does an activity contain?" toward the deeper question of how the components interact and contribute to children's learning processes.

Another meaningful finding is the increasingly prominent role of teachers within the body of early childhood STEAM research. Studies of readiness, beliefs, confidence, training, needs, and intention to sustain implementation show that teachers are not simply implementers of a predesigned STEAM program. They interpret STEAM, select content, design environments, and translate principles of integration into concrete experiences for children (Bui et al., 2023; Chang, 2023; Vu, 2023; Nguyen et al., 2025a, 2025b). This implies that the quality of STEAM implementation is unlikely to be improved merely by providing lesson plans, materials, or equipment. Teachers' capacity to understand the integrative nature of STEAM and translate that understanding into appropriate pedagogical decisions may be an important condition for implementation.

Accordingly, findings related to teacher training need to be viewed more broadly than the provision of STEAM knowledge. Chang (2023), Başaran and Bay (2023), and Stage et al. (2025) all show that professional development is associated with implementation. This suggests that STEAM teacher education should provide opportunities for teachers to experience the processes of designing, testing, and adjusting activities rather than merely introducing concepts or ready-made models. In particular, Nguyen et al. (2025b), by addressing the intention to persist in STEM/STEAM implementation, indicate that the effectiveness of training should not be evaluated solely through knowledge, attitudes, or confidence immediately after a program. A more important question is whether teachers continue to apply what they have learned in classroom practice and which conditions support or hinder that process.

From this perspective, STEAM implementation can be conceptualized as a developmental sequence involving initial preparation, competence development, translation into practice, and the sustainability of practice. However, studies in the dataset generally focus on only one or several links in this sequence. This issue is important for future research because a high level of readiness does not necessarily lead to high-quality practice, just as participation in training does not automatically ensure that teachers will sustain STEAM. Therefore, rather than continuing to examine variables such as readiness, confidence, beliefs, or intention separately, their relationships should be investigated within a continuous process of professional development. Longitudinal research designs may be particularly useful for identifying changes in teachers from before training through implementation to sustained STEAM practice.

The review findings also raise the issue of STEAM's appropriateness for the characteristics of early childhood education. Studies using storytelling, outdoor activities, food, arts, and manipulable materials show that STEAM can be incorporated into experiences familiar to children rather than organized as a miniature version of science or engineering education at higher educational levels (Areljung, 2020; Çabuk et al., 2022; Huang et al., 2023; Zdybel et al., 2024; Stage et al., 2025). This has pedagogical significance: the appropriateness of STEAM in early childhood education should be assessed not only by the amount of scientific, mathematical, or technological knowledge incorporated into an activity, but also by the extent to which the activity enables children to manipulate, explore, communicate, imagine, and solve problems in situations meaningful to them.

The development of technology and computational thinking within the reviewed studies also needs to be considered from this perspective. Technology can expand STEAM learning environments and tools, but increased use of digital devices does not necessarily make an activity more STEAM-oriented. Studies of storytelling and coding, KAPLA, interactive e-books, and digital technology integration show that technology is used in multiple forms (Çabuk et al., 2022; Huang et al., 2023; Pransiska et al., 2025; Köchig et al., 2026). Therefore, an important issue for future research is not simply whether children or teachers use technology, but what pedagogical role technology plays in STEAM integration and how it supports children's learning experiences.

Another implication arises from the increasing connection of STEAM with broader educational goals. The integration of STEAM with sustainable development, outdoor education, nutrition, and language suggests that STEAM can function as a framework for organizing cross-domain learning rather than as an isolated educational content area (Haugas et al., 2023; Zdybel et al., 2024; Stage et al., 2025). This development opens possibilities for connecting STEAM with real-world issues and children's everyday lives. However, expanding the scope also increases the risk that the STEAM concept becomes overly broad if every integrated activity is labeled STEAM. Future studies therefore need to describe more clearly the mechanisms of integration, the role of each component, and the basis for identifying the activity under investigation as STEAM.

Findings related to context also suggest that STEAM cannot readily be regarded as a model that can be transferred unchanged across educational environments. Evidence from studies conducted in Vietnam, Estonia, Spain, Germany, and other contexts shows that STEAM practice is influenced by teacher-related conditions, facilities, technology, and educational environments (Dinh, 2021; Haugas et al., 2023; Köchig et al., 2026). Therefore, the evaluation of a STEAM model needs to consider its adaptability to the context rather than focusing solely on the effectiveness of a standardized program. This is particularly meaningful in early childhood education, where learning environments, teachers' experience, and the practical conditions of educational institutions may differ considerably.

One aspect that remains comparatively underdeveloped is the participation of actors beyond teachers and children. López and Cabello (2022) show that the role of parents has received limited attention in early childhood STEM education. When this finding is considered alongside STEAM studies that focus primarily on teachers, STEAM implementation appears to remain largely viewed within the classroom. Yet preschool children learn through interactions among their families, schools, and wider environments. An ecosystem approach could therefore extend research from teacher-child relationships to coordination among teachers, families, schools, and other support resources. However, because evidence on this issue remains limited within the corpus, it should be regarded as a direction requiring further investigation rather than an established conclusion.

Taken together, the findings indicate that early childhood STEAM research is moving beyond demonstrating the feasibility of individual activities toward explaining their quality, mechanisms, contextual fit, and sustainability. Progress will depend on connecting three currently separated levels: teachers and their support conditions, the quality of STEAM enactment, and children's learning and developmental outcomes.

4.1. Practical and Policy Implications

Four practical priorities follow from the synthesis. First, preservice and in-service teacher education should include hands-on cycles in which teachers design, pilot, observe, evaluate, and revise STEAM activities rather than only receive conceptual instruction or ready-made lesson plans. Second, school leaders and policymakers should provide continuing coaching, peer-learning communities, planning time, materials, and technical support instead of relying on one-off workshops. Third, curriculum guidance and resource allocation should allow STEAM approaches to be adapted to children's developmental characteristics and local conditions, including low-resource settings. Fourth, program evaluation should connect changes in teacher competence with implementation quality, child outcomes, and, where appropriate, family participation.

4.2. Priorities for Future Research

The most urgent research priority is to generate longitudinal evidence on whether teachers maintain and refine STEAM practice after professional development, because sustainability determines whether training investments generate lasting classroom change. The second priority is to test integrated models linking readiness, beliefs, training, competence, implementation quality, and child outcomes; without these links, the mechanisms of effective practice remain unclear. A third priority is comparative, context-sensitive research examining how policy, culture, resources, and institutional support alter implementation. Development of more comparable child-outcome indicators and research on family and school-level participation are also important, but they should build on clearer evidence about sustained, high-quality implementation.

The findings should be interpreted within several limitations. The review included only 19 studies from a single Scopus-based corpus covering 2020-2026, and the studies varied substantially in context, participants, objectives, designs, and outcomes. The heterogeneity of the evidence prevented quantitative comparison of effectiveness, and single-author coding did not provide an independent intercoder check. Consequently, the identified patterns and priorities characterize this corpus rather than the entire international literature. Nevertheless, the structured comparison clarifies where evidence converges, where it remains fragmented, and which relationships require direct testing.

5. Conclusion

This review of 19 studies shows that STEAM in early childhood education is implemented through diverse, developmentally situated approaches, including projects and hands-on activities, science-arts integration, storytelling and coding, digital tools, outdoor education for sustainability, and food-based learning. The evidence does not identify a universally superior approach; suitability depends on intended outcomes, children's developmental characteristics, teacher capacity, and contextual resources.

The principal contribution of the review is to connect dispersed strands of research. In addition to mapping instructional approaches, it synthesizes teacher-focused evidence into a pathway linking readiness and beliefs, professional development, implementation competence, classroom enactment, and sustained practice. This framework shifts attention from whether STEAM is present to how high-quality implementation is developed and maintained.

The most pressing gap is the lack of longitudinal evidence on whether professional development produces durable changes in classroom practice. Other priorities include integrated studies linking teacher characteristics and support conditions to implementation quality and child outcomes, clearer accounts of how STEAM domains are combined, comparative investigation of cultural and policy contexts, more comparable outcome measures, and greater attention to families and other educational actors.

For practice and policy, the findings support practice-based teacher education, continuing coaching and institutional support, adequate planning time and resources, and flexible implementation guidance that can be adapted locally. Evaluation should follow the full pathway from teacher learning to the quality and sustainability of implementation and, ultimately, to meaningful outcomes for children.

These conclusions remain limited by the small, heterogeneous corpus, the use of Scopus as the sole database, the 2020-2026 publication period, and the absence of independent intercoder verification. The review therefore offers a structured account of the selected evidence rather than a comprehensive representation of the global field. Within those limits, it provides a focused agenda for strengthening the quality, contextual relevance, and sustainability of STEAM education in early childhood settings.

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