MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2022, 18(7), em2133
ISSN:1305-8223 (online)
OPEN ACCESS Review Article https://doi.org/10.29333/ejmste/12174

Integrating and navigating STEAM (inSTEAM) in early childhood education: An integrative review and inSTEAM conceptual framework

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Received 15 March 2022 ▪ Accepted 14 June 2022

Abstract

In early childhood education, the integration of science, technology, engineering, arts, and mathematics (STEAM) are advocated as contemporary educational goals. However, integration of STEAM is not defined in the early childhood context. We claim to 'integrate' and 'devise integration pedagogies', but there is still no clear-cut message on what integration means and how to do it. This paper presents an integrative literature review to conceptualize the integration of STEAM practices in early childhood education. The review highlighted key factors and challenges relating to STEAM integration. The paper concludes with the development of the integrating and navigating STEAM (inSTEAM) conceptual framework derived from the concepts, empirical research, and theories explored in the integrative review of the 17 articles.

Keywords: STEM, STEAM, integration, inSTEAM conceptual framework, early childhood education

INTRODUCTION

The purpose of this integrative review paper is to understand then conceptualize the integration of science, technology, engineering, arts, and mathematics (STEAM) practices in early childhood education (ECE). Science, technology, engineering, and mathematics (STEM) education has been receiving a lot of attention in the last two decades (Australian Government Department of Education, Skills and Employment, [DEST], 2021, 2020; National Research Council, 2014; The Organization for Economic Co-operation and Development, [OECD], 2019; United Nations, 2020; Victoria Department of Education and Training, [DET], 2021). One of the main concerns addressed is that the pedagogical adaptation is not well-defined. Many authors claim to integrate and devise integration pedagogies (Martín-Páez et al., 2019; Wang et al., 2011), but there is still no clear-cut message on what integration means and how to do it. In this paper, the term 'STEAM' will be used to discuss both STEM and STEAM practices collectively. Research has found that by integrating with other disciplines, such as art can help early childhood teachers to encourage creativity in young children (Yakman, 2008) and provide a space to personalized the meaning making process which will impact on children's motivation to continue to engage with STEAM (Land, 2013; Wynn & Harris, 2012). Sullivan et al. (2013) suggested that STEAM practices derived from STEM, with an additional subject arts being included can complement early childhood STEM education, wherein the "A" in STEAM covers the area of visual art and crafts, liberal arts, linguistic arts, social studies, music, and culture. Thus, it is crucial to establish a universally accepted, evidence-based and recognized understanding of integration as it impacts the introduction of STEAM in curriculum and practices which will be reflected on children's growth and development.

A seminal framework established by Vasquez et al. (2013) attempted to distinguish between the different levels of STEAM integration. This framework removes the traditional barriers of segregating the four STEAM disciplines while applying real-world, authentic learning experiences for children. Vasquez et al. (2013) articulate STEAM education as an approach to teach discipline-based subjects beyond the surface level, which means teachers are curating conditions for children to learn to develop the so-called 21st century skills, significant for children to navigate in a new and fast-developing world (Bybee, 2013). Examples of 21st century skills include the ability to construct knowledge, communicate, collaborate to solve real-life problems, and safe and appropriate use of information and

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Contribution to the literature

- A review to consolidate the multiple approaches adopted or proposed to integrating STEM in early childhood education.
- A conceptual framework resulted from the review outcomes to help guide integrating STEM in early childhood education.
- Factors to consider when integrating STEM in early childhood classrooms.

communications technologies (ICT) (Partnership for 21st Century Learning, 2016; Stehle & Peters-Burton, 2019). These skills are being developed in the very young child, thus making a natural link between 21st century skills, STEAM education, and the young child's learning. In another study that conceptualizes integrated STEAM education, Kelley and Knowles (2016) define integrated STEAM education as

> "teaching the STEAM content of two or more STEAM domains, bound by STEAM practices within an authentic context to connect these subjects to enhance student learning" (p. 3).

In the ECE context, STEAM advocated as contemporary ECE goals as seen in a recent study and policy such as VicSTEM (DET, 2018; Knaus & Roberts, 2017). Multiple studies also call for more research and attention at the STEAM ECE level (Dejonckheere et al., 2016; Falloon et al., 2020). It raises the question of how integrated STEAM is being taught if it is not defined in an ECE context. A recent critical review on STEAM education by Takeuchi et al. (2020) highlighted the lack of attention to STEAM teaching perspectives, especially in the ECE context, earlier reported by Russell (2005). Both Russell (2005) and Takeuchi et al. (2020) problematize the research in STEAM ECE providing examples for teachers on how STEAM translates into practice in ECE classroom settings. In other words, the processes of integrating STEAM in ECE are rarely discussed. For example, Smith and Cline (2016) and Smith and Samarakoon (2016) adopted the use of everyday science content-based topics (for example, the water cycle, life cycle, and habitat) to explain the process of STEAM content knowledge translation in ECE settings. These authors claim that STEAM learning is integrated into the lessons, but they did not explain the process of integration. This paper addresses the gap in understanding curriculum and practices and related techniques for integrating STEAM in ECE.

The Status Quo in the Understanding of STEAM

STEAM practices are mostly implied or unnoticed in ECE (Vasquez et al., 2020). STEAM exists in various forms, including teacher-initiated or guided play (Torres-Crespo et al., 2014), child-initiated or centered play, and free-play moments (Campbell et al., 2018; Rushton & King, 2020). STEAM education is not a brand-new 'rocket science subject' endorsed and taught nationally and internationally. Instead, STEAM education is about merging the scientific way of thinking, the technological way of doing, the process of applying mathematics, and the process of problem solving through engineering for teachers to teach and children to learn meaningfully (Vasquez et al., 2020). Research is still grappling with a conscious adaptation of the STEAM education lenses and pedagogical base for catering to current 21st century teaching and learning practices (Chomphuphra et al., 2019; National Research Council, 2014).

This integrative review study examines what integrating STEAM integration means and the related integration process in ECE. The articles included in this review explore the presentation of STEAM and its translation into practice in ECE. We are undertaking the inquiry to address the following research questions:

1. What is STEAM integration?
2. What are the STEAM integration practices in ECE?

Vasquez et al. (2020) provided four different levels of integration: disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary. Vasquez's (2015) perception of the four different levels of integration guides this review because they provided clarity and guidance to integrating STEAM. Our synthesis of the peer-reviewed and published empirical research outcomes is based on the different levels of STEAM integration explained by Vasquez et al. (2020):

1. *Disciplinary* is specific content knowledge, and skills are taught individually.
2. *Multidisciplinary* is specific content knowledge and skills taught individually but concerning a common theme.
3. *Interdisciplinary* is specific content knowledge, and the skills of two or more disciplines are closely taught to enhance the knowledge construction process.
4. *Transdisciplinary* is specific content knowledge and skills of two or more closely taught disciplines, making references to real-world problems or projects.

We have illustrated these four levels in **Figure 1**. The Vasquez et al.'s (2020) descriptions and our illustrative interpretations in **Figure 1** indicate that there is no thematic reference in the teaching of STEAM at the *disciplinary* level; each discipline is taught separately.

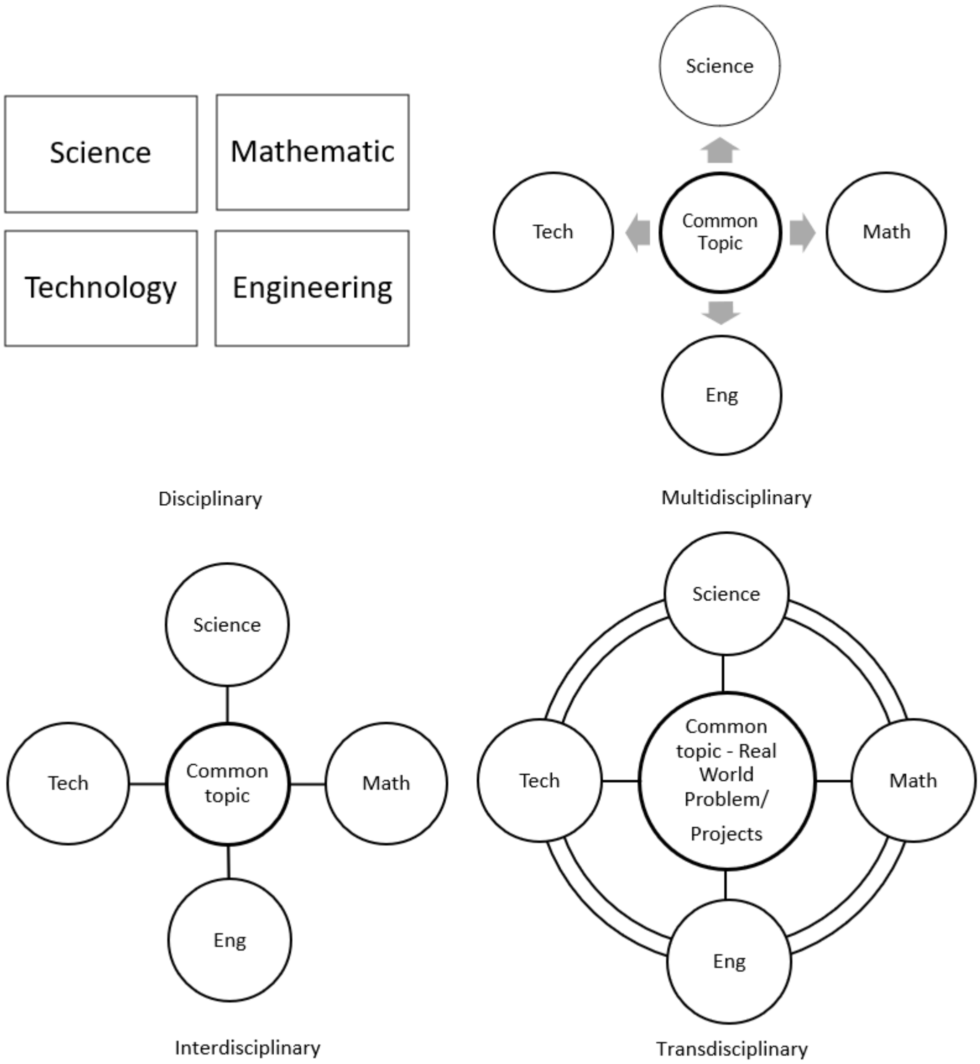

Figure 1. Disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary integration approach frameworks

However, STEAM learning may still happen in each class taught differently from other fields. In *multidisciplinary* integration, Vasquez et al. (2015) presented a multidisciplinary model connected to the thematic reference. However, this is not seen in classroom practice. Each STEAM discipline is not connected and is reflected through the gaps between the subject-related content and the theme. The arrows in the multidisciplinary model exist as a representation to acknowledge that efforts are made to refer to the theme. Vasquez et al. (2015) described the disciplines as still identifiable in *interdisciplinary* integration, but they assume less importance than in multidisciplinary integration. Thus, in contrast to multidisciplinary, STEAM disciplines are connected through the theme in an interdisciplinary approach where learning the content and skills is at a different conceptual level. Finally, *transdisciplinary* integration teaches two or more disciplines' specific content knowledge and skills, referencing real-world problems or projects. The focus on each STEAM discipline tends to fade out, and a comprehensive approach is adopted. Thus, transdisciplinary integration can be considered a potential STEAM ecosystem, achievable by connecting common topics and shared skills. This STEAM ecosystem involves a more profound conceptual thinking process that may co-occur or across all STEAM disciplines in the teaching and learning process. As described by Vasquez et al. (2020), the four levels of integration guide this study.

METHODOLOGY

This paper employs an integrative review methodology to conceptualise integrating STEAM into ECE. According to Toronto and Remington (2020), an integrative review study is a form of empirical research that develops an understanding of a specific phenomenon of interest. An integrative review follows a series of systematic steps (de Souza et al., 2010; Soares et al., 2014):

1. developing a review question,
2. developing a precise search strategy that is replicable,
3. screening for relevant papers through titles,

4. screening abstracts and full texts tentatively based on a set of inclusion and exclusion criteria, and
5. extract data in a standardised approach. Integrative reviews also evaluate the quality of each study, possible biases, analyses, and synthesises data distinctly (Gough et al., 2012).

This integrative review reports on empirical research in STEAM in ECE underpinned by Vasquez's (2015) different integration principles.

This integrative review consisted of a five-stage step-by-step process (Cooper, 1982):

1. Research questions were developed in the problem formulation stage:
   a. What is STEAM integration?
   b. What are the STEAM integration practices in ECE?
2. Searching for relevant literature included applying a search strategy to collect data. The search strategy was developed per consultation with the university librarian to ensure a comprehensive search. Search terms and variations were designed for use in the ERIC database. The search terms are in **Table 1**.
3. Screening for relevant papers: After conducting the 'search', peer-reviewed scholarly articles with a specific focus on ECE were obtained using filters. A year limit filter was not used.
4. *Rayyan* was used to screen titles and abstracts. *Rayyan* is an online screening tool used to exclude articles not meeting selection criteria.
5. Included articles were critiqued, and relevant data were extracted and organised through a thematic approach for comparison and synthesis (Bryman, 2016).

The literature search was conducted in June 2021. 96 ECE articles were screened against the inclusion and exclusion criteria in *Rayyan*. The inclusion criteria of the articles were STEM, early childhood, integration, preschool, STEAM, disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary. The exclusion criteria were articles reporting primary school, middle school, high school, tertiary education, in-service teacher education, and pre-service teacher studies. 49 articles were further appraised after screening for titles and abstracts. 17 articles were included in this integrative review.

There were two stages in the reading of each article. Firstly, the literature review and aims of each article was reviewed to ensure its relevance to integrating STEAM and associated pedagogical practices. Then, the results, discussion and conclusion of each article were considered. **Figure 2** illustrates the process of including and excluding papers as per the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines by Moher et al. (2009).

Table 1. List of search terms for STEAM integration in early childhood education

Items	Search terms
Discipline	Interdisciplinary Multidisciplinary Transdisciplinary Cross-disciplinary
Integrate	Integration
STEM/STEAM	Science Technology Engineering Mathematics Arts

Data Analysis

To synthesize the qualitative content of the selected 17 articles, we adapted the directed qualitative content analysis (DQCA) approach proposed by Assarroudi et al. (2018). In the first analysis stage, a coding scheme consistent with integrating STEAM and the study's conceptual framework was outlined. The articles were read and coded; codes were extracted into the categorisation matrix. These codes were used to identify themes. Themes were observed across the articles and used to create the integrating STEAM framework reported in this paper.

RESULTS AND DISCUSSION

Of the 17 articles, ten explicitly defined STEAM integration, while seven articles did not clearly define STEAM integration. Based on this breakdown, we move to explore the initial part of our research question–that of understanding what STEAM integration is. Then, we discuss the role of STEAM integration in ECE, who is at the centre of STEAM education, and why STEAM should be integrated into the ECE context. We also examine factors involved in STEAM integration practices and the challenges of integrating STEAM. Lastly, a conceptual framework for integrating and navigating STEAM in ECE is provided based on this review of the literature.

Defining Integrating STEAM in ECE

10 of the 17 articles considered STEAM integration. Kazakoff et al. (2013), Smith and Cline (2016), Smith and Samarakoon (2016), and Tippett and Milford (2017) each defined STEAM integration as multidisciplinary and interdisciplinary. The definitions by Smith and Cline (2016) and Smith and Samarakoon (2016) are relevant to STEAM. Some authors, such as Kermani and Aldemir (2015), defined STEAM integration from an ICT focus, and Sullivan et al. (2013) defined STEAM from an engineering perspective.

Kermani and Aldemir (2015) and Tippett and Milford (2017) defined STEAM as an interdisciplinary approach

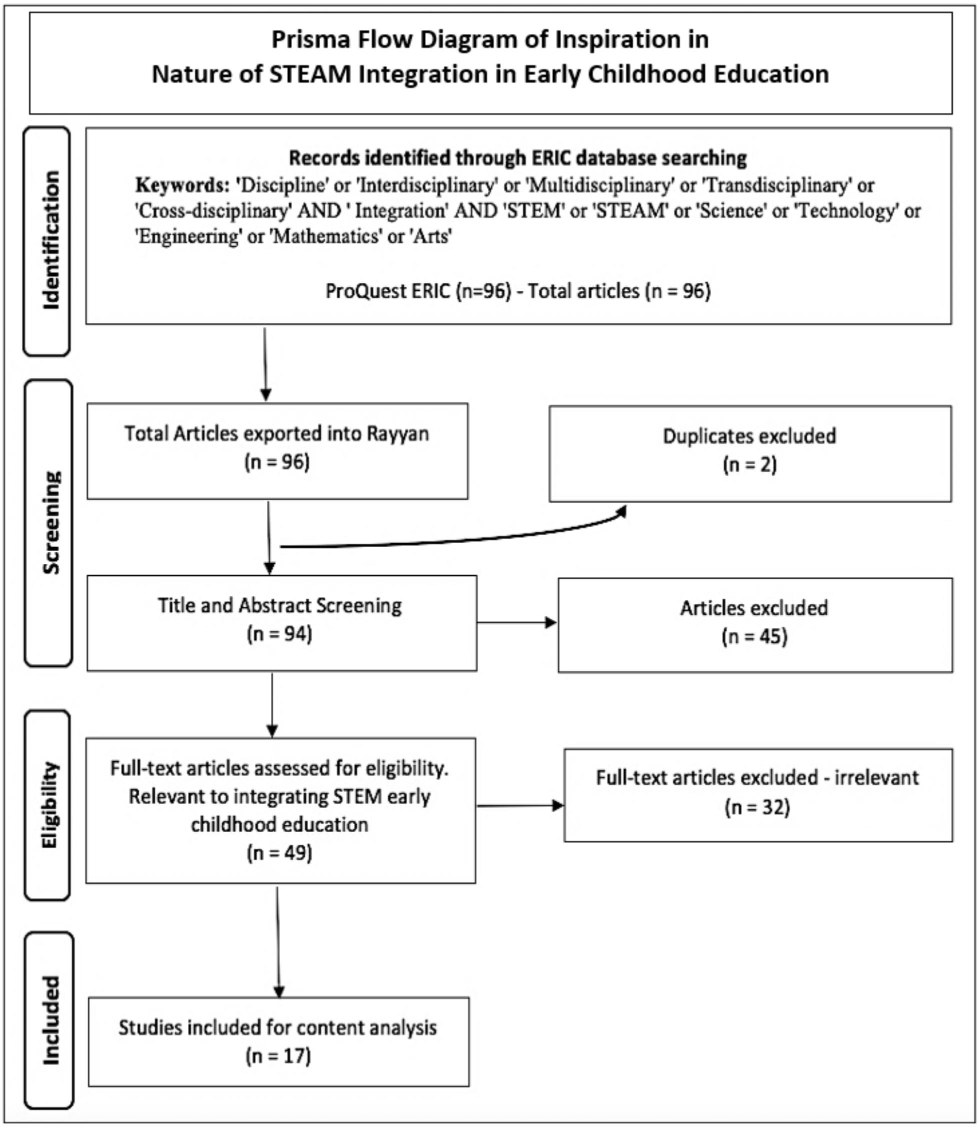

Figure 2. PRISMA flow diagram for literature search & selection process

to learning. According to Khozali and Karpudewan (2020) and Vasquez et al. (2013), interdisciplinary is where two or more subjects or disciplines are taught together. Exploring this notion of STEAM being interdisciplinary, Tippett and Milford (2017) found that interdisciplinary STEAM promotes learning across various content areas such as math, science, and technology. Smith and Cline (2016) and Smith and Samarakoon (2016) describe STEAM having a vital role in closing the gap between each subject discipline. Combining arts-based approaches such as drawing, scribbles, early writing, singing, and music helps children make connections and improve children's memory retention of the details of the STEAM task.

Sullivan et al. (2013) reported utilizing the engineering design process in a STEAM-focused robotics curriculum, demonstrating how STEAM can be interdisciplinary in ECE. As Kermani and Aldemir (2015) concurred, a robust STEAM or STEAM curriculum is beneficial for young learners to yield an overall improvement in each relevant subject and discipline. These studies attempted to define STEAM, focusing on either ICT or engineering.

12 papers aimed to provide a definition towards understanding integrating STEAM in ECE. Cinar (2019), Hassan et al. (2019), Lin et al. (2021), and Tank et al. (2018) had a STEAM definition that has the integration notion embedded. Interestingly, Smith and Cline (2016) focused on defining STEAM integration while Aldemir and Kermani (2017), Kermani and Aldemir (2015), and Lowrie and Larkin (2020) define integrating STEAM from an ICT focus that positions ICT as a tool to explore STEAM at different integration levels. John et al. (2018) and Tank et al. (2018) define STEAM integration from an engineering focus, where the introduction of developmentally appropriate engineering learning contents promotes understanding, engagement, ability to apply and problem solve. In contrast, Sullivan and Bers (2018) define STEAM with a focus on ICT, while Evangelou et al. (2010) define STEAM as easily accessible and highly relevant to support children's understanding and engagement. The perceptions and practices of the 17 reviewed articles are explored in **Table 2**.

Table 2. STEAM study description

Study title	Author(s)	What & how integrating STEAM is perceived in respective studies	Type of STEAM activity
Integrated STEM curriculum: Improving educational outcomes for head start children	Aldemir and Kermani (2017)	STEAM integration endorsed for a well-planned, stimulating, hands-on, & developmentally appropriate transdisciplinary STEAM activities integration. This curriculum allows children to achieve a deep & meaningful understanding of S STEAM–related learning to develop 21st century skills such as problem-solving, critical thinking, questioning, analyzing, & collaborative skills.	STEAM
Integration of engineering design in early education: How to achieve it	Cinar (2019)	STEAM integration identifies divergence of the multidisciplinary STEAM into the preschool. This can be achieved through age-appropriate engineering design & opportunities for problem solving. The engineering design process is a promising pedagogical tool to aid teachers in developing & delivering high relevance STEAM activities confidently.	Engineering focused STEAM
Preschool children's science motivation and process skills during inquiry-based STEM activities	Dilek et al. (2020)	Insights provided on developmentally appropriate multidisciplinary STEAM-based inquiry activities boost children's science motivation. In a collaborative environment, STEAM activities facilitate children to actively use science process skills–observation, comparison, classification, communication, measurement, prediction, & inference.	Science focused STEAM
Talking about artifacts: Preschool children's explorations with sketches, stories, and tangible objects	Evangelou et al. (2010)	The study reported the role of integrating interdisciplinary arts into the engineering of STEAM. The study offered a perspective of easily accessible, relevant, & tangible artefacts that supported the understanding of children's knowledge construction.	Engineering focused STEAM
Mathematics curriculum framework for early childhood education based on science, technology, engineering and mathematics (STEM)	Hassan et al. (2019)	In a multidisciplinary STEAM lesson, children learn science & mathematics by applying a variation of technology & engineering materials and resources in realistic & meaningful ways. The study also reports that STEAM is applicable across all disciplines, hence reducing the gaps when introduced in early childhood STEAM education through guided play sessions.	Mathematics focused STEAM
An iterative participatory approach to developing an early childhood problem-based STEM curriculum	John et al. (2018)	STEAM knowledge about science concepts, understanding of the engineering design process, & ability to apply & guide problem solving are key factors in interdisciplinary STEAM integration. This study also reports that teachers' self-efficacy plays an essential role in STEAM pedagogy integration.	STEAM
Preparing children for success: Integrating science, math, and technology in early childhood classroom	Kermani and Aldemir (2015)	Interdisciplinary STEAM integration informs how ICT is a tool for children's science, maths, & technology learning. The study offers insights into incorporating technology, materials, & resources. Teachers' instructions also provided directions to link between the intentional math & science teaching & learning with children's interest.	ICT, technology & robotics focused STEAM
Children's engineering design thinking processes: The magic of the ROBOTS and the power of BLOCKS (electronics)	Kewalramani et al. (2020)	The study assessed role of technology & engineering concepts in facilitating teachers-to-children & children-to-children interactions in multidisciplinary STEAM play activities. Both informal & formal engagement in technology-enhanced inquiry activities boosts children's metacognitive & social knowledge construction.	ICT, technology & robotics focused STEAM
Using an inquiry-based science and engineering program to promote science knowledge, problem- solving skills and approaches to learning in preschool children	Lin et al. (2021)	The authors reported that interdisciplinary STEAM integration enabled children to be curious & explore independently through the presented problem & learning materials. This research focused on inquiry-based science & engineering programs that reported positive outcomes on young children's knowledge, skills, & motivation/interests.	Science & engineering-based STEAM
Experience, represent, apply (ERA): A heuristic for digital engagement in the early years	Lowrie and Larkin (2020)	Digital technologies are support tools for play-based authentic learning. This form of multidisciplinary STEAM integration using a digital technological focus does not present itself as a substitute for the traditional learning resources. Instead, it is part of resources available to support teaching & learning.	ICT, technology & robotics focused STEAM

Table 2 (Continued). STEAM study description

Study title	Author(s)	What & how integrating STEAM is perceived in respective studies	Type of STEAM activity
Zebras and jaguars, oh my! Integrating science and engineering standards with art during prekindergarten block time	Smith and Cline (2016)	The study provided insight into integrating multidisciplinary STEAM by exploring science topics such as habitat. Children had higher engagement when art materials were available within the science tasks. Open-ended materials were also available for children to manipulate to help express & provide insights into their learnings & understandings.	Science focused STEAM
Teaching kindergarten students about the water cycle through arts and invention	Smith and Samarakoon (2016)	The understanding of interdisciplinary STEAM integration reports that arts effectively supports & addresses science & engineering teaching & learning meaningful. In the study, children expressed insights of their own understanding through visual representations & artistic elaborations.	STEAM
Dancing robots: Integrating art, music, and robotics in Singapore's early childhood centres	Sullivan and Bers (2018)	Integrating interdisciplinary STEAM challenged the traditional STEAM by adding arts subjects in their study. Children were able to present robot designs & music, dance, & fashion through carefully tailored culturally appropriate & meaningful STEAM education.	ICT, technology & robotics focused STEAM
The wheels on the bot go round and round: Robotics curriculum in pre-kindergarten	Sullivan et al. (2013)	Robotics-focused multidisciplinary STEAM integration offered a new and exciting approach to the ECE curriculum. With developmentally appropriate tools, young children could code a robot & use other technology, engineering, foundational math, literacy, & art concepts.	ICT, technology & robotics focused STEAM
Examining student and teacher talk within engineering design in kindergarten	Tank et al. (2018)	This study reports on an engineering design-based STEAM, focusing on applying engineering design with other STEAM disciplines using interdisciplinary integration. Developmentally appropriate engineering content should be scaffolded to promote discussion & problems solving using visual elements to promote understanding & engagement.	Engineering focused STEAM
Findings from a pre-kindergarten classroom: Making the case for STEM in early childhood education	Tippett and Milford (2017)	STEAM is viewed as a helpful teaching approach that allows teachers to capitalize on children' interests & to think about their teaching in a more purposeful way. The study argued that when educators integrate STEAM to frame their planning & instruction, it becomes a multidisciplinary approach that allows teachers to provide more meaningful learning experiences.	STEAM
Early technology education in China: A case study of Shanghai	Weng and Li (2018)	The study stated that introducing technological tools as learning support was essential in early interdisciplinary STEAM integration. It promotes a positive approach to developing skills to solve problems across multiple STEAM disciplines to enhance learning. This study apexed role of teachers' STEAM awareness, willingness, & presence of technological tools for integration.	ICT, technology & robotics focused STEAM

The intention to introduce STEAM into ECE is apparent. For instance, Tippett and Milford (2017) and Vasquez et al. (2013) endorsing transdisciplinary STEAM, identify how real-world problems integrate into STEAM education. Moreover, Weng and Li (2020) report that connecting the multiple disciplines and real-life situations can enhance children's learning.

Similarly, Lowrie and Larkin (2020) inform us this improves the vision of interconnecting real-world problems. Multiple disciplines aim to provide an authentic learning experience through meaningful replication based on reality. Dilek et al. (2020) found a similar result that children stay engaged, while Kewalramani et al. (2020) reported that children exhibit persistence and resilience throughout such real-world problem natured tasks. Thus, the studies in the last decade report that integrating STEAM in ECE practices utilize different levels of integration.

Studies by Evangelou et al. (2010) and John et al. (2018) have noted that the emergence of STEAM in the curriculum through the establishment of science, technology, and mathematics in the current ECE practices is essential. Tank et al. (2018) reported that this could often be observed within classroom activities, learning units, or various intentional play experiences set up by teachers to prompt spontaneous or guided learning processes. Smith and Samarakoon (2016) reported on integrating STEAM similar to Vasquez's (2015) multidisciplinary proposition could be observed. The study reported that children were encouraged to be curious and consider incorporating different materials in solving the presented problem within the task. Another study by Aldemir and Kermani (2017) described STEAM activity with ICT implementation promotes self-regulating, sharing, and collaboration skills between children to navigate among peers in facilitating the available resources. Both of these past studies projected the establishing of the STEAM curriculum as reported in John et al.'s (2018) study. A recent study by Cinar (2019) also reported by introducing arts that is a common subject in ECE STEAM improves the integration process.

Children at the Center of STEAM Education, but Whose Interest?

Out of the 17 studies, ten reported children to be at the center of STEAM education (Aldemir & Kermani, 2017; Cinar, 2019; Hassan et al., 2019; Kermani & Aldemir, 2015; Kewalramani et al., 2020; Lin et al., 2021; Lowrie & Larkin, 2020; Tank et al., 2018; Tippett & Milford, 2017; Weng & Li, 2020). Despite the established definition of children at the heart of STEAM learning, articles do not report learning initiated based on the child's interest. Vasquez et al. (2020) challenged this and provided an alternative to positing children at the center of STEAM learning. In contrast, the teacher should be more mindful and focused on presenting problems to capture children's interest. The articles did not discuss how the learning topics to engage the children were selected. Despite not having child-initiated learning tasks, Sullivan et al. (2013) still reported that children could engage with complicated tasks such as building and programming simple robots through exploratory tasks, thus promoting STEAM learning.

Vasquez et al. (2013) also reported that integrating STEAM aids in boosting children's engagement. A previous study by Smith and Cline (2016) found that children were more enthusiastic and developed meaningful connections with the STEAM activities when engaged. Teachers from a study John et al. (2018) reported knowledge growth, a change of attitude, and career awareness among the young learners. Tank et al. (2018) also reported that children build knowledge of the problem and content in the STEAM activities with teachers' support. Recent studies by Dilek et al. (2020) and Lin et al. (2021) also outlined children's interest in learning challenging topics improved through STEAM. These positive outcomes were similar to Chen and Chen (2021) and Vasquez et al. (2020) propositions of multidisciplinary and interdisciplinary integrated STEAM.

STEAM activities improved children's understanding of career awareness and roles from a young age. Sullivan et al. (2013) explain that some children provided a detailed description of an engineer's role. This sense of understanding also reflected children's agency which develops while participating in STEAM activities. Smith and Samarakoon (2016) indicate that children still understand that STEAM learning is a trial and error process. A study by Tank et al. (2018) also reported that STEAM tasks promote equality for girls in STEAM through early education. Vasquez et al. (2020) reported that a sense of confidence and community is to be nurtured from STEAM integration. Two articles reported that children develop a sense of confidence and agency through play-based activities (Dilek et al., 2020), peer-teaching and collaboration (Kewalramani et al., 2020).

Significance of Integrating STEAM Education in ECE

The 17 articles have shown that STEAM implementation is crucial to ensure that all learners have an early opportunity to receive age and developmentally appropriate high-quality early care and education. Vasquez et al. (2020) endorsed early STEAM introduction to young children, allowing a solid foundation in the STEAM disciplines. The study by Kermani and Aldemir (2015) reported that children could apply their natural curiosity and succeed in every development area with early STEAM implementation. Furthermore, a further study led by Aldemir and Kermani (2017) reinforced this finding and added that early development of STEAM concepts and skills is beneficial for future learning and acquisition of 21st century learning skills. Moreover, Smith and Samarakoon (2016) reported that STEAM implementation also promotes essential skills such as observing and registering patterns and visuals that contribute to future cognitive learning. Hassan et al. (2019) state that integration allows children to learn science and mathematics concepts in STEAM education by applying technology and engineering in tangible, realistic, and meaningful ways. Thus, early implementation of a STEAM integrated curriculum promotes the development of STEAM literacy skills through meaningful learning (Sullivan et al., 2013).

The study by Kewalramani et al. (2020) reported that STEAM education supports children's scientific inquiry, design thinking, and creativity. Furthermore, through integrating STEAM into education, children could develop vocabulary through interdisciplinary STEAM concepts. Another study by Lowrie and Larkin (2020) focused on digital technology in STEAM education integration. Lowrie and Larkin (2020) also reported that STEAM education provides rich learning tasks based on the STEAM disciplines. Therefore, early availability and support for learning STEAM reinforce vocabulary development through enriching play experiences, aligning with Vasquez et al. (2020) multidisciplinary propositions.

Recent studies, Dilek et al. (2020) and Weng and Li (2020) proposed that STEAM integration practices emphasize developmental appropriateness in ECE. Vasquez et al. (2020) outlined that inquiry-based teaching and learning approaches are used widely in STEAM integration. In addition, inquiry-based learning

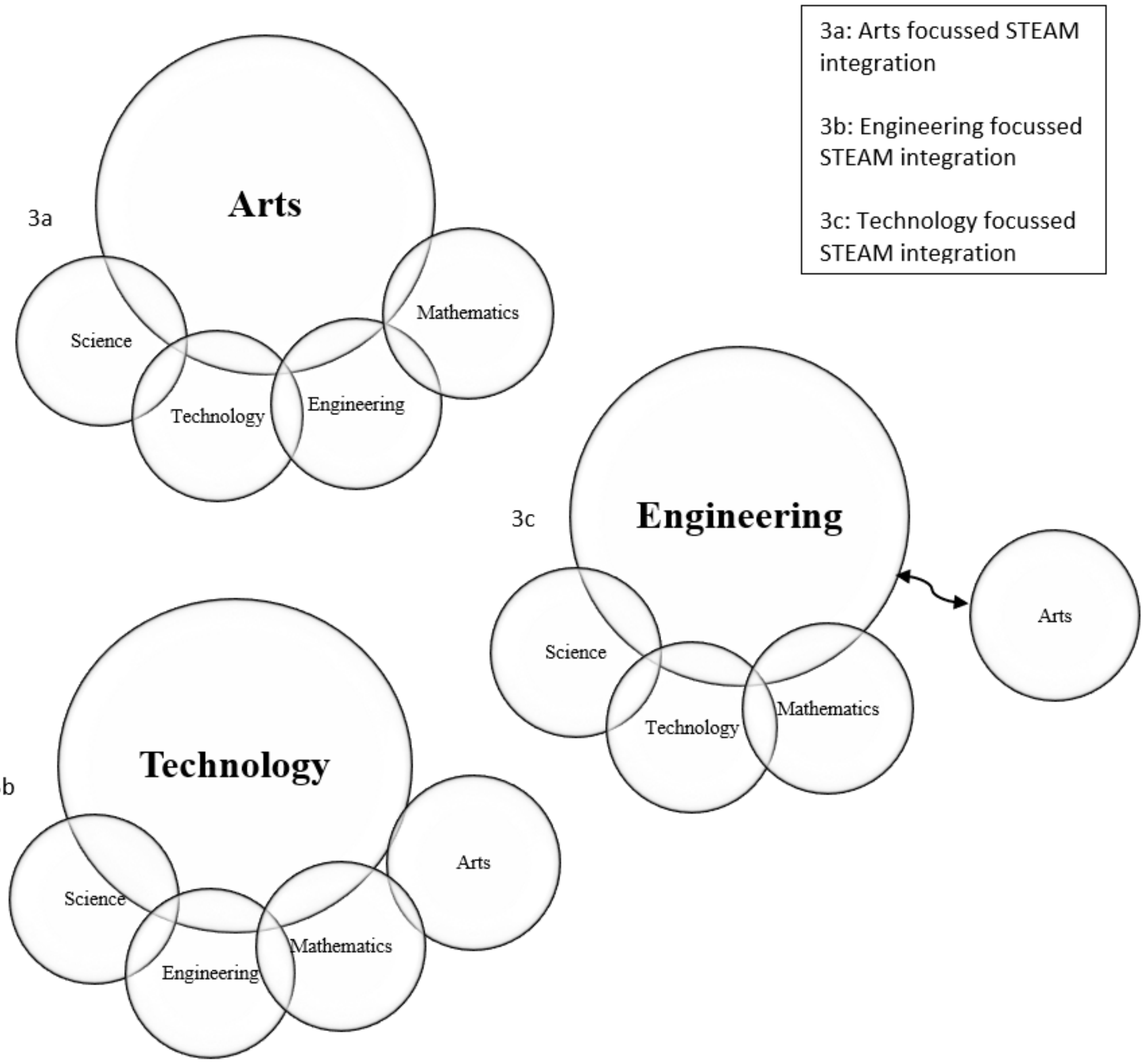

Figure 3. Arts, engineering or technology focused STEAM integration

in the ECE provides the flexibility for teachers to alter curriculum based on children's interests, strengths, and readiness. With the alterations, studies by Dilek et al. (2020) and Kermani and Aldemir (2015) found that children question, explore, and share findings through hands-on approaches according to the suitability of the context of each learning environment. Moreover, Hassan et al. (2019) reported that the inquiry process allows children to demonstrate their innate curiosity about the natural world.

Furthermore, Hassan et al. (2019) and John et al. (2018) proposed that children develop real-world problem-solving knowledge. Hassan et al. (2019) explained that this is achieved by disciplinary integration during the inquiry. A study by Kewalramani et al. (2020) described STEAM-focused playful inquiry experiences to provide an opportunity for a child-centered curriculum. The findings were similar to Vasquez's (2015) reports and justification of multidisciplinary and interdisciplinary STEAM integration.

An earlier study by Evangelou et al. (2010) found that picture storybooks helped children visualize and connect in the STEAM inquiry process. Vasquez et al. (2020) also advocated stories help introduce STEAM integration, especially for younger children. Dilek et al. (2020) indicated that reading and engaging with picture storybooks promoted interest in STEAM topics and modelling and reinforced appropriate vocabulary usage. Cinar (2019) concludes that young children without writing and reading capabilities benefit from this form of narrative-based and visual introduction.

The Existing STEAM Integration Practices

In this section, we report on existing STEAM integration practices. It consists of a multidisciplinary, art, engineering, or technology-centred approach and an interdisciplinary, art, engineering, and technology-focused approach for STEAM integration, as illustrated in **Figure 3**. These approaches are interpreted through **Figure 3** explanations.

Art focused integrating STEAM

Evangelou et al. (2010) reported that art was a form of expression and visualization for children with limited writing, speaking, and reading capabilities. Furthermore, the same study noted that visual representations allow children to connect to the world. **Figure 3a** depicts how arts are positioned in integrating STEAM integration practices. Sullivan et al. (2013) identified that arts-based approaches allow children to present their ideas while singing, and musical aspects help children engage meaningfully, allowing memory retention. Smith and Samarakoon (2016) also suggested that incorporating arts can boost children's engagement through visual representations. With arts in integrating STEAM practices, Aldemir and Kermani (2017) found that children learn by engaging actively with various materials meaningfully and with peers whilst also being scaffolded by teachers. As such, arts play a crucial role in helping link the abstract and the unknown with the children's existing knowledge and aid children's expression of understanding in their STEAM learning.

Engineering focused integrating STEAM

Lin et al. (2021) reported STEAM with engineering-focused science inquiry improved Chinese preschool children's science knowledge and skills. Tank et al. (2018) and Tippett and Milford (2017) also suggested that within engineering-focused STEAM experiences, children develop questioning, processing, scientific, and engineering skills. Interestingly, Smith and Samarakoon (2016) reported that the combination of arts and engineering also supported children's learning through project-based approaches where children engage with arts as a form of expression to communicate their engineering solution. **Figure 3b** depicts how engineering is positioned in integrating STEAM integration practices.

Technology focused integrating STEAM

Digital technologies focused integrating STEAM integration practice was reported in six studies (Kermani & Aldemir, 2015; Kewalramani et al., 2020; Lowrie & Larkin, 2020; Sullivan & Bers, 2018; Sullivan et al., 2013; Weng & Li, 2020). For example, Lowrie and Larkin (2020) and Sullivan et al. (2013) regarded the significance of digital technologies within STEAM integration.

Figure 3c depicts how technologies (ICT) is positioned in integrating STEAM integration practices. A study by Kermani and Aldemir (2015) identified that age-appropriate ICT tools, such as iPads, were reported to boost children's engagement with the task and STEAM topic through questioning and problem solving. Sullivan and Bers (2018) proposed that the KIBO robot helped children understand building and construction engineering concepts during STEAM activities. However, as Lowrie and Larkin (2020) highlighted in their study, digital technologies should not substitute traditional play experiences. Hence, the critical role of technological tools is to augment children's play, together with physical materials such as blocks and puzzles in the ECE settings.

Arts, Engineering, and Technology Focused Integrating STEAM

Arts play a crucial role in promoting technology integration in STEAM education (Jackson et al., 2021). In the study by Sullivan and Bers (2018), culturally relevant music and dance helped young children learn and understand new robotics or programming concepts with appropriate tools. Lowrie and Larkin (2020) highlighted the importance of maximizing meaningful engagement during the allocated screen time to ensure children do not lose track of their digital investigation. Lowrie and Larkin (2020) provide an excellent account of how combining the cultural aspect to increase relevance and maximizing each screen time usage is achievable in classroom settings with mindful planning. A conceptual framework illustrating art, digital technologies and engineering focused in integrating STEAM is depicted in **Figure 4**.

Lowrie and Larkin (2020) advise that educators should be mindful of digital technologies' role in STEAM integration to ensure that digital play does not overcloud the main learning goals. Sullivan et al. (2013) found the combination of engineering and robotics had promoted understanding in children's learning. This

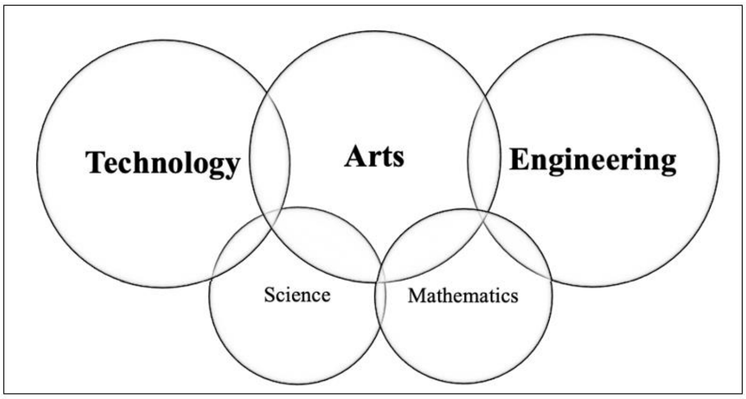

Figure 4. Arts, technology, and engineering focused STEAM integration

combination provided a suitable context for children to develop meaningful connections between the multiple STEAM disciplines. Studies by John et al. (2018) and Tank et al. (2018) demonstrated that the technological tools enable children to develop and present engineering solutions.

Factors to Consider When Integrating STEAM into Practices

Sullivan et al. (2013) posit the need for new initiatives and policies to guide STEAM integration into ECE instructional practices. Introducing exciting and relevant topics to engage children is crucial to ensure child-centered learning in ECE. Kermani and Aldemir (2015) explained transdisciplinary learning phenomena could occur across a crossover of all STEAM subject areas that incorporate learning from spontaneous, unplanned moments and planned open-ended and exploratory materials. Similarly, Smith and Cline (2016) emphasized the importance of stimulating creative play by providing open-ended materials.

Aldemir and Kermani (2017), Cinar (2019), and Hassan et al. (2019) explained children's meaningful engagement is visible because of STEAM integration. Educators provide a wide range of high-relevancy activities, both indoor and outdoor, incorporating different tools and materials, guided, and free play to extend children's learning. This approach is consistent in the following studies by Dilek et al. (2020), Kewalramani et al. (2020), and Lin et al. (2021), where learning inspired by real-life examples help children gather and translate knowledge and make links between past and present experiences. As Vasquez et al. (2013) explained, this form of learning is the highest form of STEAM integration, the transdisciplinary level of integration.

Even though STEAM education is highly relevant to real life, Cinar (2019) suggested that teachers present the learning outcomes based on the existing curriculum to explore real-life problems to achieve meaningful learning and desirable learning outcomes consecutively.

Dilek et al. (2020) and Kewalramani et al. (2020) also reported that children tend to observe and attempt to link real-life understanding situations and scientific concepts in a STEAM play-based inquiry exploration. Similarly, Lin et al. (2021) posit that children tend to ask questions guided by their curiosity while exploring with their peers and teachers when engaged in STEAM play-based inquiry.

Drawing from the findings of this integrative review study, **Figure 5** presents four factors to consider when incorporating STEAM into ECE.

Meaningful play experiences in STEAM

The first factor to consider is introducing meaningful play experiences in STEAM. Vasquez et el. (2020) argue

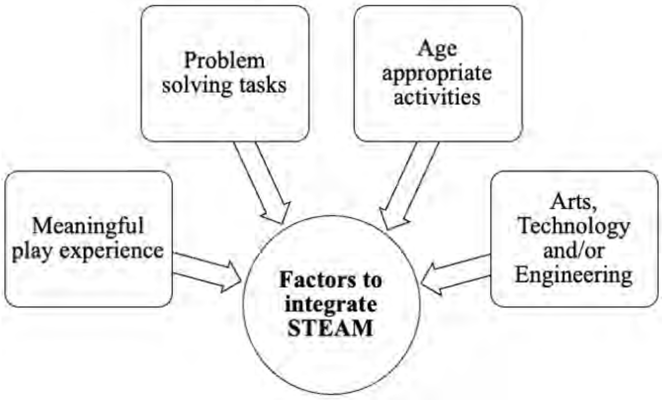

Figure 5. Factors to consider when integrating STEAM into ECE

that meaningful learning is at the heart of successful STEAM integration. For children to make meaningful connections with the learning contents, Chen and Chen (2021) and Sullivan and Bers (2018) emphasized the importance of providing relatable activities and learning experiences that incorporate STEAM subjects. Cinar (2019) added that the nature of STEAM education's teaching and learning process is through hands-on approaches. Several studies, including Aldemir and Kermani (2017), Kermani and Aldemir (2015), and Smith and Cline (2016), supported the notion of providing a wide range of meaningful hands-on learning through play. John et al. (2018) explored this notion and suggested it was a form of problem solving found in STEAM play process.

Problem solving STEAM play activities

The next factor to consider is problem solving, which can be integrated into meaningful STEAM play experiences. The notion of a meaningful experience was explored by Cinar (2019) and Hassan et al. (2019), emphasizing aspects of reality and practicality within the problem solving process. As Vasquez et al. (2013) proposed, problem solving is prominent in the fourth level of STEAM integration, transdisciplinary. During reality inspired play, children develop a sense of agency by taking on different decision-making roles and using different open-ended resources, materials, tools, and skills to stimulate creative play. The hands-on learning through the play process helps children build a personal connection with the experience by interacting physically and emotionally with the task and materials (Aldemir & Kermani, 2017). Educators can make the different play experiences meaningful and enriching through the problem solving process while also integrating science, mathematics, engineering, and technology. Thus enabling transdisciplinary inspired play also promotes the development of disciplinary skills meaningfully.

Age-appropriate STEAM learning

The third factor to consider is introducing age-appropriate STEAM learning experiences. A study by Evangelou et al. (2010) proposed that setting age-appropriate learning experiences and materials are crucial to ensure children stay engaged with the STEAM problem. This importance was also reported by Smith and Cline (2016). Smith and Cline (2016) also reported that children developed considerable skills from a practical problem that required observing, visualizing, manipulating, and recognizing patterns. A later study by Hassan et al. (2019) also clarified that age-appropriate STEAM learning encourages intuitive play with the presence of teacher's scaffolding only when necessary.

In addition, Cinar (2019) added other skills such as hypothesizing, designing, communicating and reporting information that also can be developed through age-appropriate STEAM integration. Dilek et al. (2020) reported that presenting age-appropriate topics in STEAM integration exploration could benefit children as long as the STEAM problem was well-planned, stimulating, developmentally, and physically appropriate.

Arts, technology, and engineering

The fourth factor to consider is incorporating arts, technology, and engineering into introducing integrating STEAM. In the investigation process, Hassan et al. (2019) explained that STEAM activities help guide and shape the learners' thinking as STEAM aids in connecting the different knowledge and skills. A study by Sullivan and Bers (2018) introduces and integrates new robotics technologies as tools for learning programming concepts together with music, culture, and dance. Another study by Lin et al. (2021) explores integrating science and engineering with movement. However, it is essential to acknowledge that digital actions enhance the whole play experience rather than dominating traditional hands-on play, and play does not always have to be digital.

Furthermore, Dilek et al. (2020) elaborated that multiple, meaningful, yet personal learning moments anchor children to gather, develop, transfer, and translate knowledge from one play activity to another. The study by Lin et al. (2021) concludes that meaningful STEAM activities enable young learners to participate in the decision-making process by exploring real-life scenarios. Hence, as per Vasquez et al. (2013), this level of meaningful participation reflects the full integrated learning experience of transdisciplinary integrating STEAM.

Challenges to Integrating STEAM in ECE

The multiple definitions that attempt to clarify integrating STEAM do not provide enough guidelines for the integrate STEAM practices. As a result, several

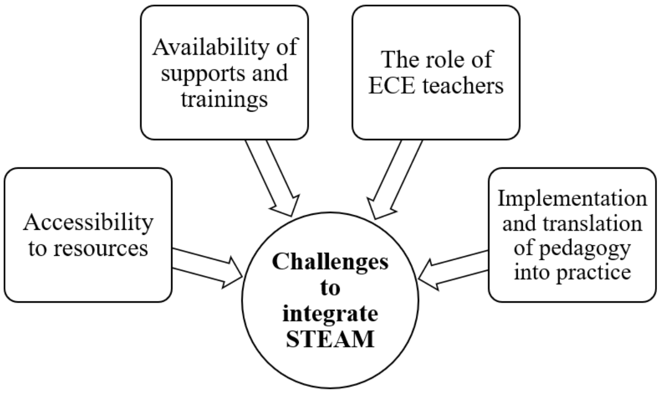

Figure 6. Challenges to integrating STEAM into ECE

challenges have been identified. **Figure 6** highlights the key challenges that include perspectives of accessibility, availabilities, teachers, educators, and implementation and translation from pedagogy into practice.

Accessibility to resources

The articles report that the limited availability of professional development opportunities for teachers, external training, teaching resources, and support are not often available to allow integrating STEAM integration skills. Aldemir and Kermani (2017), John et al. (2018), and Weng and Li (2020) have shown that resources, training, and support are crucial to developing clarity of integrating STEAM and STEAM knowledge, skills, and integration into ECE settings. However, when resources, training and support are absent, educators have reported that it is overwhelming to teach and integrate integrating STEAM into the existing curriculum (John et al., 2018; Lowrie & Larkin, 2020; Weng & Li, 2020).

However, the reality of anxiety regarding the accessibility of age-appropriate materials, accommodating EAL learners, lack of sequencing curriculum units and lack of time continue to challenge teachers in implementing STEAM (John et al., 2018). The resourceful teachers that Tippett and Milford (2017) recruited expressed that limited resources were not an actual obstacle in integrating STEAM. A similar finding found teachers used the arts to help understand and improve communication with children (Smith & Samarakoon, 2016).

Availability of support and training

Tippett and Milford (2017) found that despite the anxiety in integrating STEAM practices, teachers consciously implement STEAM and improve their teaching practices. A study by Smith and Samarakoon (2016) found that training and support provided to teachers targeting Arts in STEAM helps improve teachers' understanding of their children's performances. Similarly, Aldemir and Kermani (2017) reported that teachers felt supported in their STEAM integration when they supplemented teaching materials and activities. Supplementing teaching resources promotes teachers' confidence to integrate the multiple STEAM subjects.

In addition, Weng and Li (2020) reported that teachers and ECE leaders continue to express the difficulties to include early technology education for children younger than five years old despite technological tools being widely available and affordable. In the study by Weng and Li (2020), teachers reported that the missing special professional training affected the integration process as teachers had little experience in engaging technology in China's ECE. In the study by Sullivan et al. (2013), teachers and educators had to provide high levels of attention and scaffolding to help children master the newly introduced programming concepts. The younger children require higher levels of scaffolding and personal interactions. This may be an obstacle for STEAM integration as there may be limited staff available along with the appropriate content knowledge and expertise to meet every child's individual learning needs.

The role of ECE teachers

The role of the teacher impacts children's STEAM learning. However, teachers STEAM professional learning is a critical challenge in ECE. Teachers reported a boost in their confidence and understanding of STEAM teaching pedagogies with improved ability to incorporate STEAM tasks when support is being available (John et al., 2018). Another study in the same year by Weng and Li (2020) expressed that teachers in China also recognized the importance of STEAM integration and the crucial role that teachers' play in the success of integration and deliverance of STEAM education. The Chinese teachers expressed low confidence in translating the STEAM pedagogical approaches into classroom practices. Teachers find integrating STEAM activities too challenging (Hassan et al., 2019) and need support from educational leaders. The saying 'it takes a village to raise a child' can be translated into the ECE STEAM context as it requires more than just teachers' involvement to ensure the successful STEAM integration in ECE.

Implementation and translation from pedagogy into practice

Limited content knowledge of STEAM fields also poses a challenge for STEAM integration practices. Aldemir and Kermani (2017), John et al. (2018), and Weng and Li (2020) discussed these challenges. Aldemir and Kermani (2017) identified that teachers teach STEAM subjects separately, especially engineering. However, when supported through professional learning, teachers continue to improve their knowledge and capability to integrate STEAM. Weng and Li (2020) reported teacher anxiety surrounding limited content knowledge, thus affecting teachers' confidence in their personal ability to design and provide age-appropriate activities with STEAM education in mind. But, John et al. (2018) had proposed that teachers could adapt, reuse, and modify the STEAM curriculum to help introduce a STEAM integrated classroom. This form of guidance acts as a disposition to teachers' attitudes when teaching STEAM.

The previous sections of this paper have presented the findings of an integrative literature review that explored the initial research question: What is STEAM integration? The review results revealed no clear definition of integration, nor is there a clear indication of what the integration process in ECE classroom entails. The review highlighted key factors and challenges as reported by teachers. The remainder of this paper responds to the second research question: What are the STEAM integration practices in ECE?

TRANSDISCIPLINARY INTEGRATION AND NAVIGATING STEAM (inSTEAM): A CONCEPTUAL FRAMEWORK

We utilize the learnings from the first research question and present a conceptual framework that best explains the current research literature around integrating STEAM integration in ECE settings. The conceptual framework derives from the concepts, empirical research and theories explored in our integrative review of the 17 articles. Our conceptual framework, presented below, is a visual representation of the integration of the 17 articles, providing a display of how ideas reported in the 17 articles relate to one another. Creating a conceptual framework based on the 17 articles offers many benefits to our learning. For instance, it assists our understanding of the nature of integrating STEAM integration in ECE settings. From this deeper understanding, we can make suggestions for improving the teaching of integrating STEAM in ECE settings. Our integrative review has highlighted that the existing theories are insufficient to create a firm understanding of the ECE integrating STEAM integration process. The remainder of this paper presents the conceptual framework, which addresses this shortcoming in the literature.

Figure 7 illustrates the conceptual framework drawn from the findings of this study for integrating and navigating STEAM in ECE. This framework contributes to the literature by exploring integrating STEAM practices and guiding the implementation of transdisciplinary integrating STEAM practices in ECE. Even though this STEAM transdisciplinary framework derives from the ECE articles, it is still of benefit to other school levels', teachers and students. The framework covers the factors and challenges for integrating STEAM practices that emerged from the review of the 17 articles.

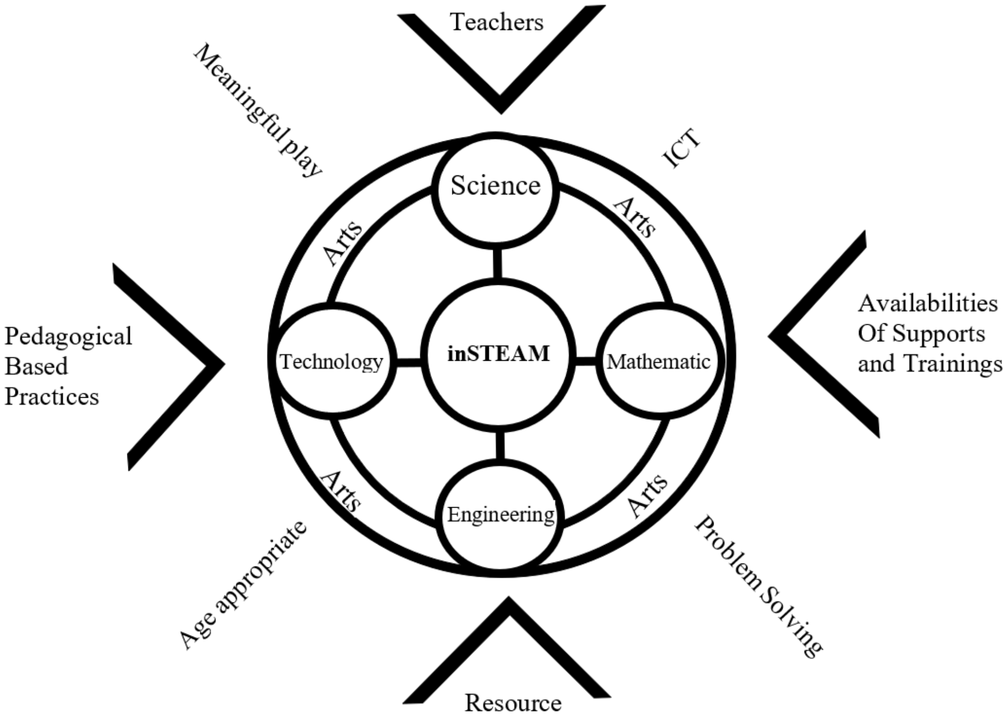

Figure 7. Transdisciplinary integrating and navigating STEAM (inSTEAM) conceptual framework

Figure 7 illustrates the *transdisciplinary integrating and navigating STEAM (inSTEAM) conceptual framework* in the form of a four-exit roundabout. These four exits represent a way to navigate STEAM integration. The methods that aid in navigating STEAM integration are meaningful play, the usage of ICT, age-appropriate learning tasks, and problem-solving based activities. In addition, the road reserves between each intersection represent the challenges that intercept STEAM integration based on the 17 STEAM articles. These reserves, as in possible holdbacks from integrating STEAM, are

(1) teachers' interest, content knowledge and capabilities to teach STEAM,

(2) the interpretation and implementation of relevant STEAM based pedagogical practices,

(3) relevant availability of support and training to aid the integration process, and

(4) the accessibility to relevant resources for teaching STEAM.

The central island represents the essence of integrating and navigating STEAM, which includes an equal emphasis between the STEAM disciplines–science, technology, engineering, and mathematics. However, in this conceptual framework, arts present itself as a loop that connects the STEAM disciplines, and the arts are an overarching bridge rather than an individual subject. Our review findings uncover how the arts enable each STEAM discipline integration. Furthermore, it is acknowledged that not every STEAM play activity will emphasise all STEAM disciplines equally. However, the key learning is that this framework develops an in-depth understanding of the relationships between STEAM disciplines to help navigate their process of integrating STEAM and enable transdisciplinary integration. This study extends Vasquez et al.'s (2020) four-level framework by offering the factors to facilitate integrating STEAM while also understanding the challenges and processes of STEAM integration.

Implications and Application of Integrating and Navigating STEAM (inSTEAM) in Research and Practice

The integrating and navigating inSTEAM conceptual framework offers perspectives into the implication and application of navigating STEAM integration into ECE. This framework is a guideline for ECE STEAM programs, school, kindergarten, preschool settings, and early learning centres. This framework aims to help teachers and educators of inSTEAM deliver rich and relevant authentic transdisciplinary learning experiences. In the process of integrating STEAM into the early childhood curriculum, the provided options to help deliver STEAM can exist in the form of both planned and unplanned learning through play. Teachers and educators can use the suggested approaches (see **Figure 3**) on their own or a combination to help mitigate the presented challenges as covered in the inSTEAM framework. However, when planning, teachers and educators are encouraged to include all areas of STEAM disciplines by introducing authentic and relevant real-life problems when possible.

The inSTEAM conceptual framework guides STEAM integration-related research in the future. The framework was developed based on the published empirical studies reporting STEAM integration in ECE. The inSTEAM conceptual framework provides a pedagogical lens to analyze and interpret future study data in STEAM integration will allow continuity for an endorsement of highly relatable authentic STEAM education. Lastly, the inSTEAM conceptual framework should be used as a baseline example to develop more frameworks suited at the curriculum and policy levels. As reported in this study, STEAM integration is ambiguous, especially in ECE. This inSTEAM conceptual framework aims to consolidate and act as a lens to guide research and practice. This review also revealed the importance of STEAM integration and its approach in ECE. Despite the challenges, integrating and navigating STEAM into ECE is possible, as indicated by the inSTEAM framework. The inSTEAM conceptual framework responds to the second research question: What are the STEAM integration practices in ECE? The framework provides a pedagogical lens into integrating STEAM practices. This then provides a foundation for the analysis and interpretation of future study data in STEAM integration.

CONCLUSION AND FURTHER RESEARCH

In conclusion, this integrative review synthesizes the existing state of integrating STEAM understanding, quality, and existing gaps in the literature of integrating STEAM in ECE. This paper also provides certainty to integrating STEAM through the inSTEAM conceptual framework. The literature also revealed how STEAM integration was perceived, current approaches to integration, and the challenges of integrating STEAM in ECE. Integrating STEAM needs to provide an equal opportunity to access STEAM professional learning (Aldemir & Kermani, 2017), engage children in authentic and meaningful learning experiences (Smith & Samarakoon, 2016), and boost children's interests in learning STEAM-related topics (Smith & Cline, 2016). It was possible to move beyond the single silo subject teaching approaches to merging the STEAM disciplines across early learning tasks. There is an increased need for children to learn through authentic experience to build relevant 21st-century skills (Partnership for 21st Century Learning, 2016). Although challenges exist, it should not deter the teachers and educators from prioritizing integrating STEAM and inSTEAM, which often may be switching teachers' pedagogy and aligning their teaching according to the current needs of their learners and society.

In addition, transdisciplinary integration should not be considered the end destination that STEAM educators should have as the end goal. According to Vasquez (2015), no one level of integration is superior to the others. Transdisciplinary learning is not the ultimate answer to integrating STEAM. Instead, STEAM integration focuses on the 'doability' and the personalization of lessons and experiences. The inSTEAM conceptual framework positions itself as a guidance tool to help support teachers' practices. The argument of the indefiniteness of STEAM integration is not to be confused with the lack of structure and professional learning for actual practice translation (Vasquez, 2015). The flexibility offers an opportunity for STEAM to be integrated into almost every classroom, accommodating different curriculum standards, national policies, and the resources available in each educational setting.

This universality of STEAM further highlights the need to study and perhaps conceptualize the practices of STEAM integration as a learning continuum at all schooling levels. However, additional research and further discussions of STEAM integration in ECE, primary, secondary and tertiary learning are needed to develop a methodology of implementation into the classroom. Future research could also evaluate the inSTEAM conceptual framework focusing on how the framework can guide real-life practices. This can be studied from the perspective of teachers, learners, educational leaders, and the management level. Teaching approaches supporting STEAM integration can be studied concerning how they address the challenges present in the STEAM integration process.

Author contributions: AN, SK, & GK: co-conceptualized the ideas, formulated the overarching research goals and aims, co-developed and co-designed the methodology and the creation of models, and reviewed and edited the draft; **AN:** wrote the original draft, acquired, analyzed, and interpreted the results and other research outputs; and **SK & GK:** validated and verified the interpreted results and other research outputs and supervised and oversighted the research activity planning and execution. All authors have sufficiently contributed to the study. All authors have agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Declaration of interest: No conflict of interest is declared by authors.

Availability of data and materials: All data generated or analysed during this study are included in this published article.

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