The iSTEM Rope Model: defining integrated early childhood STEM education and its pedagogical linages to the Reggio Emilia-Inspired Approach

Journal of Research in Innovative Teaching & Learning

131

Received 13 May 2024
Revised 29 July 2024
Accepted 29 July 2024

Alyse C. Hachey and Pratimaben J. Mehta
Teacher Education Department, The University of Texas at El Paso, El Paso, Texas, USA

Abstract

Purpose – This paper discusses the implementation of integrated science, technology, engineering and mathematics (EC-iSTEM) education with children in birth-to-age 5 classrooms. It offers a conceptualization for EC-iSTEM, as well as a developmental trajectory in the form of the iSTEM Rope Model. It further highlights the intersection of EC-iSTEM education and the Reggio Emelia-Inspired Approach (RE-IA) as a lens for both viewing EC-iSTEM implementation with young children and as an area of needed research.

Design/methodology/approach – This paper uses a qualitative interpretive methodology, drawing from a wide array of theoretical and research literature on early childhood education and integrated STEM education.

Findings – Despite growing research and policy reports that advocate for the inclusion of integrated STEM education in early childhood classrooms, today there is currently imprecision in understanding what exactly "integrated STEM" means when applied to the instruction of very young children. This suggests a need for the creation of a unifying conceptual framework, as well as finding alignment with currently known pedagogical approaches to ground the work of birth-to-age 5 teachers and researchers.

Research limitations/implications – This paper proposes a new conceptualization of integrated STEM education for use in birth to age 5 classrooms, as well as a systhsis of the current literature to assess the pedagogical linkages between EC-iSTEM and RE-IA. As the proposed conceptualization offered in this paper is new and research in this area is nascent, further empirical investigation is warrented.

Originality/value – This paper proposes a new conceptualization of integrated STEM education for use in the early childhood education field. It further synthesizes the current literature to assess the pedagogical linkages between EC-iSTEM and RE-IA, suggesting practice implications for supporting the knowledge and skill development of young children from birth to age 5.

Keywords Early childhood education, Integrated STEM education, Reggio Emilia-Inspired approach, Early STEM learning

Paper type Conceptual paper

Introduction

With the need to aid the development of 21st century skills as well as to provoke interest in science, technology, engineering and mathematics (STEM) careers (Widya *et al.*, 2019), there continues to be a focus on engaging elementary and middle school students in STEM education. However, many students do not develop STEM identities or see themselves in STEM careers by middle school, particularly those who come from racially minoritized and

Journal of Research in Innovative Teaching & Learning
Vol. 19 No. 1, 2026
pp. 131-144
Emerald Publishing Limited
2397-7604
DOI 10.1108/JRIT-05-2024-0125

lower socioeconomic backgrounds (Talafian *et al.*, 2019). This has led to recent calls for more focused attention on shifting STEM education efforts to earlier ages (Aldemir and Kermani, 2017; Hachey, 2020; University of Chicago STEM Education Center [UCHICAGO], 2017; Johnston *et al.*, 2022; McClure *et al.*, 2017). Yet, data suggest that less than 10% of kindergarten through second-grade instructional time in the USA is devoted to STEM content (Pantoya *et al.*, 2015).

The literature indicates even less integrated early childhood STEM [EC-iSTEM] [1] education under age 5 (e.g. Johnston *et al.*, 2022; NASTA, 2024; Smart and Lessons Learned From Successful Schools, 2013; Tippit and Milford, 2017), perhaps because discussions of EC-iSTEM have only recently become more of a focus (University of Chicago STEM Education Center [UCHICAGO], 2017). However, the early years are an important period for establishing many prerequisite conceptual knowledge and skills for building later expertise across STEM disciplines (Aldemir and Kermani, 2017). Instructional experiences during the birth to age 5 range lay the foundation and shape trajectories for all later learning and development, including STEM (Hachey, 2020; Shonkoff, 2017; Tippet and Milford, 2017), as well as arousing interest in STEM disciplines (NRC, 2011) and setting the stage for early STEM academic identity development (Hachey, 2020). While the current literature does provide evidence of young children as capable of science (Köksal, 2022; Larimore, 2020; Sikder and Fleer, 2018), mathematics (Clements and Sarama, 2021; Ginsburg *et al.*, 2008; Franzén, 2021) and engineering (Dorie and Cardella, 2014; Pantoya *et al.*, 2015; Lippard *et al.*, 2017) learners under age 5, there is little evidence of purposeful instructional integration across STEM disciplines in birth-to-age 5 classrooms and in particular with children under age 3 (Johnston *et al.*, 2022; Milford and Tippit, 2015; Tippit and Milford, 2017). Further, technology integration remains controversial in birth-to-age 5 classrooms, despite the term technology denoting any invented tool used to help humans complete a task (Vogels *et al.*, 2020) and digital technology (which is how the term is narrowly defined) being both ubiquitous in the daily lives of children under age 5 and having been shown to produce early learning affordances (Johnston *et al.*, 2022; Plowman *et al.*, 2012; Slutsky *et al.*, 2021; Sundqvist and Nilsson, 2018). Hence, the lack of widespread intentional implementation of EC-iSTEM runs counter to mounting evidence that exposure to integrated STEM instruction in the earliest years may hold critical relevance for life-long learning and interest in STEM (Johnston *et al.*, 2022).

Taken together, what little research is available, along with the policy literature, strongly avers the need to refocus attention on purposeful integrated STEM teaching practices with young children under age 5. Yet, across all age levels and particularly in the early years, there is often inconsistent use of language, failure to define terms and a lack of a framework for grounding STEM education as an integrated concept (Honey *et al.*, 2014). Hence, it is crucial that researchers and practitioners consider conceptions and related pedagogical practices that may assist in the implementation of high-quality EC-iSTEM education for children in this age range (Hachey, 2020; University of Chicago STEM Education Center [UCHICAGO], 2017; Larkin and Lowrie, 2023; McClure *et al.*, 2017). This paper explores the current literature on EC-iSTEM education, and it offers a conceptualization for practical usage. Further, it provides a comprehensive comparison and analysis of the core characteristics of EC-iSTEM and the Reggio Emilia-Inspired Approach (RE-IA) to early childhood education as a lens for enacting EC-iSTEM pedagogical practices with very young children.

EC-iSTEM and the iSTEM Rope Model

Though available scholarship argues the importance of deliberate STEM instruction for children under age 5 and nascent conceptualizations as to the nature of STEM applied to education in the earliest years are forming, the field currently lacks an adopted definition and means for pedagogical practice. Tippit and Milford (2017) note that while STEM as an interdisciplinary approach to learning has gained wide attention in North America, there is little application of it in early childhood classrooms, combined with ambiguity and imprecision in the usage of the STEM acronym itself when applied to the education of young children. They, along with other scholars (i.e. Moomaw, 2013), contend that if any two of the four STEM disciplines are intentionally explored together with young children, then a learning activity may fall under the designation of "STEM." Other scholars (i.e. Soylu, 2016) contend that STEM education applied to the early years includes the integration of all four disciplines as a whole as the instructional focus (with knowledge and skill growth in one discipline dependent on knowledge and skills from *all* three of the other disciplines and all disciplines equally emphasized). Still, other policy reports (i.e. McClure *et al.*, 2017) view STEM education in the early years as present any time one discipline is integrated to enhance the teaching and learning in another discipline (i.e. a primary discipline knowledge and/or skill is used to enhance the learning of a second discipline knowledge and/or skill – for example, utilizing a technology application to teach mathematical concepts). While integration is a common theme in these varied conceptions of STEM education for young children, the imprecision previously noted is readily apparent in terms of what constitutes the exact nature of integration; this mirrors similar disparate interpretations of what constitutes "integrated STEM" in the literature for higher age levels (English, 2016; Ortiz-Revilla *et al.*, 2020, 2022). The confusion is further compounded when accounting for international research with early childhood teachers, which strongly suggests that a majority of them view STEM as just a listing of the four identified disciplines, as a substitute for science (rather than some form of cross-discipline integration as noted by most scholars) or as a stand-in term for hands-on, and/or play-based instruction related to general problem-solving (Honey *et al.*, 2014; Wan *et al.*, 2021). This, too, is reflected in the early childhood literature, where STEM in the early years is often used as a catch-all term for any instruction that touches on one of the individual disciplines, particularly when connected to inquiry-based teaching practices.

Therefore, the first major issue for teachers and researchers is the different interpretations of what actually constitutes STEM education in early childhood education. The literature conceptualizes STEM education (generally) from disciplinary to transdisciplinary explanations (see Table 1).

The claims for the cognitive and affective benefits of integration found both in early childhood and older-age literature (e.g. Hachey, 2020; English, 2016; Honey *et al.*, 2014; Nadelson and Seifert, 2017; McClure *et al.*, 2017; Moomaw, 2013; Soylu, 2016; Tippit and Milford, 2017) preclude the adoption of a strict disciplinary stance. For this reason, we deliberately use the term EC-iSTEM to draw explicit attention to knowledge and skills *across* disciplines as the foundational element. Further, we argue the adoption of a multidisciplinary

Type of integration	Definition
Disciplinary	Discipline-specific knowledge is learned separately with no connections made to other disciplines
Multidisciplinary	Discipline-specific knowledge is learned separately yet within a common theme and/or towards a common goal
Interdisciplinary	Closely connected discipline knowledge is learned together from different disciplinary perspectives
Transdisciplinary	Seamless amalgamation and/or seamless web of knowledge from multiple disciplines, considered simultaneously without regard to the perspective of any given discipline

Source(s): Adapted from English (2016), Ortiz-Revilla *et al.* (2020, 2022) and Nadelson and Seifert (2017)

Table 1.
Definition of STEM education from lowest to highest level of knowledge integration

conception of EC-iSTEM specifically for *knowledge development*, whereby concepts from *all four disciplines* are utilized to address aspects of a common theme and/or toward a common problem-solving goal and, although working in tandem, knowledge development draws from each discipline's perspective (English, 2016; Ortiz-Revilla *et al.*, 2022).

In this way, multidisciplinary-level teaching and learning occurs when concepts are addressed within each discipline while using the same instructional problem space. Adopting a multidisciplinary conception of EC-iSTEM for knowledge development, as opposed to an interdisciplinary or transdisciplinary stance for the education of children from birth to age 5, acknowledges the mental processing demands of these higher levels of integration, and that very young children first need time to gain competency within discipline-specific knowledge (Honey *et al.*, 2014; Wan *et al.*, 2021) before they gradually (in later grades) build from this foundation to translate and apply knowledge representational fluency between them. Yet still, it recognizes that from birth, humans have the capacity for nascent conceptual knowledge representation that they are ready to mentally begin the process of assimilation and accommodation of domain-relevant inputs (Aldemir and Kermani, 2017; Gelman, 1998) and that engagement with STEM concepts results in meaningful educational experiences for young children (Farris and Cammy, 2021).

Therefore, from a multidisciplinary perspective, integration is viewed as incorporating the building and use of disciplinary-specific learning opportunities (i.e. knowledge from all four disciplines) within the context of the overarching focus of the experience (a theme and/or problem-solving goal); it is the learning context and/or focus that is domain-general and thus requires knowledge from across disciplines (Nadelson and Seifert, 2017). We give the example of a three-year-old classroom exploration of spiders, whereby the children may learn terminology and characteristics of spiders (biological science), learn to take photographs of spiders on the playground and how to click through a spider presentation on a computer (technology), learn to follow a design process to create three-dimensional models of spiders (engineering) and learn shapes and patterns from those found on spiders (geometric math). The potential benefit of this multidisciplinary stance is that having young children engage in particular knowledge gain from the different discipline lenses serves to clarify and make explicit diverse ways of knowing and doing (Reynante *et al.*, 2020) while anchoring the learning to a conjoint purpose. Experimental support for utilizing a multidisciplinary stance to increase each conceptual knowledge gain is found in research by Aldemir and Kermani (2017) with diverse children ages 3–4.

While this does not situate EC-iSTEM knowledge development at the highest level of integration, it recognizes higher levels of integration as a longer-term developmental trajectory. Further, a multidisciplinary stance does offer the opportunity for knowledge gain that is wider in scope (Honey *et al.*, 2014) than it could be generated from attention to only individual (or perhaps two) disciplines, as well as leaving potential developmental room for connections to big ideas (associated multidisciplinary processes that interact) that may (Ortiz-Revilla *et al.*, 2022) be more interdisciplinary and/or transdisciplinary in nature. Additionally, by explicitly calling for teachers and researchers' attention to *all four* of the STEM disciplines, our conception of EC-iSTEM challenges stances both in the wider literature and early childhood literature that emphasize an "any two discipline" definition by centering the relevance of them all for young children, serving to mitigate growing concerns about inequitable foundational knowledge development in consistently less-prioritized STEM disciplines (English, 2016; Honey *et al.*, 2014).

Taking a multidisciplinary perspective for STEM knowledge development with young children does not, however, preclude teachers and researchers from recognizing a transdisciplinary stance toward EC-iSTEM *skills development* (also often referred to in the wider literature as process stills or cross-cutting practices). We argue this may be critical in

EC-iSTEM education. Collapsing the skills identified by Reynante *et al.* (2020), we identify four cross-discipline skill development areas that have application to children under age 5:

(1) *Investigating:* Novelty or the unexpected has been shown to draw the attention of young children; they are sensitive to ways of beginning inquiry by orienting to a perceived puzzle, making progress by drawing on sense-making resources (i.e. observations and/or examinations, experiments and imagined embodiment) and orienting to end exploration (i.e. a satisfactory explanation and a failed outcome) (Keifert and Stevens, 2018). Data suggest that young children are proficient questioners between ages 2 and 4 (they have knowledge based on things they find interesting and can ask significant questions) and that by age 5, much of their questioning centers on how and why (Engel, 2021; Helm *et al.*, 2023)

(2) *Problem-solving:* Young children (age 2–4) are capable of flexible, tool-dependent problem-solving (Bobrowicz *et al.*, 2020) and toddlers have been shown to solve problems in natural and meaningful ways (Babbington, 2006), as well as to seek out and use social support to help in problem-solving (Culver *et al.*, 2013). Research shows that preschoolers use developing content knowledge and reasoning skills to solve both real and hypothetical problems involving their everyday physical and biological world (Fusaro and Smith, 2018).

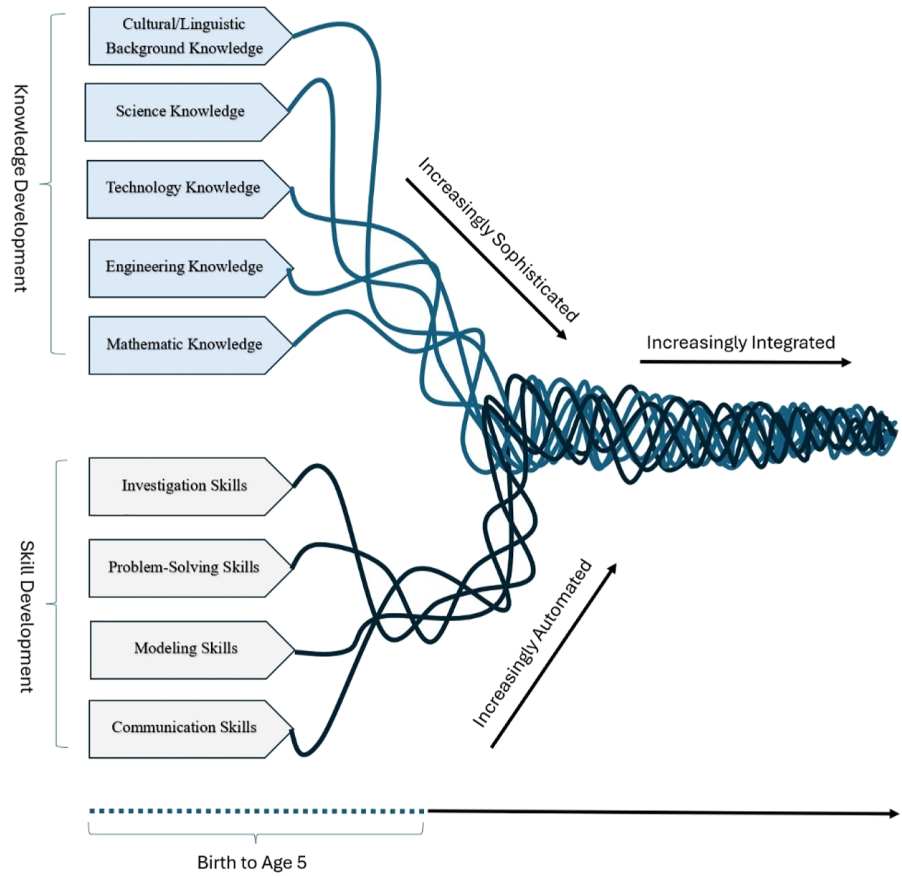
(3) *Modeling:* Young children (1 ½ years) construct using objects (Marcinowski *et al.*, 2019), and they start early to acquire the symbols needed to participate in their culture based on experience and/or exposure from everyday life (DeLoache, 1995). Around age 3, they can use modeling practices, both thinking with and thinking about models, as well as creating models and/or representations, as central to their engagement with evidence-based explanations (Plumber and Ricketts, 2018).

(4) *Communicating:* Children from birth to age 5 draw on a wide range of modalities, including movement, gestures, gaze and/or facial expression and, from toddlerhood and beyond, the addition of drawings, writings, diagrams, models, dramatization, symbolic play and other cultural tools and artifact usage that enable them to communicate and illustrate their meanings, perspectives, interests and ways of understanding aspects of their world (Marsh *et al.*, 2019; Taylor and Leung, 2020; Vygotsky, 1978).

Further acknowledged is that for young children, these four areas of skill development may be envisioned as a seamless amalgamation (Nadelson and Seifert, 2017) or a seamless web (Ortiz-Revilla *et al.*, 2020) of practices irrespective of discipline, whereby instructional attention is provided without regard to STEM discipline boundaries and/or perspectives. This acknowledges the adoption of a transdisciplinary conception for the identified EC-iSTEM *skill development* areas during the pursuit of authentic inquiry and problem-solving with young children.

Analogous to Scarborough's (2001) Reading Rope Model of integrated literacy, we thus put forth a conceptual framework of iSTEM that both offers starting strings of focus for work with children from birth to age 5, as well as providing a developmental trajectory for higher levels of STEM integration across later schooling (see Figure 1).

From this, we offer a precise definition of EC-iSTEM education for children from birth to age 5 as: within the pursuit of a common theme and/or toward a common goal, young children learn multidisciplinary conceptual knowledge *in each of the four disciplines* (separately) while utilizing transdisciplinary investigative, problem-solving, modeling and communication skills.



Source(s): Figure by authors

Figure 1.
iSTEM Rope Model-individual strands of discipline knowledge and process skills weave together over time toward fully integrated STEM usage by adulthood[2]

Pedagogical practice - considering RE-IA as a lens for EC-iSTEM education

With the starting strings of knowledge and skill development identified in our model, the question then turns to how these may be nurtured through deliberate instructional implementation in birth-to-age 5 classrooms. The task of engaging very young children with EC-iSTEM may seem daunting to practitioners, especially given data suggesting that early childhood teachers often have a limited understanding of both what EC-iSTEM is and how to teach it (Aldemir and Kermani, 2017; Ndijuye and Tandika, 2020; Park *et al.*, 2017). However, we contend that there is a strong and recognizable starting point for enacting EC-iSTEM education with children from birth to age 5 when the little available literature on “best practices” is married to a close consideration of an established approach in the early childhood field, RE-IA.

The pivotal characteristic of nearly all discussions of iSTEM education in the literature, regardless of the age level, is the utilization of everyday, real-world inquiry and problem-solving (e.g. Cherniak *et al.*, 2019; Conradty and Bogner, 2018; Kurup *et al.*, 2021; MacDonald *et al.*, 2020; McClure *et al.*, 2017; Yata and Isobe, 2020). High-quality EC-iSTEM education is viewed as child-centered inquiry experiences that promote investigative, hands-on, action-based engagement that encourages children to use all their senses to be responsive to their environment, explore objects and events, make observations and share their reflections (Hachey, 2020; Aldemir and Kermani, 2017; Campbell and Speldewinde, 2022; Farris and Cammy, 2021; McClure *et al.*, 2017; Smart and Lessons Learned From Successful Schools, 2013; Tippett and Milford, 2017). Thus, the emphasis is on teachers providing young children with objects, materials and phenomena to manipulate through play-based means and on engaging children in problem-based inquiry and creative making to encourage the generation of both ideas and artifacts (Johnston *et al.*, 2022; Marsh *et al.*, 2019; McClure *et al.*, 2017; Smart and Lessons Learned From Successful Schools, 2013; Stylianidou *et al.*, 2018; Wan *et al.*, 2021). In this way, inquiry and problem-based pedagogical practices serve to support not only the interconnectedness of the world and individual STEM discipline knowledge but also to foster skills and mindsets (dispositions) that are transferable and cross-disciplinary (Hachey, 2020; Wan *et al.*, 2021).

RE-IA is a unique teaching philosophy that offers a specific perspective on developmentally and culturally appropriate practices for young children (Gandini, 1993; Vatalaro *et al.*, 2015; Smith, 2021). We contend RE-IA as a well-known and widely practiced approach to early childhood education that embodies what the emerging literature contends is essential for EC-iSTEM education. In particular, there are four central pedagogical aspects of RE-AI that may offer guidance to teachers and researchers (both those in the RE-AI tradition and more generally) for EC-iSTEM education with children from birth to age 5: (1) RE-IA's image of the child; (2) provocation (also called learning invitations) and questioning as an instructional methodology and (3) the facilitation of open-ended projects and the prepared environment to support the "100 languages" of children.

Foremost, RE-IA recognizes that the choice made by teachers about the child's image has to be explicit, as this serves as the basis of all interaction, pedagogical or otherwise (Moss, 2016). The image of the child held by teachers in birth-to-age 5 classrooms is critical, as it sets the stage not only for a belief in the necessity of EC-iSTEM but also situates how to begin nurturing the starting strands of STEM knowledge and skill development. RE-IA philosophy is grounded in an image of the child as capable and a natural inquirer (asker of questions) and investigator (seeker of answers and/or information) through the hands-on manipulation of objects, the solving of real-world problems and trustful, collaborative interactions with peers and teachers (Gandini, 1993; Inan *et al.*, 2010). While many pedagogical frameworks use inquiry and investigation in practice (Farris and Cammy, 2021), RE-IA is anchored in questioning and self-directed reflection by both students and teachers, emphasizing the instructional value of beginning with uncertainty and inquiry. This sets children as protagonists and contrasts with an image of the child as an empty bottle to be filled with knowledge (whereby teaching practices may focus on stationary, rote drill); instead, instructional techniques are based on young children as skilled, creative and innately curious (Arseven, 2014; Moss, 2016). RE-IA positions young children as researchers (marked by their curiosity, ability to develop questions, openness to exploration and drive for discovery) (Fox, 2023; Stegelin, 2003). It positions teachers as facilitators, where they act as "compasses" that point children toward self-discovery and collaboration, with teachers deemed as co-constructors of knowledge (Arseven, 2014; Moss, 2016). Both this orientation of young children and of teachers in RE-IA aligns with the unvoiced yet inferable image of the child found in much of the EC-iSTEM literature, as well as our positioning of children birth to age 5 at the starting strands in the iSTEM Rope Model.

In RE-IA, teachers carefully observe young children, reflect on how their emerging knowledge and interests fit within conceptual and skill learning opportunities and then provide "provocations." Provocations occur when teachers offer different materials to children (natural objects or "lose parts" that may be freely used and manipulated in open-ended ways, books, pictures or photographs), present common materials in different ways, make an unusual and/or unexpected change in the physical environment, offer purposeful questions or comments or engage in intentional sense-making discussions that serve to draw children's attention (Kaynak-Ekici *et al.*, 2021). Provocations and teacher-modeled questioning are utilized to provoke interest and/or invite young children to explore materials, use objects and tools (i.e. technology) and ask questions themselves as they interact in self-driven ways with the physical and social world around them. Provocations as a method of instruction inextricably intertwine participants' use of cultural resources such as language and material tools (Martin and Evaldsson, 2012), allowing for a recognition of cultural and place-based learning effects on early conceptual and skill development. The teacher's role is to both thoughtfully provide provocations and support children (through additional materials and/or social scaffolding) as they study and then produce and test their hypotheses (Arseven, 2014). In this way, provocations as a teaching technique may serve as both the impetus and the means for active engagement in open-ended ways that promote personal and collective excitement and meaning-making (Inan *et al.*, 2010). Learning experiences based on intentional provocation may serve to provide the opportunity to deepen conceptual knowledge within STEM disciplines while at the same time allowing for the practice of process skills (Farris and Cammy, 2021).

Projects are another central instructional methodology in RE-AI (New, 2007). From children's everyday experiences and interests, investigative projects are undertaken, whereby teachers assist children in conducting their project by providing the materials, space and social scaffolding needed for observation, hands-on exploration, mistake-making, sense-making, problem-solving and creative expression around child-generated themes and ideas (Arseven, 2014; Gardner and Jones, 2016; Kaynak-Ekici *et al.*, 2021; Fernández Santín and Feliu Torruella, 2017). In RE-AI, projects may be short-term or long-term, based on children's interests, with teachers following children's sense of time and personal rhythms (Gandini, 1993). Further, projects may evolve from teacher provocation and/or questioning or chance events (we reference again our example of finding spiders on the playground, which engendered an EC-iSTEM investigative project with three-year-olds that utilized all the starting strings identified on the iSTEM Rope Model). Children working on projects in small groups is also an essential aspect of the RE-IA, serving to allow children to interact with each other and the materials in the environment in ways that are not highly structured (Vatalaro *et al.*, 2015) but which are organized toward a common theme or problem of interest. The teacher's role in project work is to carefully observe children as they interact with each other and the materials provided to determine (and provide) what additional materials or responses may be needed to help foster communication among the children and deepen conceptual thinking and the practicing of process skills (specifically, in this case, in each of the STEM disciplines and the four identified process skill areas). A strong emphasis in RE-AI is placed on reciprocity (social give-and-take) and the exchange of ideas and dialog between children, teachers and the wider community in pursuit of project goals (Inan *et al.*, 2010).

RE-IA also advocates for the purposeful design of classroom environments and experiences that provide materials, time and space for children to utilize their "100 languages" through artistic and/or emergent literacy engagement and storytelling (i.e. dance, visual arts, music, drama and emergent symbolic writing) (Arseven, 2014). This includes ensuring that classrooms are carefully equipped with print-rich materials, an array of visual arts and writing materials, communication-based technologies and dramatic and storytelling props so children have the opportunity to translate concrete experiences into symbolic expression. RE-IA teachers recognize language as including yet going beyond verbal means (Fernández Santín and Feliu Torruella, 2017). In RE-AI, multimodal artistic expression is not secondary – instead, multimodal representational and artifact creation in many media is seen as a central element for gaining, deepening and depicting thinking (Baker, 2015; Gandini, 1993; Swann, 2008). We note that RE-IA's concept of Ateliers (i.e. art workshops or studios (Moss, 2016; Parnell, 2011) closely parallels STEM makerspaces, which are viewed as material-rich environments that allow for iterative, experimental and playful creative expressions of knowledge (Gurjar, 2021; Marsh *et al.*, 2019). The study of Ateliers and the arts-infused practices of RE-IA may be critical for teachers engaging in EC-iSTEM education, as research strongly suggests materials and experiences that foster multimodal engagement offer the opportunity for pre-formal literate children to use verbal, kinesthetic and physical modes of communication both for gaining early STEM multidisciplinary conceptual knowledge and practicing modeling and communication skill development (Hu *et al.*, 2021; Johnston *et al.*, 2022; Malone *et al.*, 2018).

However, it is unclear if teachers who are utilizing RE-IA are making explicit pedagogical connections to EC-iSTEM, and there is a specific lack of knowledge of implementation with children from birth to age 3 (Trepanier-Street *et al.*, 2001). And, with the lack of implementation of EC-iSTEM in birth-to-age 5 classrooms (e.g. Johnston *et al.*, 2022; Smart and Lessons Learned From Successful Schools, 2013; Tippit and Milford, 2017), it is likely that practitioners and researchers more generally are not utilizing RE-IA as a potential pedagogical lens for EC-iSTEM. Specifically, there is a lack of investigation into how practitioners, especially toddler and preschool teachers, perceive and implement both EC-iSTEM and RE-IA in their classrooms. Since educational experiences from birth to age 5 play a foundational role in shaping future learning paths and incorporating EC-iSTEM education is crucial, this gap needs to be addressed.

Conclusion

The wider educational landscape, along with emergent thinking and research specific to the early childhood education field, highlights the value and relevance of integrated understandings of STEM both for academic success and everyday life (Johnston *et al.*, 2022). Yet, a major impetus for the dearth of implementation of STEM education in the early years seems to be a lack of a precise framework for STEM as an integrated concept. In moving forward, we suggest the iSTEM Rope Model and the conceptualization outlined in this paper specifically for EC-iSTEM as a common starting point for grounding work with children from birth to age 5. From this place, teachers and researchers will need to address how the starting strings of knowledge and skill development identified in the iSTEM Rope Model may be nurtured. Our discussion of key aspects of RE-IA indicates that this may not be as great a pedagogical quandary as one might first suspect, with this well-known and practiced approach to early childhood education offering potential insight into implementing EC-iSTEM education. However, both the practical application of the conceptual framework offered in this paper, as well as further investigation of linkages between EC-iSTEM and RE-IA, need further study in birth-to-age 5 classrooms if we are to better support the EC-iSTEM knowledge and skill development of our youngest children.

Notes

1. In the United States of America, early childhood education is generally defined as from birth to age 8 [3rd Grade] (NAEYC, 2020). However, this paper is specifically focused on the earliest end of this spectrum – birth to age 5 (which, from the USA perspective, we denote as "Prekindergarten"). While EC-iSTEM education generally spans from birth to age 8, when it is referenced here, we are specifically speaking to intentional iSTEM instructional experiences with children from age 5 (in the infant, toddler and preschool range).

2. It is important to note that, like Scarborough's reading rope model, the iSTEM Rope Model accounts for the influence and impact of the sociocultural nature of learning (Vygotsky, 1978). However, unlike Scarborough's model, which suggests full integration and literacy expertise by around 3rd grade (age 8–9), the trajectory for full integration and learner expertise in the iSTEM Rope Model is posited to span through adolescence and/or adulthood.

References

Aldemir, J. and Kermani, H. (2017), "Integrated STEM curriculum: improving educational outcomes for head start children", *Early Child Development and Care*, Vol. 187 No. 11, pp. 1694-1706, doi: 10.1080/03004430.2016.1185102.

Arseven, A. (2014), "The Reggio Emilia approach and curriculum development process", *International Journal of Academic Research*, Vol. 6 No. 1, pp. 166-171, doi: 10.7813/2075-4124.2014/6-1/B.23.

Babbington, S. (2006), "Emma's story: a case study of a toddler's problem solving development", *ACE Working Papers, Issue 17: Science, Mathematics and Technology Education*, available at: https://researchspace.auckland.ac.nz/bitstream/handle/2292/25158/ACE_Paper_3_Issue_17.pdf?sequence=1&isAllowed=y (accessed 1 May 2024).

Baker, F.S. (2015), "Reflections on the Reggio Emilia approach as inspiration for early childhood teacher education in Abu Dhabi, UAE", *Early Child Development and Care*, Vol. 185 No. 6, pp. 982-995, doi: 10.1080/03004430.2014.974036.

Bobrowicz, K., Lindstrom, F., Lindblom Loven, M. and Psouni, E. (2020), "Flexibility in problem solving: analogical transfer of tool use in toddlers is immune to delay", *Frontiers in Psychology*, Vol. 11, p. 573730, doi: 10.3389/fpsyg.2020.573730.

Campbell, C. and Speldewinde, C. (2022), "Early childhood STEM education for sustainable development", *Sustainability*, Vol. 14 No. 6, pp. 1-11, doi: 10.3390/su14063524.

Cherniak, S., Lee, K., Cho, E. and Jung, S.E. (2019), "Child-identified problems and their robotic solutions", *Journal of Early Childhood Research: Experimental Cell Research*, Vol. 17 No. 4, pp. 347-360, doi: 10.1177/1476718X19860557.

Clements, D.H. and Sarama, J. (2021), *Learning and Teaching Early Math: the Learning Trajectories Approach*, Routledge, New York.

Cluver, A., Heyman, G. and Carver, L.J. (2013), "Young children selectively seek help when solving problems", *Journal of Experimental Child Psychology*, Vol. 115 No. 3, pp. 570-578, doi: 10.1016/j.jecp.2012.12.011.

Conradty, C. and Bogner, F.X. (2018), "From STEM to STEAM: how to monitor creativity", *Creativity Research Journal*, Vol. 30 No. 3, pp. 233-240, doi: 10.1080/10400419.2018.1488195.

DeLoache, J.S. (1995), "Early understanding and use of symbols: the model model", *Current Directions in Psychological Science: A Journal of the American Psychological Society*, Vol. 4 No. 4, pp. 109-113, doi: 10.1111/1467-8721.ep10772408.

Dorie, B.L., Cardella, M. and Svarovsky, G.N. (2014), *Capturing the Design Thinking of Young Children Interacting with a Parent*, Purdue University E-Pubs, 24.256.1-24.256.7, available at: https://docs.lib.purdue.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1051&context=enegs (accessed 10 May 2024).

Engel, S.L. (2021), *The Intellectual Lives of Children*, Harvard University Press, New York. doi: 10.4159/9780674250512.

English, L.D. (2016), "STEM education K-12: perspectives on integration", *International Journal of STEM education*, Vol. 3 No. 3, pp. 1-8, doi: 10.1186/s40594-016-0036-1.

Farris, S. and Cammy, P. (2021), "STEM in early childhood: establishing a culture of inquiry with young children", *Dimensions of Early Childhood*, Vol. 49 No. 2, pp. 15-20, available at: https://files.eric.ed.gov/fulltext/EJ1317025.pdf5.pdf (accessed 5 May 2024).

Fernández Santín, M. and Feliu Torruella, M. (2017), "Reggio Emilia: an essential tool to develop critical thinking in early childhood", *Journal of New Approaches in Educational Research*, Vol. 6 No. 1, pp. 50-56, doi: 10.7821/naer.2017.1.207.

Fox, A. (2023), *The Reggio Emilia Approach in the United States*, ProQuest Dissertations & Theses Global, (Order No. 30485217), available at: https://utep.idm.oclc.org/login?url=https://www.proquest.com/dissertations-theses/reggio-emilia-approach-united-states/docview/2846792082/se-2 (accessed 5 May 2024).

Franzén, K. (2021), "Toddlers' mathematics: whole body learning", in *Embedding STEAM in Early Childhood Education and Care*, Springer International, Cham, pp. 201-215, doi: 10.1007/978-3-030-65624-9_10.

Fusaro, M. and Smith, M.C. (2018), "Preschoolers' inquisitiveness and science-relevant problem solving", *Early Childhood Research Quarterly*, Vol. 42, pp. 119-127, doi: 10.1016/j.ecresq.2017.09.002.

Gandini, L. (1993), "Fundamentals of the Reggio Emilia approach to early childhood education", *Young Children*, Vol. 49 No. 1, pp. 4-8, available at: http://www.jstor.org/stable/42725533

Gardner, A.F. and Jones, B.D. (2016), "Examining the Reggio Emilia approach: keys to understanding why it motivates students", *Revista Electrónica de Investigación Psicoeducativa y Psicopedagógica*, Vol. 14 No. 3, pp. 602-625, doi: 10.14204/ejrep.40.16046.

Gelman, R. (1998), "Cognitive development", in Wilson, R.A. and Keil, F.C. (Eds), *The MIT Encyclopedia of Cognitive Sciences*, Massachusetts Institute of Technology, pp. 128-129, available at: https://web.mit.edu/morrishalle/pubworks/papers/1999_Halle_MIT_Encyclopedia_Cognitive_Sciences-paper.pdf (accessed 10 May 2024).

Ginsburg, H.P., Lee, J.S. and Boyd, J.S. (2008), "'Mathematics education for young children: what it is and how to promote it,' Social Policy Report", *Society for Research in Child Development*, Vol. 22 No. 1, pp. 3-26, available at: https://files.eric.ed.gov/fulltext/ED521700.pdf (accessed 24 April 2024).

Gurjar, N. (2021), "The Italian makerspace", *Childhood Education*, Vol. 97 No. 3, pp. 48-53, doi: 10.1080/00094056.2021.1930924.

Hachey, A.C. (2020), "Success for all: fostering early childhood STEM identity", *Journal of Research in Innovative Teaching and Learning*, Vol. 13 No. 1, pp. 135-139, doi: 10.1108/JRIT-01-2020-0001.

Helm, J.H., Katz, L.G. and Wilson, R. (2023), *Young Investigators: the Project Approach in the Early Years*, Teachers College Press, New York.

Honey, M., Pearson, G. and Schweingruber, A. (2014), *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*, National Academies Press, New York.

Hu, J., Gordon, C., Yang, N. and Ren, Y. (2021), "'Once upon a star': a science education program based on personification storytelling in promoting preschool children's understanding of astronomy concepts", *Early Education and Development*, Vol. 32 No. 1, pp. 7-25, doi: 10.1080/10409289.2020.1759011.

Inan, H.Z., Trundle, K.C. and Kantor, R. (2010), "Understanding natural sciences education in a Reggio Emilia-inspired preschool", *Journal of Research in Science Teaching*, Vol. 47 No. 10, pp. 1186-1208, doi: 10.1002/tea.20375.

Johnston, K., Kervin, L. and Wyeth, P. (2022), "STEM, STEAM and makerspaces in early childhood: a scoping review", *Sustainability*, Vol. 14 No. 20, pp. 1-20, doi: 10.3390/su142013533.

Kaynak-Ekici, K.B., İmir, H.M. and Temel, Z.F. (2021), "Learning invitations in Reggio Emilia approach: a case study", *Education*, Vol. 49 No. 6, pp. 703-715, doi: 10.1080/03004279.2020.1775272.

Keifert, D. and Stevens, R. (2018), "Inquiry as a members' phenomenon: young children as competent inquirers", *The Journal of the Learning Sciences*, Vol. 28 No. 2, pp. 240-278, doi: 10.1080/10508406.2018.1528448.

Köksal, Ö. (2022), "Scientific thinking in young children: development, culture, and education", in Şen, H.H. and Selin, H. (Eds), *Childhood in Turkey: Educational, Sociological, and Psychological Perspectives. Science across Cultures: the History of Non-western Science*, Springer, Cham, Vol. 11, pp. 225-246, doi: 10.1007/978-3-031-08208-5_16.

Kurup, P.M., Yang, Y., Li, X. and Dong, Y. (2021), "Interdisciplinary and integrated STEM", *Encyclopedia*, Vol. 1 No. 4, pp. 1192-1199, doi: 10.3390/encyclopedia1040090.

Larimore, R.A. (2020), "Preschool science education: a vision for the future", *Early Childhood Education Journal*, Vol. 48 No. 6, pp. 703-714, doi: 10.1007/s10643-020-01033-9.

Larkin, K. and Lowrie, T. (2023), "Teaching approaches for STEM integration in pre-and primary school: a systematic qualitative literature review", *International Journal of Science and Mathematics Education*, Vol. 21 No. Suppl.1, pp. 11-39, doi: 10.1007/s10763-023-10362-1.

Lippard, C.N., Lamm, M.H. and Riley, K.L. (2017), "Engineering thinking in prekindergarten children: a systematic literature review", *Journal of Engineering Education*, Vol. 106 No. 3, pp. 454-474, doi: 10.1002/jee.20174.

MacDonald, A., Huser, C., Sikder, S. and Danaia, L. (2020), "Effective early childhood STEM education: findings from the little scientists evaluation", *Early Childhood Education Journal*, Vol. 48 No. 3, pp. 353-363, doi: 10.1007/s10643-019-01004-9.

Malone, K.L., Tiarani, V., Irving, K.E., Kajfez, R., Lin, H., Giasi, T. and Edmiston, B.W. (2018), "Engineering design challenges in early childhood education: effects on student cognition and interest", *European Journal of STEM Education*, Vol. 3 No. 3, p. 11, doi: 10.20897/ejsteme/3871.

Marcinowski, E.C., Nelson, E., Campbell, J.M. and Michel, G.F. (2019), "The development of object construction from infancy through toddlerhood", *Infancy*, Vol. 24 No. 3, pp. 368-391, doi: 10.1111/infa.12284.

Marsh, J., Wood, E., Chesworth, L., Nisha, B., Nutbrown, B. and Olney, B. (2019), "Makerspaces in early childhood education: principles of pedagogy and practice", *Mind, Culture and Activity*, Vol. 26 No. 3, pp. 221-233, doi: 10.1111/infa.12284.

Martin, C. and Evaldsson, A.C. (2012), "Affordances for participation: children's appropriation of rules in a Reggio Emilia school", *Mind, Culture and Activity*, Vol. 19 No. 1, pp. 51-74, doi: 10.1080/10749039.2011.632049.

McClure, E.R., Guernsey, L., Clements, D.H., Bales, S.N., Nichols, J., Kendall-Taylor, N. and Levine, M.H. (2017), "STEM starts early: grounding science, technology, engineering, and math education in early childhood", in *Joan Ganz Cooney Center at Sesame Workshop*, New York, NY, available at: https://joanganzcooneycenter.org/wp-content/uploads/2017/01/jgcc_stemstartsearly_final.pdf (accessed 5 May 2024).

Milford, T. and Tippett, C. (2015), "The design and validation of an early childhood STEM classroom observational protocol", *International research in early childhood education*, Vol. 6 No. 1, pp. 24-37, available at: https://files.eric.ed.gov/fulltext/EJ1150965.pdf (accessed 5 May 2024).

Moomaw, S. (2013), *Teaching STEM in the Early Years: Activities for Integrating Science, Technology, Engineering, and Mathematics*, Redleaf Press, New York, NY.

Moss, P. (2016), "Loris Malaguzzi and the schools of Reggio Emilia: provocation and hope for a renewed public education", *Improving Schools*, Vol. 19 No. 2, pp. 167-176, doi: 10.1177/1365480216651521.

Nadelson, L.S. and Seifert, A.L. (2017), "Integrated STEM defined: contexts, challenges, and the future", *The Journal of Educational Research*, Vol. 110 No. 3, pp. 221-223, doi: 10.1080/00220671.2017.1289775.

NAEYC (2020), *Developmentally Appropriate Practice Position Statement*, National Association for the Education of Young Children, available at: https://www.naeyc.org/sites/default/files/globally-shared/downloads/PDFs/resources/position-statements/dap-statement_0.pdf

NASTA (2024), "National science teaching association [NAST]", available at: https://www.nsta.org/nstas-official-positions/early-childhood-science-education (accessed 5 April 2024).

National Research Council (2011), *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*, National Academy Press, Washington, DC.

Ndijuye, L.G. and Tandika, P.B. (2020), "STEM starts early: views and beliefs of early childhood education stakeholders in Tanzania", *Journal of Childhood, Education and Society*, Vol. 1 No. 1, pp. 29-42, doi: 10.37291/2717638X.20201128.

New, R.S. (2007), "Reggio Emilia as cultural activity theory in practice", *Theory Into Practice*, Vol. 46 No. 1, pp. 5-13, doi: 10.1207/s15430421tip4601_2.

Ortiz-Revilla, J., Adúriz-Bravo, A. and Greca, I.M. (2020), "A framework for epistemological discussion on integrated STEM education", *Science and Education*, Vol. 29 No. 4, pp. 857-880, doi: 10.1007/s11191-020-00131-9.

Ortiz-Revilla, J., Greca, I.M. and Arriassecq, I. (2022), "A theoretical framework for integrated STEM education", *Science and Education*, Vol. 31 No. 2, pp. 383-404, doi: 10.1007/s11191-021-00242-x.

Pantoya, M., Hunt, E. and Aguirre-Munoz, Z. (2015), "Developing an engineering identity in early childhood", *American Journal of Engineering Education*, Vol. 6 No. 2, pp. 61-68, doi: 10.19030/ajee.v6i2.9502.

Park, M.-H., Dimitrov, D.M., Patterson, L.G. and Park, D.Y. (2017), "Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics", *Journal of Early Childhood Research*, Vol. 15 No. 3, pp. 275-291, doi: 10.1177/1476718X15614040.

Parnell, W. (2011), "Revealing the experience of children and teachers even in their absence: documenting in the early childhood studio", *Journal of Early Childhood Research*, Vol. 9 No. 3, pp. 291-309, doi: 10.1177/1476718X10397903.

Plowman, L., Stevenson, O., Stephen, C. and McPake, J. (2012), "Preschool children's learning with technology at home", *Computers and Education*, Vol. 59 No. 1, pp. 30-37, doi: 10.1016/j.compedu.2011.11.014.

Plummer, J. and Ricketts, A. (2018), *Preschool-age Children Practicing Science: the Intersection of Explanations, Modeling, and Gesture Use*, International Society of the Learning Sciences, Inc.[ISLS], available at: https://www.researchgate.net/profile/Amy-Ricketts-3/publication/332513968_Preschool-Age_Children_Practicing_Science_Intersections_of_Explanations_Modeling_and_Gesture_Use/links/5cb8dd08a6fdcc1d499ef058/Preschool-Age-Children-Practicing-Science-Intersections-of-Explanations-Modeling-and-Gesture-Use.pdf (accessed 15 April 2024).

Reynante, B.M., Selbach-Allen, M.E. and Pimentel, D.R. (2020), "Exploring the promises and perils of integrated STEM through disciplinary practices and epistemologies", *Science and Education*, Vol. 29 No. 4, pp. 785-803, doi: 10.1007/s11191-020-00121-x.

Scarborough, H.S. (2001), "Connecting early language and literacy to later reading (dis)abilities: evidence, theory, and practice", in Neuman, S. and Dickinson, D. (Eds), *Handbook for Research in Early Literacy*, Guilford Press, pp. 97-110.

Shonkoff, J.P. (2017), "Breakthrough impacts: what science tells us about supporting early childhood development", *YC Young Children*, Vol. 72 No. 2, pp. 8-16, available at: https://www.jstor.org/stable/90004117 (accessed 5 May 2024).

Sikder, S. and Fleer, M. (2018), "The relations between ideal and real forms of *small science*: conscious collaboration among parents and infants–toddlers", *Cultural Studies of Science Education*, Vol. 13 No. 4, pp. 865-888, doi: 10.1007/s11422-018-9869.

Slutsky, R., Kragh-Müller, G., Rentzou, K., Tuul, M., Gol Guven, M., Foerch, D. and Paz-Albo, J. (2021), "A cross-cultural study on technology use in preschool classrooms: early childhood teacher's preferences, time-use, impact and association with children's play", *Early Child Development and Care*, Vol. 191 No. 5, pp. 713-725, doi: 10.1080/03004430.2019.1645135.

Smart, S.T.E.M. and Lessons Learned From Successful Schools (2013), "Nurturing STEM skills in young learners, PreK–3", pp. 1-4, available at: https://successfulstemeducation.org/resources/nurturing-stem-skills-young-learners-prek%E2%80%933 (accessed 5 May 2024).

Smith, A.E. (2021), *How Teachers Identify Characteristics of the Reggio Emilia Philosophy in Practice: A Case Study (Order No. 29111170)*, ProQuest Dissertations & Theses Global, 2665128309, available at: https://repository.lsu.edu/cgi/viewcontent.cgi?article=6384&context=gradschool_theses (accessed 27 April 2024).

Soylu, Ş. (2016), "STEM education in early childhood in Turkey", *Journal of Educational and instructional studies in the World*, Vol. 6 No. 1, pp. 38-47, available at: https://arastirmax.com/en/system/files/dergiler/116392/makaleler/6/1/arastirmax-stem-education-early-childhood-turkey.pdf (accessed 5 May 2024).

Stegelin, D.A. (2003), "Application of the Reggio Emilia approach to early childhood science curriculum", *Early Childhood Education Journal*, Vol. 30 No. 3, pp. 163-169, doi: 10.1023/A:1022013905793.

Stylianidou, F., Glauert, E., Rossis, D., Compton, A., Cremin, T., Craft, A. and Havu-Nuutinen, S. (2018), "Fostering inquiry and creativity in early years STEM education: policy recommendations from the Creative Little Scientists Project", *European Journal of STEM Education*, Vol. 3 No. 3, pp. 1-13, doi: 10.20897/ejsteme/3875.

Sundqvist, P. and Nilsson, T. (2018), "Technology education in preschool: providing opportunities for children to use artifacts and to create", *International Journal of Technology and Design Education*, Vol. 28 No. 1, pp. 29-51, doi: 10.1007/s10798-016-9375-y.

Swann, A.C. (2008), "Children, objects, and relations: constructivist foundations in the Reggio Emilia approach", *Studies in Art Education*, Vol. 50 No. 1, pp. 36-50, doi: 10.1080/00393541.2008.11518754.

Talafian, H., Moy, M.K., Woodard, M.A. and Foster, A.N. (2019), "STEM identity exploration through an immersive learning environment", *Journal for STEM Education Research*, Vol. 2 No. 2, pp. 105-127, doi: 10.1007/s41979-019-00018-7.

Taylor, S.V. and Leung, C.B. (2020), "Multimodal literacy and social Interaction: young children's literacy learning", *Early Childhood Education Journal*, Vol. 48 No. 1, pp. 1-10, doi: 10.1007/s10643-019-00974-0.

Tippett, C.D. and Milford, T.M. (2017), "Findings from a Pre-kindergarten Classroom: making a case for STEM in early childhood education", *International Journal of Science and Mathematics Education*, Vol. 15 No. 1, pp. 67-86, doi: 10.1007/s10763-017-9812-8.

Trepanier-Street, M., Hong, S.B. and Donegan, M.M. (2001), "Constructing the image of the teacher in a Reggio-inspired teacher preparation program", *Journal of Early Childhood Teacher Education*, Vol. 22 No. 1, pp. 47-52, doi: 10.1080/10901027.2001.10486435.

University of Chicago STEM Education Center [UCHICAGO] (2017), "Early STEM Matters: providing high-quality STEM experience for all young learners. A policy report by the early childhood STEM working group", available at: https://ecstem.uchicago.edu/ (accessed 24 April 2024).

Vatalaro, A., Szente, J. and Levin, J. (2015), "Transformative learning of pre-service teachers during study abroad in Reggio Emilia, Italy: a case study", *The Journal of Scholarship of Teaching and Learning*, Vol. 15 No. 2, pp. 42-55, doi: 10.1080/00393541.2008.11518754.

Vogels, E.A., Rainie, L. and Anderson, J. (2020), *Tech Is (Just) a Tool*, Report, Pew Research Center, available at: https://www.pewresearch.org/internet/2020/06/30/tech-is-just-a-tool/ (accessed 5 May 2024).

Vygotsky, L. (1978), *Mind in Society: the Development of Higher Psychological Processes*, Harvard University Press, New York.

Wan, Z.H., Jiang, Y. and Zhan, Y. (2021), "STEM education in early childhood: a review of empirical studies", *Early Education and Development*, Vol. 32 No. 7, pp. 940-962, doi: 10.1080/10409289.2020.1814986.

Widya, Rifandi, R. and Laila Rahmi, Y. (2019), "STEM education to fulfil the 21st century demand: a literature review", *Journal of Physics: Conference Series*, Vol. 1317 No. 1, pp. 1-7, doi: 10.1088/1742-6596/1317/1/012208.

Yata, C., Ohtani, T. and Isobe, M. (2020), "Conceptual framework of STEM based on Japanese subject principles", *International Journal of STEM Education*, Vol. 7 No. 1, pp. 1-10, doi: 10.1186/s40594-020-00205-8.

Corresponding author
Alyse C. Hachey can be contacted at: ahachey@utep.edu