Chapter 1
Introduction: The Role of Play and STEM in the Early Years

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Abstract This introductory chapter provides an overview of the entire content of the book, *Play and STEM Education in the Early Years: International Policies and Practices,* providing various viewpoints representing 47 STEM experts from 16 countries defining developmental milestones during the early years and the importance of play during this critical developmental period. As the book is divided into four sections: (1) Play as the foundation of STEM experiences during a child's learning journey; (2) Policies and training for formal education environments; (3) Early years experiences in kindergarten and formal schools for 5–8-year-olds; and (4) Informal settings and family involvement in play, this chapter provides preliminary information and definitions as related to educational development in the early years. The chapter maintains that with a greater understanding of what constitutes play and why it is important, an appreciation and acceptance of the beneficial roles for the child, as well as the adult's role within the development of play, will emerge. It is posited that sharing international policies and practices promoting STEM subjects in the early years, through unstructured and structured play, will provide exemplary models that parents, citizen scientists, daycare practitioners, primary school teachers and preservice teachers, as well as researchers and policy makers, can employ to design the best learning experiences for the children in their care.

Keywords Early years · Heuristic play · STEM · Structured play · Unstructured play · Early childhood care and education (ECCE)

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1.1 Play and the Early Years

Early childhood is generally marked by achievements in specific developmental milestones over various life stages. The United Nations Educational, Scientific and Cultural Organization (UNESCO) defines early childhood as the period from birth to eight years of age (UNESCO, 2019a), affirming that early childhood care and education (ECCE) is "one of the best investments a country can make to promote human resource development, gender equality and social cohesion, and to reduce costs for later remedial programmes" (para. 3). It is increasingly recognized that the first 1001 days from conception to a child's second birthday are the most critical time for the developing brain since during this pivotal stage in a child's life they are shaped and influenced by the environment and people around them, particularly by their family members (Cupp et al., 2018; Pramling Samuelsson & Kaga, 2007, p. 13). Studies of this age group reveal the importance of holistic development in terms of a child's social, emotional, cognitive, and physical needs to build a solid and broad foundation for lifelong learning and well-being.

"Play has been at the center of early childhood curriculum from the beginning of our history in early childhood education to present-day models—from Pestalozzi and Froebel's kindergartens to Montessori's method, and Rudolf Steiner's Waldorf schools to Reggio Emilia curriculum" (Wisneski & Reifel, 2012, p. 175). According to Pramling Samuelsson and Kaga (2007, p. 12), "It is in the early childhood period that children develop their basic values, attitudes, skills, behaviours and habits, which may be long lasting." In addition, many researchers define the end of early childhood at the age of eight because it reflects "a critical year for mastery of the reading skills upon which further learning will build and a reliable predictor for future educational success" (Center for High Impact Philanthropy, 2021, para. 1). We believe that children also form the beginning of their understanding of science and engineering before age eight.

The early years (EY), however, represents different age ranges to different audiences. There is a clear divide between the types of experiences encountered before entering school and once in formal school, and our particular interest lies in pre-formal educational experiences. Further, the age when a child begins formal schooling also varies by country. For example, in Mauritius, formal schooling previously began at 7 years of age, however in 2015 the government, at the instigation of their education minister, a former teacher, changed this age to 5. The new program is contained in the *Nine Years Continuous Basic Education* plan developed by the Mauritius Institute of Education (n.d.), which will be discussed in detail in Chapters 13 and 20. In Germany, formal school begins at 6 years of age, while in the United States, it typically begins at age 5, with entry into a formal early childhood program occurring when children are between 3–5 years of age (Workman & Jessen-Howard, 2018). However, in England, early years education describes a child's progression from "nursery" to the Early Years Foundation Stage (EYFS). Therefore, the distinction between formal education is not the key, since the EYFS covers children from birth to five years for registered providers and covers the following areas through play and games: communication and language, physical development, personal, social, and emotional development, literacy, mathematics, understanding the world, expressive arts, and design (Department of Education, n.d.). Additional examples are provided throughout the forthcoming chapters, as the examples above represent only four of the 16 countries addressed in this book.

As previously stated, ECCE is increasingly reconsidered as key in the development of the child's social, emotional, cognitive, and physical needs, and may establish a firm holistic foundation for lifelong learning and well-being. ECCE has the possibility to nurture caring, capable, and responsible future citizens. However, in the everyday activities occurring around them, children gradually become involved or investigate phenomena by themselves. In "playing" a child often uses toys, everyday items at home, or manipulates artefacts found in their surrounding environment. It is through these actions which we seek to encourage recognizing their activities as foundational "STEM in action."

The United Nations 2030 Agenda for Sustainable Development, adopted in 2015, established 17 Sustainable Development Goals (SGDs). Goal 4, Quality Education, aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all," further specifying through SDG target 4.2 that "by 2030, all girls and boys will have access to quality early childhood development, care and pre-primary education so that they are ready for primary education" (United Nations, 2015). While SDG 4 acknowledges that "prior knowledge stems from various formal and informal contexts including everyday-life observations" (Osman et al., 2017, p. 28), "quality" is not specifically defined. The SDGs are similar to the Commonwealth Development Goals (Pisupati, 2018), which are also limited in their description of the nature and scope of the term "quality." Clarification regarding the definition of "quality early childhood development, care and pre-primary education" would strengthen these goals and subsequently provide guidance promoting adult–child interactions that support higher-order thinking. For example, some researchers have attempted to quantify the "quality" of play in early childhood through investigating play as a means of self-expression, as well as the use of play as a channel of achieving social sense, specifically examining beliefs, perspectives and theories related to the effects of culture, media, and technology on play (Johnson et al., 2005).

Throughout this book, we hope to illuminate potential factors contributing to "quality" educational experiences from various international perspectives. Young children are natural scientists. Beginning at an early age, children eagerly observe, explore, and discover the world around them. Technology also plays a role in science discovery through photography, recording and listening to sounds of insects and animals, and virtual play on educational websites and games (Lan, 2019).

Causal knowledge is a key element of understanding the world since it determines which aspects of specific concepts become more important than others to the learner. The question remains as to whether children come to understands by their own active exploration of their world. Piaget (1930) believed so, originally proposing three levels of play coinciding with early childhood during the Preoperational Stage (occurring from the age of 2 to 7 years): functional play (using body movements such as running and jumping), symbolic/fantasy play (using symbols to represent ideas, images, and words), and games with rules (strategy games such as checkers or chess). A fourth level of play, constructive play, was added by Smilansky, known for her work in the area of developmental psychology related to children and play, and for her research collaborations with Piaget. According to Smilansky, each type of play emerges at different ages and stages of cognitive development in an attempt to achieve social sense, noting that the level of play changes with maturation (Klugman & Smilansky, 1990; Smilansky & Shefatya, 1990). Through constructive play, children explore science in action, use mathematics through counting and comparing sizes and shapes, apply their imagination and curiosity by creatively exploring the world around them, and cooperate and communicate their understandings of their own environment.

Scholars such as Spelke et al. (1992) explained that children actually know and understand much more than that. According to Spelke (1994, p. 431), "Early developing knowledge appears to be both domain-specific and task-specific, it appears to capture fundamental constraints on ecologically important classes of entities in the child's environment, and it appears to remain central to the common-sense knowledge system of adults." Many believe that children's learning and usual level of understanding is conservative yet flexible; integrating what they see, experience, and evidence with their prior beliefs and competing causal hypotheses within their exploration, explanation, and learning (Bonawitz et al., 2011; Schulz & Bonawitz, 2007). Their inquiring approach to learning is inspired through their personal self-directed play, forming the major purpose for their actions to explore and build a scientific basis of evidence from inquiry.

Play typically occupies much of the time for many children and is considered by most to be one of the keys to their future development and learning (Lillard, 1993; Lillard et al., 2013). Much research has explored the development of symbolic play (Pellis & Pellis, 2007; Pellis et al., 2010). Vygotsky (1978) believed that play is a purposeful activity, providing changes in needs and in consciousness, stating that "play creates a zone of proximal development (ZPD) of the child. In play a child always behaves beyond his average age, above his daily behaviour in play it is as though he were a head taller than himself" (p. 102). Vygotsky's sociocultural theory (SCT) focused on two levels of learning; first through social interactions with others, and second, when ideas are integrated into one's mental structure. According to Vygotsky, a child's ZPD represents "the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers" (1978, p. 86). Curiosity is the primary motivator of young children, and therefore they are actively involved in their own learning throughout their social development.

According to Daneshfar and Moharami (2018, p. 600), "Children are immersed in a social environment where it represents them with all social, cultural and interpersonal experiences." Daneshfar and Moharami's interpretation of Vygotsky's sociocultural theory (SCT) focuses on the importance of the continuous process of learning, and its effect on cognitive development through social learning. We agree and acknowledge the important influence play has on a child's development and learning, especially when considering science education in play-based settings, as it provides children with opportunities to use creativity and imagination to interact with the world around them.

However, not all critics recognize Vygotskian influences on today's interpretation of the importance of play. An analysis of a translated work of Vygotsky, concluded how "it is surprising that at the end of his paper he does not say more about the further development of play, focusing instead on the way in which it is replaced by 'a limited form of activity, predominantly of the athletic type,' referencing only symbolic play" (Veresov & Barrs, 2016, p. 33). Nevertheless, Bruner focused on a symbolic representation within the context of play, acknowledging the development of tools and strategies resulting in problem solving (Bruner & Haste, 1987). As explained by Petrović-Sočo (2014, p. 242), "Bruner reaffirms Vygotsky's theory which enriches Piaget's constructivism with the emphasis on the importance of the social dimension in the development of a human being, and therefore adds a significant role of culture in human development." Several chapters within this book dive deeper into Vygotskyian influences in support of the importance of play in learning.

Definitions of play vary. Fagen (1974, 1978, 1981, 1995) proposed an ethological view identifying behaviors associated with play, and suggested three categories: locomotor play, object play, and social play. Other researchers have defined play according to the functional and dispositional aspects involved in play. Hughes and Melville (2002) identified 16 types of play (symbolic play, rough and tumble play, socio-dramatic play, social play, creative play, communication play, dramatic play, locomotor play, deep play, exploratory play, fantasy play, imaginative play, mastery play, object play, role play, and recapitulative play), while Miller and Almon (2009, p. 55) included a list of 12 types of play (large motor play, small motor play, mastery play, rules-based play, construction play, make believe play, symbolic play, language play, playing with the arts, sensory play, rough and tumble play, and risk taking play); emphasizing that "play does not stay neatly in categories, but knowing and watching for the broad types helps sensitize teachers and parents to the shifting landscapes children create" (p. 53).

Burghardt (2011) identified five criteria for a given behavioral sequence to be classified as play, which encompass both functional and structural criteria, the nature of the actions, and what it does for the player. Broadly summarized as five categories, Burghardt described play as an unstressed activity with no pressure, it is spontaneous, voluntary, and repeated similarly; it is not aimed at survival and is a pleasurable experience. Other researchers, including ourselves, note that the construction of play often overlaps with other creative activities including object play and aspects of art, such as modeling and coloring for example. As science educators, we maintain that in whatever play genre children display these actions, a foundation of science and engineering is typically present. Gopnik (2009, 2016) pointed out, through a wealth of research papers and popular books for non-scientists, that the variability and flexibility of play promotes innovation and creativity, which are intuitive scientific and engineering-related actions. We propose that during play, children often employ strategies utilized in formal schooling, strategies identified as science, technology, engineering, and mathematics (STEM) educational activities, and, therefore, learn through intuitive play. Often, children will work together and organize a play episode, observing, asking questions and planning what to do, while also selecting what instruments they will use. They evaluate the outcomes and use their findings to interpret their world.

We, as practitioners, need to understand what is play, why it is important, and recognize what the child's as well as adult's role is within the development of play. This includes the context for learning through play, where children organize and make sense of their social worlds as they actively engage with people, objects, and representations. The foundations of learning, in particular learning of content in the subjects subsumed by the acronym STEM, include, embrace, and recognize that these areas overlap and are not exclusive. The Play Cycle described in Fig. 1.1, depicts distinct identifiable stages that can be observed while children are at play. The cycle is particularly applicable to phenomena related to physical science as well as biological and environmental issues that are observable.

The cycle begins when children directly interact with their environment; when they notice something of interest which inspires them to begin investigating and exploring possibilities of actions to take in order to make sense of the item or the phenomena. During the final phase, the child makes decisions to either repeat or change actions in order to reinitiate exploration or loses interest and exits the cycle early to find something else of interest. These variations depend on the science in question and typically

Fig. 1.1 The Play Cycle (Tunnicliffe & Kennedy, 2021)

include communicating and sharing discoveries. Through structured non-participant observation, adults blend into the background and provide an environment where children can act more naturally, hopefully avoiding the phenomena of performing differently for an audience, often referred to by researchers as the Hawthorn Effect (McCambridge et al., 2013). Adults can easily monitor children's progress through the stages of the Play Cycle without interrupting their decision-making processes. "Developmental monitoring means observing and noting specific ways a child plays, learns, speaks, acts, and moves every day, in an ongoing way. Developmental monitoring often involves tracking a child's development using a checklist of developmental milestones" (Linke, 2016, p. 4). For example, the *Act Early Milestone Checklist* (CDC, 2018) and the online *Milestone Tracker* mobile app (for children 2 months to 5 years of age), adapted from resources developed by the American Academy of Pediatrics (Hagan et al., 2017; Shelov & Altmann, 2009), provide easy ways to monitor milestones in social and emotional development, language and communication development, cognitive activity (learning, thinking, and problem-solving) and physical development as children move through the Play Cycle.

Children are both problem solvers and problem generators, constantly attempting to solve the problems they encounter in their environment, while also seeking and creating novel challenges along the way (NRC, 2000a, p. 102). One question often asked—Why do children choose certain items with which to play?—remains largely unanswered. Krapp (1999, pp. 23–24) explains that the theoretical considerations of the interest-construct, including those related to curiosity, attention and achievement motivation, intrinsic motivation, and flow, have often been excluded from scientific discussion, stressing the importance of the "person-object relationship" as well as the "notion of personal relevance and a readiness to engage." Renninger (1990) postulates that the individual represents the potential source of action, the environment is the object of action, and the interest shown is a product of the specific relationship between the two, stressing the specific relationship between the person and their life-space. Regardless of the attraction to specific items, experiences resulting from interactions throughout the various stages of play build on important schemas about the real world, and "encourage aspects of social, emotional, cognitive and physical development that cannot be achieved any other way" (Feinberg, 2010, p. 267).

According to the National Research Council (NRC) of the USA, children enter formal educational settings, such as preschool and early-care education programs, with a substantial knowledge of the natural world, much of which is implicit (NRC, 2007). Active involvement in everyday STEM activities during the formative years occur through play, and through free-choice, unstructured activities. Although the toys or objects children play with are typically designed by adults, children form their own ideas about how and when these objects become important and useful in their play. Play for children means to them their choice of activity and the chance to investigate whatever they come across. Whereas to many adults, play refers to recreational activities such as a game of tennis, golf, football, or card games, and, therefore, children are "just playing."

Schools mandate games and lessons, as well as organize teams to play other schools at sporting events while providing playgrounds, play equipment in primary schools, and play times. However, a recent report in England (Baines & Blatchford, 2019) found that play time in schools (referred to as recess in the United States) had been significantly reduced since 1995. Despite this decline in the time allocated to play, playing games with rules, and frequently including teamwork, is a common characteristic of developing children's play featured in many schools and educational systems around the world. For example, during a recent research activity working with 4-year-old children in a foundation stage class in England, after about 15 to 20 minutes these children usually asked, "can I go and play now?" The activity they had been asked to do was not "theirs," resulting that in their minds it was not "play" nor was it their choice (Bottrill, 2018). Children often become frustrated and bored in directed settings. As Weldon shared when discussing boredom versus free play, "the more we structure children's time, the more we interfere with their own drive to learn, explore, imagine and simply be" (2018, para. 11).

Early years experts have analyzed play allocating various categories to the phenomenon. Goldschmied and Jackson (2004) introduced the term "heuristic play," referring to scenarios where children are provided with different kinds of objects and receptacles with which to engage in free play without adult intervention. Such heuristic play is also recognizable in the investigative activities that children carry out when they visit a room or location where there are "things" which they can touch or pick up in a manner similar to the very young immobile child. As examples, Goldschmied and Hughes (1992) used heuristic play to describe how babies could sit upright and investigate a "treasure basket" of objects, and Forbes and Jackson (2015) described examples of heuristic play during outdoor learning scenarios.

Tunnicliffe (2019) categorized play as either *structured* or *unstructured. Structured* referring to situations when items for play are available, and *unstructured* referring to when a child investigates with whatever is available. *Free choice*, sometimes called *spontaneous play*, is an important element of both aspects and refers to situations when the play items selected are either their idea, the use of the items is as expected by the toy manufacturer, or play scenarios imitate the actions of an adult using similar items, such as what occurs within the context of the play shop, play kitchen, playhouse and dress up clothes. Tunnicliffe (2019) refers to such activities with provided items that allow for *free choice* of action as *mediated* play, whereas when the child is instructed as what to do it is referred to as *facilitated play,* that is on occasion instructional. There is a place for instructional facilitated play when introducing necessary skills, such as using scissors or filling an item with water.

The child as a constructor, who is competent and capable of directing their own learning, begins at 0–3 years of age. This principle is the basis of the child-directed philosophical approach coined *Reggio Emalia* developed by Loris Malaguzzi in 1945 in Italy. The approach focuses on "cooperative experiences and *Progettazione,* projects designed by teachers in cooperation with their students" who share the results of their projects with classmates, in playgroups and other cooperative learning situations, to promote learning from one another (Kennedy & Sundberg, 2020, p. 489). This educational framework, closely aligned with past constructivist studies by Piaget, begins with recognizing that the child initiates their own learning, and that teachers and other adults, families and center personnel can interact supportively and developmentally with the learner, but take the cue for initiating intervention from the child. This approach recognized that learning, at any age, begins with an engaged learner who can actively direct their own learning, with the learner at the center, not the teacher. In this scenario, the role of the teaching adult is to find how to promote the learning of each learner, recognizing the way they think, their aptitudes and skills. This model encourages the participation of families, and all the factors that create the whole learning environment, including the team, the building, and the ambient culture (Bucher, 2020; Rock, 2020).

1.2 Play in Informal, Formal, and Non-formal Education Settings

Most academics agree that distinguishing between the meaning and uses of informal versus formal education is a very difficult task. According to Smith (2002, p. 1), "Many of the debates around informal and formal education have been muddied by participants having very different understandings of basic notions." Simply put, they mean different undertakings to different players. The following definitions generically describe the differences between informal and formal educational settings.

- **Informal education** generally refers to knowledge acquisition that occurs outside of a structured curriculum. It allows individuals to build knowledge, skills, and values from daily experiences, including home, work, friends, and media (Percy, 1997). We contend that informal education also encompasses learning that occurs independently outside of a formal classroom environment and without adult intervention or formalized programming, such as through visiting science museums, zoos, and other public access community settings, often in a spontaneous manner.
- **Formal education** generally refers to knowledge and skills acquisition that occurs through systems of organized learning in which the goals and objectives are defined, hierarchically structured, and chronologically graded. These organized experiences include classroom instruction received from a child's first schooling through higher education. Formal education occurs both inside and outside of school time, driven by curricular aims and under the auspices of the school. We maintain that formal education also includes academic, vocational, technical, and professional training delivered through web-based and remote learning, e-learning courses, workshops, and seminars.
- **Non-formal education** generally refers to organized, yet free choice, leisure education programs and activities occurring outside the established formal school system. We believe that although these activities are structured, with identifiable learning objectives, they are voluntary and often are closely aligned with personal interest. Examples of non-formal education include community education and learning experiences gained from attending organized classes and special

programming at science museums, zoos, botanic gardens, science centers, and other public community settings.

The simplest definition of formal learning is that which occurs within the context of school, while informal learning may be defined as that which occurs away from the typical school classroom environment, through activities on the grounds around the school, outside the classroom, at home, in other venues such as the wide genre of museums, and during leisure time in the learner's community. However, when defining informal versus formal experiences, some educators consider whether the learner has voluntarily visited such sites or whether they are receiving a conscripted curriculum led by educators (Smith et al., 1998). Children taken to a museum by parents or caregivers during out-of-school time, or in the case of pre-formal school learners, in playgroups or in childcare situations, are in fact conscripts too because they are taken, although on occasion a young child asks to be taken, often as repeat visits to locations such as a pond or zoo. Children's playgrounds are another outside learning venue for experiential STEM learning to generate, for example with their body actions, the movements of a swing or discovering gravity effects through experiencing the action of a slide, and as they get older, trying to climb back up the actual slide. These are all foundational learning opportunities.

Museum educators specializing in teaching typically provide educational experiences for children at these informal sites. Most of the programming reported has been created for older children and considers the pedagogies of formal out-of-school learning (Braund & Reiss, 2019). Zhai (2012) considered the pedagogical practices necessary for effective learning in botanic gardens, particularly those practices adopted by botanic garden educators. Often school-organized visits without a booked site educator devise their own pedagogical technique which has all too often been that of filling in a worksheet. However, over the past thirty years, more research has been disseminated about learning in museums, zoos, botanic gardens, horticultural gardens, field centers, science centers, and geological sites, including those of industrial archaeology as well as cultural museums. Many of these sites serve as important centers for environmental education, adding to the growing interest in education for sustainable development (ESD) amongst science educators (UNESCO, 2019b).

The pedagogical position of museum educators is moving from declaring knowledge to employing narrative alongside recognition of the importance of dialogic interactions, together with the emergence of delivering hands-on sessions. Two of the most influential researchers in this field, Falk and Dierking (2016), described five categories of adult visitors by identifying their motivation. They identified a particular category of parents/caregivers motivated to bring very young children to learn, as well as children in preschool and the early years of formal school. More and more out-of-school venues are catering to these beginning learners, developing experiences for those in the earliest of years and their adult caregivers, such as the parent and baby sessions provided by the Museum of London. Activities for toddlers, children from 1–3 years old, include family museum programs as well as interactive exhibits, for example those at the American Museum of Natural History (AMNH) in New York City. Hands-on sessions with objects in cultural museums, biofacts and animals in zoos, or natural history museums including role play in early years classes have grown while themed play areas with subtle educational messages have emerged in museums, zoos, gardens, and science centers, of which some examples are discussed in later contributions included in this book.

Pre-formal aged school children, not in kindergarten or nursery environments where formal learning does occur, learn from observations in their environment. Visitors at any exhibit or out-of-school location, looking at something in their world, generally follow the 4Is sequence: first noticing or identifying whatever has caught their attention, then displaying interest, followed by interpreting, and investigating (Tunnicliffe & Scheersoi, 2010). When looking at exhibits or naturally occurring phenomena, and particularly in the case of experiences in Earth and biological sciences, following the 4Is expands young learners' discussions of their earliest encounters with the world, regardless of experiences inside or in outside environments. The youngest children are predominantly learning names and listening to the rhythm of the language(s) they hear when adults speak with them and answer their questions.

Thus, children first learn from observations and experiences outside of formal education structures starting in their family and community. We know that in animal societies the young learn their culture and language (van Schaik & Burkart, 2011). Such learning applies just as much to humans in learning our group's language and customs. We consider that it is important in the preschool years, which we are regarding as informal since learning is societal but not focused on a formal curriculum, to be the vital precursor of theoretical understanding. Our contention is based on an observation, listening, and doing approach in which, as Gopnik (2009) and others point to, caters to the inherent inquisitiveness and curiosity of a child, particularly in developing basic STEM competencies.

1.3 Play and STEM Education

STEM education has evolved into a meta-discipline. This shift marks an integrated effort to remove the traditional barriers between the content areas of science, technology, engineering and mathematics, to focus on innovation and the applied process of designing solutions to complex contextual problems using current tools and technologies, and to challenge students of all ages to innovate and invent, while promoting problem-solving and critical thinking skills that can be applied to their academic as well as everyday lives (Kennedy & Odell, 2014). Preparing our children for the twenty-first century begins in the early years when they are naturally curious and excited learners and are constantly asking questions. The key elements for developing STEM capital and promoting active citizenship, and a scientifically literate workforce, begin with young children (Kennedy & Sundberg, 2020).

The 5E Model of Instruction (see Fig. 1.2) is recognized as one of the best processes by which educators can employ opportunities to personalize STEM

Fig. 1.2 Evidence-based practices: The 5E Model of Instruction (Graphic used with permission from the San Diego County Office of Education, 2018. https://ngss.sdcoe.net/Evidence-Based-Practices/5E-Model-of-Instruction)

learning for students of all ages, and the model is applicable to even the earliest educational experiences. The five phases of the 5E Model are Engage, Explore, Explain, Elaborate, and Evaluate. The model "has a 'common sense' value; it presents a natural process of learning" (Bybee, 2015, p. ix).

While not all phases of the model are applicable to young learners, the first four phases (engage, explore, explain, and elaborate) are particularly important as children *engage* and focus on phenomena to make connections between past and present learning experiences; *explore* their environment using prior knowledge, generating new ideas through experimentation and trial and error to make sense of their surroundings; *explain* their observations and understandings through their excitement and verbal explanations, further constructing a deeper understanding; and *elaborate* on their understandings through extended activities, building on their initial understandings and applying them to similar situations. The Play Cycle, described earlier in this chapter, aligns closely with the first four stages of the 5E Model, and aspects of both will be presented throughout the book within international contexts.

The research literature is rich in information and reports about developing STEM in primary and secondary education, however, developing STEM in early years education is an evolving field of study in need of documentation to provide effective and creative models for replication as well as promote collaboration amongst programs internationally. While it is safe to say that these experiences provide general understandings about the natural world, and that science concepts can be learned in many ways, "too few researchers take that into account when studying the impact of informal science activities" (Mervis, 2009, para. 4).

Schools in many countries do not teach science in the early years. However, many countries do have policies and practices to share regarding educational opportunities for STEM education for their young learners. For example, the English pre-formal school curriculum, the Early Years Foundation Stage (EYFS), encourages practitioners in formal settings and child care environments to help children explore and make sense of their physical world, their everyday settings, in order to ensure that all areas of learning and development are "implemented through planned, purposeful play and through a mix of adult-led and child-initiated activity" (Department of Education, 2017, p. 9), further stating that "play is essential for children's development, building their confidence as they learn to explore, to think about problems, and relate to others. Children learn by leading their own play, and by taking part in play which is guided by adults." Emphasis on numeracy and language, as well as building social skills, provides ample opportunities to identify STEM in action.

Most learning of STEM is through everyday activities. In this sense, STEM in action includes opportunities for children to experience and observe phenomena of interest to them, in their everyday lives at home and in their community, as well as relate formal school science topics to their local and personal situations. Science achievement in schools has shown to be at its highest "when individual pupils were involved in fully planning, carrying out and evaluating investigations that they had, in some part, suggested themselves" (Ofsted, 2013, p. 6). These everyday experiences and manifestations form a crucial component of the start of a child's learning journey.

Research has shown that students learn to think, talk, and act scientifically through sense-making experiences, and that formal science learning "builds on the knowledge that students bring with them to school from their home cultures, including their familiar discourse practices" (NRC, 2000b, p. 188). Children are born observers; they investigate and collect experiences which become their personal data used in later experiences and when interpreting the world around them.

However, in their play, children also show that they are inherent mathematicians as their early play typically incorporates mathematical themes, identified by Athey (2007) as the basics of play. For example, they collect items such as pinecones or toy animal models and place them in a horizontal line or manipulate building blocks into a balanced tower, a mathematical as well as engineering task. "Toddlers as young as 12 months old are able to recognize numbers" (Swinson, 2018, para. 1), even if they do not yet know the accepted way in which our systems designate the values. Indeed, these types of activities, along with other activities, are traditionally taught in pre-secondary school science such as making a string bridge, interrogating frictions, and engaging in engineering or design and technology activities.

While observations are recognized as the starting point of science (Eberbach & Crowley, 2009; Johnston, 2009), observations are also a basis of the beginning of mathematical understandings. “Approaches to early mathematics teaching incorporate the premises that all learning involves extending understanding to new situations, that young children come to school with many ideas about mathematics, that knowledge relevant to a new setting is not always accessed spontaneously, and that learning can be enhanced by respecting and encouraging children to try out the ideas and strategies that they bring to school-based learning in classrooms” (NRC, 2000b, p. 172).

Mathematical learning and science understanding occur naturally as children begin to explore their personal world, such as by becoming aware of the number of limbs they have, and then individual digits eventually become quantified as a child learns the naming and counting conventions. According to a report by the National Council for Curriculum and Assessment, “In the curriculum, a view of all children as having the capacity to engage with deep and challenging mathematical ideas and processes from birth should be presented. From this perspective, and in order to address on-going concerns about mathematics at school level, a curriculum for 3–8-year-old children is critical. This curriculum needs to take account of the different educational settings that children experience during these years” (Dunphy et al., 2014, p. 128).

We recognize that both the content of what is frequently referred to as ‘science’ in preschool, as well as the curricular focus during the years of formal education prior to secondary schooling, typically involve aspects of mathematical competencies and understandings. In addition, these experiences often include fundamental engineering actions utilizing basic science content while acquiring understanding, which is intuitive in the earliest of learners. Making sets of like artefacts, according to properties identified by the child, such as similar model animals which they recognize, e.g., cattle or elephants, or red blocks and separating them from blue blocks, involves children developing an understanding of measurement, or “the symbolic-meaning relationship” in the words of Vygotsky (1978).

Indeed, children frequently use graphics or symbols to represent the numbers of artefacts, or, for example, to explain upwards growth of a seedling. This approach is similar to the work of Symington et al. (1981, p. 51), who studied the development of children’s drawings of natural phenomena, suggesting that “concepts of symbolism, intellectual realism and visual realism” contribute to processes employed by young children while recording natural phenomena. Children have a need to make marks, as many parents know. Such mark making is the beginning of written communication, be it through letters or numbers.

In their play, children often refer to numbers or quantities as well as shapes and spatial positioning, essential skills and understanding (Carruthers & Worthington, 2004). Hughes (1996), however, pointed out that children generally find it difficult to represent the mathematical operations of addition (+) and subtraction (−), and instead prefer to show these operations by representing a quantity. He suggested that this may explain why children’s comprehension of these symbols, and the operations they refer to (addition and subtraction), typically do not progress beyond the context in which they are taught. Thus, children develop a utilitarian use of the relationship between these observations. However, in regard to symbols, such as small lines representing one object, in comparison to small lines representing mathematical actions in exercises (such as + or −), children were reluctant to recognize and use them in other situations.

Developing skills in math and science, essential tools used in the engineering design process, result in future innovation and technological expansion. The word "engineering" derives from the Latin word "ingenerare," which means "to create" or "to produce." Engineering encompasses a large range of industries. However, engineering, as a profession, has historically been looked down upon in some countries, such as in England, where it is often viewed as a trade as opposed to an academic profession, such as law and theology for example. However, there is an increasing awareness of the importance of engineering and the technologies resultant in our modern societies, and a recognition of the vital contribution engineering has made to the development of societies from the earliest recorded history.

Unfortunately, a common misconception or misunderstanding held by many members of the public is that the subjects included in STEM (science, technology, engineering, and mathematics) are for older students. Further, many parents question the role of play in their children's preschool experiences and early formal years, failing to appreciate the key role of play in developing basic STEM competencies. Figure 1.3 shows the progression of engineering capabilities in initial early years learners, beginning with the development of manipulative skills, learning and following safety rules, following instructions in a competent manner, recognizing a problem, planning and recording a solution, recognizing necessary items and realizing a design, evaluating outcomes, and building self-esteem after a successful discovery.

Fig. 1.3 Progression of engineering capabilities in initial early years learners

The recognition of the incidence of fundamental engineering processes in preschool children's play, and in more formal settings of playgroups and preschool, as well as incrementally in primary school curricula, is currently being addressed in schools around the world. Engineering competency is now regarded as one of the essentials of education in these important times when the planet is facing the deleterious impact of human activity. "Science and engineering can be understood as ways of knowing that children can deploy to address questions and issues that matter to them. These investigations can be playful, creative, and sources of joy. They can also be challenging and even troubling as children seek to understand the sources of difficulties and dangers in their lives. Regardless of the direction in which children point their curiosity, young children are developmentally and cognitively capable of making robust, recognizable, and meaningful use of the practices, tools, and big ideas of science and engineering on their own terms and for their own purposes across the contexts of their activity" (National Academies of Sciences, Engineering, and Medicine, 2022, p. 74).

A recent study of the impact of curriculum design, including curricula focused on engineering processes in meaningful and sociocultural contexts in primary (1–3) and middle school (6–9) classrooms, revealed that these learners not only understand engineering practice, but also understand the science involved (Cunningham et al., 2019). These gradually changing perceptions of the role of engineering are key to the success of societies.

Design and technology appeared in the National Curriculum for the UK, before devolved powers were granted to its constituent countries, from the earliest statutory school age, and in the USA, engineering is a key component of the core competencies and cross curricular themes of the Next Generation Science Standards (NGSS) which a number of the constituent States have adopted (NGSS Lead States, 2013). However, due to the rapid development of PreK-3 engineering curricula, Bagiati et al. (2010, p. 22) recommend that engineering educational materials and content "should be offered from universities, museums, foundations, institutions, and other such entities formally recognized to be related to engineering, education, and curriculum issues" in order to ensure the pedagogical fidelity and content validity of curricula and programs implemented.

1.4 Extended STEM Subjects

As STEM education implementation models have evolved, expanded iterations of the acronym for **S**cience, **T**echnology, **E**ngineering, and **M**athematics have been created to include additional disciplines as a more holistic approach to education which focuses on individual students' needs and interests. For example, STE**A**M education refers to a pedagogical approach using Science, Technology, Engineering, the **A**rts and Mathematics as access points for guiding student inquiry, creativity, critical thinking, and communication.

This emerging discipline aims to develop a rounded approach to education, particularly in formal teaching and learning ranging from preschool environments in homes and communities through kindergarten, primary and secondary schools, and to university and vocational education settings as well. STEAM educators believe the arts serve as a mechanism by which children can use artistic expression to communicate and make better sense of their learning, and that it provides expanded opportunities to reflect, imagine, create, express, and represent ideas. This broadening of the curriculum is also viewed by advocates as a way of increasing student interest and engagement in STEM subjects by integrating creative arts with various aspects of inquiry-based teaching and learning, including the role of engineering, whose importance in traditional culture has increased in the last few decades at the end of the twentieth and beginning of the twenty first centuries. After all, as Dewey proclaimed in his pedagogical creed written in 1897, "when science and art thus join hands the most commanding motive for human action will be reached; the most genuine springs of human conduct aroused and the best service that human nature is capable of guaranteed" (Article V, para. 12).

STEAM education also carries with it overtones of the debate introduced in 1959 by C.P. Snow in a seminal book entitled *The Two Cultures and the Scientific Revolution* and its sequel, *The Two Cultures and a Second Look: An Expanded Version of the Two Cultures and the Scientific Revolution* (Snow, 1963), which described his perception of the cultural divide that separates "Science" and "the Arts" through a comparison of the dichotomy between scientists and technologists and that of humanists and artists. The discussion set forth in his book has been considered by academics as one of the most important to influence Western thinking since the end of the Second World War in 1945. Subsequent discussion suggested that the rigid divide in some countries, such as the UK and the USA, resulted from expectations placed on secondary school children to decide whether to study the Arts or the Sciences in their early teenage years. Hence, in the UK, the cultural valuing of arts but not the sciences and the awarding of university degrees in either Arts or Science. Furthermore, it was argued that Arts were driven by patterns whereas Science by logic.

Indeed, the debate does continue, and we now recognize that the two cultures, Arts and Sciences, are not incompatible, for STEM embodies aspects of both. Undeniably, some activities employed in preschool are very much based on patterns, colors, shapes, dance, songs, and actions. Braund and Reiss (2019), recognize the growing relationship between the Arts and Sciences, which more and more practitioners have come to recognize, particularly those working in the pre-secondary and preschool sectors. Braund and Reiss proposed three different levels at which Arts could improve the teaching of science: at a *macro-level*, focusing on the ways in which subjects are structured; the *meso-level*, employing guided approaches that engage students in contexts closely related to Science, Technology and Society (STS); and the *micro-level*, using pedagogical techniques employed in Arts subjects. They suggest that these three strategies garner the possibilities of catching the interest of reluctant science learners. Such a view has often been raised by practitioners teaching in secondary schools, and particularly those in primary school levels, as the research of Avraamidou (2016) reveals. In addition, the introduction of the Next Generation

Science Standards in the USA seeks to address this in some way by including literacy and engineering in the integrated curriculum (NGSS Lead States, 2013).

As science educators, we recognize the use and practice of drawings and their presentational fields as well as the creativity required in investigations. We also identify the importance of recording and dissemination techniques that are key features of our subject practices as well as the visual arts, music and poetry, and other writings which they have inspired. Pre-secondary, preschool and many childcare practitioners tend to be quite skilled in the integration of subjects and provide invaluable insight into successful pedagogical approaches promoting positive outcomes for young children and their families.

An expanded iteration of STEAM education is STREAM, which adds the disciplines of reading and writing. Advocates of STREAM see literacy as an essential part of a well-rounded curriculum, requiring critical thinking and creativity (Fernandes, 2021). Others believe that STEAM education should direct itself toward design and design thinking, thereby coining the acronym STEAMD (Henebery, 2020). In emphasizing higher level thinking skills through design-based learning (DBL), Petrina (2020) argues that C.P. Snow "fails to consider design as a third culture" (p. 2), challenging educators to recognize the benefit of "designerly ways of knowing and a scope of design that includes an expansive definition of artifacts" (p. 4). The tenets of "designerly" ways of knowing and thinking seek to articulate and understand the nature of design cognition, including the processes used by designers such as architects, engineers, product designers, and the like (Cross, 1982).

However, STEAMD has also taken on another debate. The intent of some advocates of using the acronym STEAMD is to extend the approach to learning of the traditional STEM subjects not only by including the Arts, but also by focusing on the use of drama in scaffolding the STEM understanding of learners (McGregor, 2017). In the preschool and early years, learners act out their narratives as they play, whether imaginative or representation narratives and dramas of adult everyday occasions such as tea parties, shopping or visiting medical facilities. The use of various forms of drama are utilized in many places of learning, formal and particularly informal. The creative use of drama to place children in scientific roles and encourage scientific activities has become well documented and implemented widely (Carol-Ann Burke, et al., 2020; McGregor, 2017; McGregor & Precious, 2015; Özsoy & Özyer, 2018).

Although some scholars believe that adding an **A**, **R** or **D** is a dilution of STEM's focus and objectives, most agree that the earlier a child is exposed to STEM subjects, the better their chances are of sticking with them. "Integration within each of these four areas (e.g., within STEM) is challenging enough while deliberate and formal integration across these four and other areas is quite difficult for students and teachers, to say the least. However, as STEM was popularized through the late 1990s, iterations were introduced and rationalized (e.g., STE**A**M, STE**E**M, STE**H**M, letters for **A**rts, **E**nvironment, **H**umanities, etc.). At times, these iterations are symbolic reminders that STEM disciplines are enriched by other disciplines, such as the arts, and at other times they are substantive challenges to integrate" (Petrina, 2020, p. 1). The bottom line is to ensure that all children have opportunities to experience and learn about the natural world, as well as to realize that scientific knowledge is reliable. "Science is based on curiosity, and when children aim to learn more about the world around them, it is science that often holds the clues they need for a better understanding" (Learning Liftoff, 2018, p. 1).

The recent COVID-19 pandemic revealed the critical thinking and problem-solving capabilities of engineers, all genres of medical practitioners, and scientists, in collaboration with design teams producing newly designed equipment items for assisted breathing apparatuses in intensive care units and other innovative solutions to challenges presented. It also provided primary and secondary students with opportunities to develop and share their STEM solutions globally (Kennedy, 2021). These actions and their outcomes showcased the collaboration possible between perhaps hitherto discreet areas of organization, resulting in STEM benefits. The debate between science and the arts has historically been divided, but recognizing Leonardo da Vinci's contribution to both areas, perhaps indicated that the Industrial Revolution's rise of industry caused attitudes related to science and engineering to change as Western societies began valuing the benefits and financial rewards of the output rather than art, and the workforce moved from working the land to working in the factories.

As STEM education becomes more recognized as a societal solution, through applications related to social issues and needs, we are recognizing its use while acknowledging that all content areas, including the arts, reading, writing, and the humanities, design, drama and music, and their allied pedagogies and knowledge effectively integrate into STEM subjects, particularly during the early years. Thus, we will generally use the acronym STEM in this book and recognize the contribution of all content areas subsumed in its application.

In summary, STEM teaching is an innovative and interdisciplinary approach to learning that is extremely effective with the earliest of learners when play, as the primary context for learning, allows children to organize and make sense of their social worlds.

- Through science, children learn about the world around them and gain an understanding about how it works through exploration, gathering information (data), looking for relationships and patterns, and using the evidence they gather to generate explanations and ideas.
- Technology provides opportunities to use tools, such as a magnifying glass to closely inspect the coloration of a caterpillar's body, as well as use digital tools like a tablet or computer.
- Engineering processes help design tools, systems and structures to solve problems.
- Through mathematics, young learners study quantities, structures, space, and chance.

Early childhood settings naturally support STEM learning, especially through heuristic play. From pre-formal school years through the early years of formal school, the role of play in social-intellectual development, as well as in the development of competencies leading to enhanced confidence and resiliency, is critical. "Playful curricular experiences facilitate children developing creativity, inventiveness, and engagement with others and their ideas" (Ornstein & Hunkins, 2017, p. 220).

1.5 The Role of Adults and Children as Initiators and Drivers

According to the National Science Teaching Association (NSTA, 2014, p. 1), "learning science and engineering practices in the early years can foster children's curiosity and enjoyment in exploring the world around them and lay the foundation for a progression of science learning in K-12 settings and throughout their entire lives." Children enter formal educational settings, such as preschool and early-care education programs, with a substantial knowledge of the natural world, much of which is implicit (NRC, 2007). Preparing our children for the twenty-first century begins in the early years, as early as 2 years of age. According to a recent two-year study, "young children are capable of engaging in, at developmentally appropriate levels, the scientific practices that high school students carry out" (McClure, 2017, p. 2; McClure et al., 2017, p. 16).

In the words of Jean Piaget, "Play is the answer to how anything new comes about (…) Children should be able to do their own experimenting and their own research. Teachers, of course, can guide them by providing appropriate materials, but the essential thing is that in order for a child to understand something, he must construct it himself, he must reinvent it. Every time we teach a child something, we keep him from inventing it himself. On the other hand, that which we allow him to discover by himself will remain with him visibly (…)" (1972, p. 27). Research on play and interaction between children and adults is extensive, especially the body of literature focusing on close proximity and joint attention between both children and adults during play. Quiñones, Li, and Ridgway postulate that active positioning between adult and child, keeping continuous close proximity to the child, "can increase the high level of children's play engagement" since affective engagement enhances toddlers' learning and play development, especially when adults "actively position themselves towards infant-toddlers' needs and interests in play" (2021, p. 90). They refer to this as "creating motivating conditions by use of pedagogical questioning and explorative talk" which naturally extends children's play engagement and stimulates learning (Quiñones et al., 2021, p. 92).

Child-led play promotes ownership of learning, allowing young learners to make choices, solve problems that are important to them, and acquire knowledge about their surrounding environment, with no pressure to learn. Interest drives questions and the quest to seek answers which results in learning on multiple levels. According to Elkind, "Play operates as more than a creative urge; it also functions as a fundamental mode of learning" (2008, p. 4). Through exploration, investigation and experimentation, children figure things out on their own, and as a result, gain deeper understandings. Egan (2020, para. 1) adds, "Given that play is such a powerful element of a child's development, understanding our role as the adult in child's play is critical in promoting play and embracing the development and learning. We need to be mindful to support play without influencing or controlling play."

We can think of no better way to close this section than to quote Dewey (1897), who stated, "I believe that only through the continual and sympathetic observation of childhood's interests can the adult enter into the child's life and see what it is ready for, and upon what material it could work most readily and fruitfully" (Article IV, 3.4). The key then, is to allow young children the freedom to experience discovery, and intentionally explore and make sense of their environment. Our role as adults is to help them realize and expand their STEM capacities in a manner that fosters, guides, and builds on their interests (Early Childhood STEM Working Group, 2017, p. 12). Early STEM experiences shape the minds of the next generation in very powerful ways. Science literacy is acquired through everyday experiences. The key elements for developing STEM capital and promoting active citizenship, and a scientifically literate workforce, begin with young children and revolve around play.

1.6 Outline of the Book

Play and STEM Education in the Early Years: International Policies and Practices provides examples of the diversity of early STEM activities occurring around the world, highlighting the policies and practices uniting play and STEM education in the early years. Our goals are to recognize and acknowledge that the "leaky pipeline" issue in science education (Huyer, 2015) begins in the early years, and to provide model activities and creative experiences that involve young learners in STEM.

The following 21 chapters bring together 47 STEM experts from 16 countries (Argentina, Australia, Belgium, Canada, England, Finland, Germany, Israel, Jamaica, Japan, Malta, Mauritius, Mexico, Russia, Sweden, and the USA) spanning all six regions of the world, to provide insights into informal and formal play scenarios crucial to developing young children's interest in and ability to learn science.

The map in Fig. 1.4 shows the global distribution of contributors to this book, whose expertise spans institutions of higher education, museums, zoos, governments, policy making and NGOs. Topics covered include STEM pathways in early childhood, play-based behaviors, STEM experiences in preschools, conceptual knowledge and learner variability, engineering in the early years, policies and practices to integrate STEM in the early years, museums and outdoor learning, mathematics and project-based learning, changes in young children's lives and society, and the transition to STEM learning in primary schools and beyond.

This book focuses on STEM activities occurring globally for young learners 3–4 years of age, as well as students attending formal-nursery school, early primary school, and the early years classes post 5 years of age. It discusses the many strategies that have been identified around the world to successfully build twenty-first century skills including child-centered education and learning pedagogies, whole child development strategies, play-based learning concepts, as well as cooperative, blended, flexible, and differentiated learning structures that are consistently evaluated through formal assessment practices and a combination of learning domains (Ross, 2019).

The content of the book is divided into four parts: (1) Play as the foundation of STEM experiences during a child's learning journey; (2) Policies and training

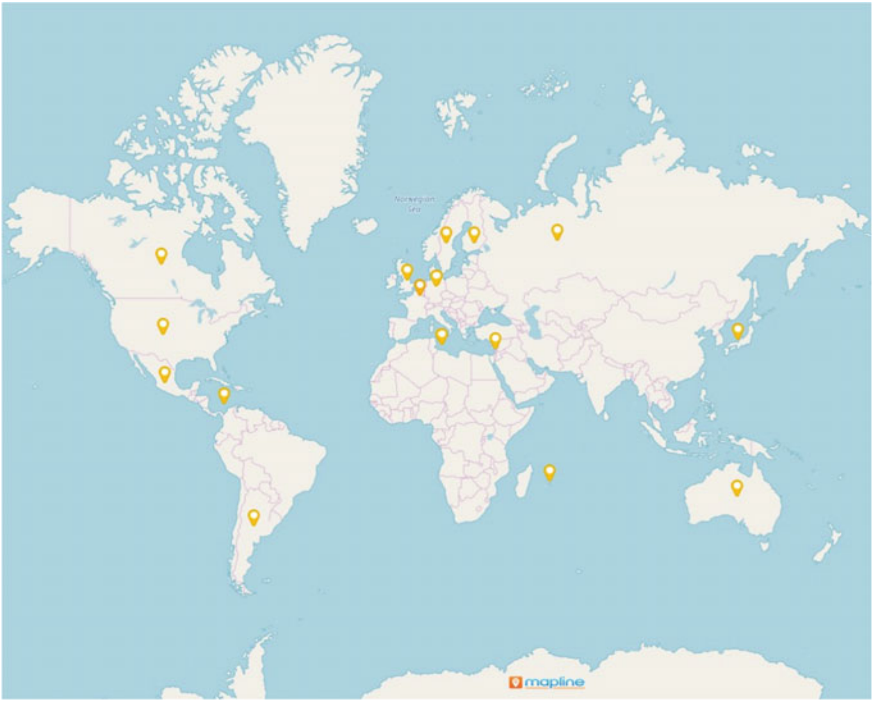

Fig. 1.4 Global distribution of contributors to this book

for formal education environments; (3) Early years experiences in kindergarten and formal schools for 5–8-year-olds; and (4) Informal Settings and family involvement in play. A description of the four sections of the book, along with short summaries of the contents of the chapters included in each section, are described below.

1.6.1 Part 1: Play as the Foundation of STEM Experiences During a child's Learning Journey

Chapters 2–9 present perspectives from 13 science educators representing six countries in three regions: Asia and the Pacific (Australia), Europe (England, Germany, and Russia) and North America (Canada and the United States).

In Chapter 2, Sue Dale Tunnicliffe provides an overview of the beginnings of play. The chapter points out that play is not confined to young humans but to other, particularly mammalian species, where it is a rehearsal for adult skills. She describes in detail the way play has differing genres, from spontaneous free choice play that is a child's choice to other play occasions that are inspired by items provided for them to explore. The general message is that "play" is what children do, it is their work, and it does not have to have another purpose or an end.

Chapter 3 focuses on the work of Valerian Gabdulchako and Evgeniya Shishova from the Republic of Kazan, Russia, as they explore the issues related to the role of children's play in the development of cognition, emotion, imagination, and creativity in childhood. A thorough discussion of Vygotsky's cultural-historical conception as the methodological basis for inclusion of play in preschool activities is included. They also provide an overview of the rationale for preschool education in Russia and discuss their research on teacher quality, the degree of popularity of the features of play activities in day-care centers in Russia, and the effectiveness of teachers on children's STEM learning.

In Chapter 4, Lara Weiser from Germany describes the organization and training of practitioners for early years provision. After exploring the development of play in the first years, she points out that there is no such thing as "just playing" and outlines a published taxonomy of play and the role of play as an 'engine' for a child's development. Although German children spend much time indoors, as is the case in many developed countries, she explores the benefits of outdoor settings, describing how natural settings support STEM development.

Eric Worch, Michael Odell, and Mitchell Magdich from the United States of America also explore the benefits of science learning through outdoor play in natural settings in Chapter 5. They note that past generations of children experienced a rich heritage of self-directed play unencumbered by safety concerns and the distractions of modern society and digital media, while today, most early years children spend little time outside in self-directed play using objects in the environment like stones, bushes, and branches. Time spent in natural settings is however recognized as beneficial to well-being, emotional regulation, and cognitive function. These authors focus on the relationship of different types of play to specific science learning behaviors as children engage in outdoor play.

In Chapter 6, Eirini Gkouskou and Sue Dale Tunnicliffe explore play in pre-formal schooling in England and describe how play develops understanding in STEM subjects at home, in structured play settings, as well as on playgrounds. They particularly explore the progression of play in specific examples as a child develops skills, understanding, and experience as they play and develop. Moreover, the activities they observed and documented reveal the natural tendency of children to discover and use basic engineering techniques which are essential for the understanding of biology, physics, and in general, STEM education. Their research study also suggests that children, as emergent scientists, accomplish progression via the activities they choose, which provides a firm experiential base for later formal learning.

Monica Smith also provides perspectives from England in Chapter 7, outlining the role of play in mathematical understanding in her classroom of 4-year-olds, during the year before statutory schooling begins in an inner London primary school. Her chapter describes the Early Years Foundation Stage (EYFS) curriculum that sets the standards for early years learning in England, the learning areas and provisions in English nursery classrooms, as well as the main paths to qualify as an Early Years practitioner.

In Chapter 8, Coral Campbell and Chris Speldewinde provide insight into science and engineering learning through play in early childhood education in Australia, discussing the roles of government, the curriculum documentation, and educators' involvement. Early childhood education in Australia is directed by government legislation at both the Federal and State levels. They describe the guiding document for early childhood educators, the Early Years Learning Framework (EYLF), which provides direction for the structure, care, and practice in early childhood learning and development across the country. Their chapter discusses several initiatives which are influencing current policy and practice and uses recent research findings to comment on the engagement of science and engineering presented through children's play experiences.

Chapter 9 takes us to Nova Scotia, Canada, where Michael Bowen, Eva Knoll, and Amy Willison provide an overview of the provincial early learning curriculum documents for early childhood and kindergarten education in Canada's ten provinces. They explain that educators are strongly encouraged to use play-based approaches to achieve learning outcomes at both pre-kindergarten and kindergarten ages and therefore initiatives to use technology such as Bee-Bots, small floor-based programmable robots for early ages, have begun in some provinces in order to develop foundational understandings of math, science, and literacy which will be built upon in kindergarten and later grades. They also discuss the implications of these robotic technologies for professional development with early childhood educators.

1.6.2 Part 2: Policies and Training for Formal Education Environments

Chapters 10–14 cover policies and training for formal environments from the perspectives of 18 science educators representing seven countries in four regions: Africa (Mauritius), Asia and the Pacific (Australia), the Caribbean (Jamaica), and Europe (Belgium, Finland, Malta, and Sweden).

In Chapter 10, Coral Campbell, Kerstin Backman, Thijs Eeckhout, Chris Speldewinde, Annie-Maj Johansson, and Anders Arnqvist, early childhood educators from Australia, Belgium and Sweden, provide examples from their respective countries to consider research designed to help them understand cultural influences that have affected the teaching of STEM, the factors that affect their decision-making processes, and how the policy and cultural backgrounds of their individual countries have influenced teaching practice and pedagogy.

Chapter 11 focuses on the Finnish educational system. Jaakko Hilppö, Jenni Vartiainen and Pasi Silander discuss how twenty-first century skills, along with other skills such as computational thinking, could be advanced in early childhood education via science, technology, engineering, arts and mathematics (STEAM) education. They present three distinctive approaches to early STEAM education developed in

Finland: (1) phenomenon-based learning, (2) children's maker-spaces, and (3) children's projects. In addition, they discuss and provide suggestions as to how these approaches could potentially address the concerns of Finnish early years STEAM educators who are cautious about implementing STEAM and phenomenon-based learning.

Karlene DeGrasse-Deslandes and Nicole Morgan discuss play-based learning in Chapter 12 as a natural teaching strategy in Jamaican preschools. Although play-based learning has been encouraged by national initiatives, a debate persists in the country as to its purpose and the value of play during the preschool years. They discuss the challenges related to implementation as well as consider the experiences of early childhood practitioners using play-based learning to encourage STEM in early childhood environments.

In Chapter 13, Ravhee Bholah, Rajeev Nenduradu, and Jyotsanah Thaunoo from the Republic of Mauritius describe how the 2010 National Curriculum Framework Pre-Primary (3–5 years) developed, along with its six areas of learning including body and environmental awareness, and mathematical and logical thinking. This policy document has influenced teacher education, curriculum development and the practice of STEM. They highlight the role of relevant educational institutions, particularly the Mauritius Institute of Education, in preparing the early year practitioners. The mainstreaming of STEM in teacher education programs, the development and provision of learning resources, the use of ICT and other pedagogical supports are also explored.

Chapter 14 provides yet another perspective to national curriculum reform measures as Jacqueline Vanhear, Alexis Reid, Isabel Zerafa, and Melanie Casha Sammut describe implementation efforts in Malta to prevent early school leaving. Their chapter provides details about their use of the Universal Design for Learning (UDL) approach to scaffold STEM learning experiences and provide all students with an equal opportunity to succeed in STEM subjects. Focus is placed on brain development in the early years and establishing learning environments through intentional design. They also provide examples of their initiatives focusing on UDL specifically highlighting how executive function is explicitly scaffolded into early years STEM learning experiences.

1.6.3 Part 3: Early years Experiences in Kindergarten and Formal Schools for 5–8-Year-Olds

Chapters 15–18 describe early years experiences in formal schooling for students aged 5–8 years from the perspectives of six science educators representing five countries from five regions: Asia and the Pacific (Japan), Europe (Germany), Latin America (Mexico), the Middle East Region (Israel), and North America (USA).

This section begins with a description of the educational recommendations made by the Israeli Royal Academy of Engineering to engage in engineering education from childhood, specifying six Engineering Habits of Mind (EHoM): systems-thinking, problem-finding, visualizing, creative problem-solving, adapting, improving. In Chapter 15, Ornit Spektor-Levy and Taly Shechter describe their research study consisting of two hundred preschoolers, 5–6 years of age, from six urban classrooms. They identify early EHoM indications among young children during a problem-solving play-like task and include examples of how to enhance preschoolers' cognitive capabilities in a play-based manner through learning environments that provide open-ended materials.

In Chapter 16, Timo Reuter and Miriam Leuchter from Germany describe a guided play learning environment for 5–6-year-old kindergarten children that aims to foster children's conceptual knowledge about their *gear play environment*, which consists of gear construction sets and a choice of task cards focusing children's attention on turning direction and turning speed. They describe the process that adults follow to verbally scaffold children's play towards the learning objectives and the overall results from their study on guided play to facilitate scientific learning in kindergarten children.

Manabu Sumida describes how problem-based and socially implemented play is expanded from local to the national and global levels by reorganizing traditional play activities for Japanese children in the context of current 'glocal (global+local)' issues in Chapter 17. Young Japanese kindergarten children learn about natural disaster prevention through STEM play that utilizes sand play, toy building blocks, water play, and play hoses, items that are traditionally familiar to them. He explains that at the start of the twenty-first century, in highly information-oriented societies such as Japan, it is important for young children to acquire science literacy to prevent information poverty while acquiring the competencies necessary to change their lives and the society in which they live.

In Chapter 18, César Mora Ley describes the incorporation of STEM challenges into the PreK and Kindergarten curriculum in Mexico, describing student opportunities for play and discussion. The multidisciplinary approach to student exploration in Mexico places high priority on developing STEM-skills facilitating students to think and act as scientists and engineers in their earliest experiences of play through hands-on, minds-on activities, with the goal of ensuring students are comfortable with and engaged in STEM in their later academic years, igniting a life-long love of exploration and learning.

1.6.4 Part 4: Informal Settings and Family Involvement in Play

Chapters 19–22 describe early years experiences in informal settings involving family and the community from the perspectives of 11 science educators representing three countries from three regions: Africa (Mauritius), Latin America (Argentina), and North America (USA).

In Chapter 19 Ana Prieto and Teresa Kennedy describe the Argentine educational system and the implementation of STEM learning experiences balancing unstructured and structured play in outdoor environments with two third grade classrooms of the María Auxiliadora Institute (IMA) in the city of Junín de los Andes, located in the northwest of the Patagonia region of Argentina. Students were exposed to different audiences including professionals, NASA scientists, educational community members, science fair participants and others while serving as role models to their younger siblings at home and providing them with authentic scientific experiences leading to their own free choice unstructured play scenarios in their backyard environments through data gathering activities with the GLOBE Program. The results of this citizen science application of the GLOBE Program are analyzed and discussed providing an example that can be replicated in other countries.

Chapter 20, by Jayantee Naugah, Bhamini Kamudu Applasawmy, Ian Li Kim Khiook, Sookdeo Rungoo, and Aman Kumar Maulloo, describes how the Rajiv Gandhi Science Centre implementes its early science education program in Mauritius. They discuss their systemic approach, which is implemented through a collaborative strategy between teachers, parents, children, as well as supervisors of the early education sector. Their educational program includes a science exhibition by preschoolers and the continuous professional development of teachers.

In Chapter 21, Scott Pattison and Smirla Ramos-Montañez discuss the diverse and interdisciplinary ways that children and their families engage with STEM in their everyday lives. Over the last several years, the Head Start on Engineering (HSE) initiative, based in Portland, Oregon, USA, has been developing a family-based program to engage preschool-age children (3–5-years-old) and their families from low-income communities in the engineering design process, and then study how these experiences support long-term family interests related to engineering. The findings from a retrospective interview study with parents one to two years after they participated in HSE revealed three distinct interest pathways (a) engineering focused, (b) prior interest focused, and (c) family values focused. The findings problematize traditional approaches to studying STEM-related interests and highlight the importance of understanding the complex ways families make sense of and engage with STEM through play and other informal learning experiences.

In the final chapter of the book, Chapter 22, Jamie Wallace and Jenny Ingber explore early childhood educators' experiences and perceptions of young children's play and learning at dioramas, portrayals of frozen moments in time depicting three-dimensional scenes of the natural world. Their study includes a sample of ten early childhood educators at the American Museum of Natural History in New York, exploring examples of play-based, diorama-based science learning activities, as well as teaching strategies and affordances of dioramas. Their findings suggest that play and learning inspired by dioramas look different across classes of differing age groups and contexts but are perceived as vital in sparking imagination and creativity for young children when integrated into experiences that afford unique opportunities for role play, games, and discovery. Their study highlights how dioramas can be integral in play-based science learning, making museums that are not traditionally designed for children into places for play.

The editors recognize there are many ways in which various governments and institutions contribute to the promotion and delivery of STEM in the early years, and that our collaborative global efforts will result in building the worldwide STEM capital that will inevitably move us into the next century through the development of vital skills such as problem-solving and critical thinking, which young children intuitively possess and utilize. In addition, we recognize that preschool and early formal school experiences and pedagogy differ according to cultures and government initiatives, as well as the confidence in the science content teachers are facilitating as practitioners. Simple everyday life experiences can deeply engage young children for extended periods of time, building interest in the world around them and fostering a seamless transition to STEM-focused pathways in primary school and beyond. These activities promote creativity as children question, explore, investigate, and construct meaning through problem-solving and applying previous experiences, all important skills employed in the STEM learning paradigm which includes most academic subjects and promotes the development of twenty-first century skills. We hope that this book will facilitate readers to continue down an enriching path in STEM education, and ultimately inspire and facilitate the children around them to become STEM-literate lifelong learners.

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