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Highlighting the importance of STEM education in early childhood through play-based learning: A Literature Review

Tshering Sydon[1]* and Sonam Phuntsho[2]

Changzamtok Middle Secondary School, Thimphu

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Abstract

This paper aims to focus on the international studies regarding early integrated STEM education and its importance for developing 21st-century skills in young children to prepare them for an ever-changing world. The paper reviews the importance of integrated STEM education in early childhood settings and how it supports the development of scientific concepts and 21st-century skills such as critical thinking and problem solving through play-based learning based on the current literature. Adding to the importance of STEM education, the paper explores what STEM education means in early childhood and how different types of play-based learning can support early integrated STEM concepts and skills in young children concerning the literature from different parts of the world. Furthermore, the literature presents the role of teachers in implementing STEM practices and the challenges encountered by teachers. The literature indicates low self-efficacy and confidence in teachers as the main factor affecting the delivery of STEM teaching and suggests ways to overcome this through STEM professional development to enhance the STEM practices in early childhood. The paper concludes with further recommendations and implications for stronger policies, and more research in this field to achieve high-quality integrated STEM education in early childhood.

Keywords: STEM education, early childhood, play-based learning

Email: tsheringsydon2020@education.gov.bt

Introduction

STEM education in early childhood is the acronym for interconnected science, technology, engineering, and mathematics disciplines that has gained global attention (English, 2016) and a considerable body of evidence supports the importance of building the foundation of STEM learning from the early years (Early Childhood STEM Working Group, 2017; Hu & Yelland, 2019; McClure et al., 2017; Park et al., 2017; Simoncini & Lasen, 2018; Sneideman, 2013). The push to start early STEM education correlates with its significant influence in preparing students for 21st-century world and later STEM success (Dou et al., 2019; Madden et al., 2016). The analysis by Murphy et al. (2019, p.123) for various Australian STEM education strategies informs the importance of early engagement in STEM practices as it is found "to develop 21st-century skills such as problem-solving, critical thinking and creativity," which in turn will help prepare children for global health, environmental, and economic challenges. Likewise, DeJarnette (2012) also argues that STEM education should start early as it promotes problem-solving, and critical thinking and engages children in an open-ended inquiry through classroom STEM activities. The concept of STEM education has undergone various interpretations since its inception in the 1990s by the National Science Foundation (Vasquez, 2014). More recently, the term STEM is used to denote a more integrative approach to combining the concepts and skills from the four disciplines to solve problems (English, 2016; Kelly & Knowles, 2016; Madden et al., 2016).

In early childhood education (ECE), STEM practices are observed through children's play as children question, explore and experiment in their world (Buchan & Cron, 2020). Although there are different types of play such as free or guided play the evidence supports that learning happens through both (Zosh et al., 2017). However, structured play with appropriate resources for children to explore objects and phenomena is found to result in more meaningful learning experiences (Johnston, 2015). For instance, a study conducted during a STEM summer camp for ten four-year-old participants with various activities such as block play, balloon races, mixing liquids, and use of engineering applications on the iPad contributed significantly to children's understanding of STEM skills in the post-test result (Torres-Crespo et al., 2014). In another research conducted for nine European Union countries, Stylianidou et al. (2018) also recommended a play-based approach in their educational policy as playful experimentation and exploration fostered inquiry learning in children. Providing playful and meaningful experiences entails educators to be thoughtful and purposeful in supporting children's learning using intentional teaching to recognize the STEM concepts in regular activities such as making play dough or building blocks or any child-instigated explorations (Campbell & Chealuck, 2015). Therefore, the role of an educator is important in creating STEM educational practices and learning environments based on intentional actions to "build student STEM capabilities and nurture STEM dispositions" (Murphy et al., 2019, p.125). Furthermore, the qualitative data on the Little *Scientist* program that provides STEM professional development for early childhood educators across Australia reports that participants found learning through

STEM inquiry and play-based explorations with adult support as the best strategy for teaching STEM (MacDonald, 2019). Given the role of educators in implementing STEM practices, many researchers propose and support STEM professional development programs for educators to deepen their content and pedagogical knowledge, to build their confidence and self-efficacy in teaching STEM lessons (Early Childhood STEM Working Group, 2017; DeJarnette, 2018; MacDonald et al., 2019; Murphy et al., 2019).

Section one will present a literature review on STEM education and its importance in early childhood for developing 21st-century skills in children. Section two will investigate different types of play-based learning approaches to support STEM learning and practices to emphasize learning through play. Section three will discuss the role of early childhood teachers and challenges in implementing STEM education with ways to overcome these issues in early childhood settings based on the literature to inform future policy and research. Finally, a conclusion and recommendation to provide a summary of the literature review.

Aims / Objective

The main purpose of this review is to discuss the importance of STEM education in early childhood through play-based approaches to create further awareness in the early childhood community. Furthermore, the research around STEM in early childhood is at an early stage (Park et al., 2017) despite its importance and coming to the home, Bhutan has no studies on the topic. His Majesty the King of Bhutan issued a Royal edict on education reform on 17th December 2020 stating that to achieve 21st-century competencies in our children "STEM subjects should be part of their everyday language" (Kuenselonline, 2021, para. 6) and early STEM experiences mean giving a head start in their life to face the future world as first eight years is crucial in the life of a human being (Torres-Crespo et al., 2014). Therefore, this review will draw upon scholarly articles from international research and organizational reports to present the importance of STEM education through play-based learning to Bhutanese stakeholders to initiate our policy and programs to strengthen STEM learning from early childhood to early years of primary education. Through this paper, I also hope to create awareness of integrated STEM education among Bhutanese educators and early primary teachers (PP-III). Above all, understanding the importance of STEM education in early childhood is imperative for educators as it enables them to incorporate STEM concepts through play-based learning (Torres-Crespo et al., 2014).

Section One: Importance of STEM education in early childhood

Awareness of early STEM education:

It is essential to understand what STEM education means and why there is a major focus on starting early in many global contexts. STEM education has gained extensive attention from governments across the world for over a decade to address a wide range of local, national, and global issues concerning health, well-being, environment, and the economy (Gough, 2015). Advancing STEM education in many countries was for economic and skilled workforce development (Marginson et al., 2013). This drive has pushed the focus on engaging young children in STEM education to promote their early STEM identity development through exploration and meaningful STEM-related experiences in early childhood classrooms (Hachey, 2020). Although a large body of evidence indicates that early STEM education is important for building 21st-century workforce to face global challenges and later STEM study (Hu & Yelland, 2019; Madden et al., 2016; McClure et al., 2017; Park et al., 2017; Sneideman, 2013), a study of 117 early childhood professionals' survey findings before engagement in a STEM workshop show that early childhood professionals do not consider STEM as the most important learning area with little understanding of STEM as an integrated approach (Simoncini & Lasen, 2018). Another study of 830 early childhood teachers in rural areas of Western Kentucky revealed that a lack of awareness of the importance of STEM education posed zero readiness for teaching STEM lessons regardless of their teaching experience (Park et al., 2017).

Therefore, advocacy is required to raise the awareness and understanding of early childhood STEM education among key stakeholders like teachers, parents, administrators, curriculum developers, and policymakers (Early Childhood STEM Working Group, 2017). Furthermore, teacher education courses are recommended for practice-based contexts for STEM learning (Hu & Yelland, 2019). The most integral part of effective STEM education is to support in-service early childhood teachers with integrative STEM-related professional development programs to implement high-quality STEM experiences in their classrooms (Early Childhood STEM Working Group, 2017).

An integrative STEM approach:

An integrative STEM approach is seen as a logical approach to teaching STEM as it is grounded in constructivist and educational theory using inquiry and problem-solving approaches to learning for real-world applications (Blackley et al., 2015). Moore and Smith (2014, p.7) explain that integration of some or all STEM disciplines "has the potential to help children learn more deeply, enjoy the STEM disciplines, and provide better access to future careers." Furthermore, Vasquez (2014) posits that the real power of integrated STEM education is that it can solve meaningful problems using the concepts and skills from different disciplines. It is further supported by DeJarnette (2018) stating that integrated STEM experiences improve children's interest in STEM learning and prepare them for the 21st-century world. Therefore, integrated STEM education not only focuses on content knowledge but involves problem-solving skills and inquiry-based learning (Wang et al., 2011). Moreover, integrated STEM education in absence of a specific science curriculum in early childhood can give children a better understanding of how concepts from different STEM areas are correlated or brought together to create meaningful STEM experiences (Madden et al., 2016).

On the other hand, researchers also acknowledge that teaching integrated STEM can be challenging and requires a strategic approach with deliberate planning for effective implementation (Early Childhood STEM Working Group, 2017; Kelly & Knowles, 2016). For instance, in a case study of 120 Shanghai Chinese educators, Weng and Li (2020) reported uneven curriculum content in technology and engineering with fewer hands-on activities which required formulating an explicit and integrated STEM curriculum. However, there are rich opportunities to integrate STEM disciplines and if implemented well in the early years it is found to promote higher order thinking and inquiry learning in children assisting them to understand their world thereby developing 21st-century skills (Madden et al., 2016). To achieve this, supporting preschool teachers in integrating STEM into their curricula is found to be a lever in creating accessible learning experiences for all the children in the classroom (Brenneman et al., 2019). Tao's (2019) study of 430 kindergarten teachers across China, though teachers lacked confidence in teaching STEM they displayed a positive attitude toward STEM education and were integrating STEM content areas making it a comprehensive curriculum for the holistic development of children.

Developing 21st-century skills through STEM education:

Today's world is faced with many uncertain challenges and identifying new competencies for 21st-century learners has become crucial (Luna Scott, 2015). The National Education Association (2012, p.3) that promotes 21st-century education identifies the "Four Cs: critical thinking and problem solving, communication, collaboration, and creativity" as the most important skills for preparing students for a global society. The Association emphasizes that the four skills can be integrated into all grade levels and disciplines for classroom teaching and learning. A significant body of empirical research illustrates that integrated STEM projects and activities that are either digital or non-digital can enhance the four skills in children (English & King, 2015; Kazakoff et al., 2013; Lowrie & Larkin, 2020; Nguyen, 2020; Torres-Crespo et al., 2014; Zviel-Girshin et al., 2020). However, fewer STEM opportunities are available in the early years of education despite the positive result achieved through early STEM exposure by engaging children in problem-solving activities and building later success in STEM study (DeJarnette, 2012).

In a case study undertaken by Zviel-Girshin et al. (2020) with Lego robotics construction in an Israeli early childhood setting children designed robots, explained problems and solutions, collaborated as teams, and discussed STEM concepts used in robots thereby opening the door for the development of 21st-century skills. In another small study of 10 four-year-old participants of STEM summer camp, Torres-Crespo et al. (2014) further validate children's engagement in STEM activities with support from educators to encourage problem-solving, critical thinking, inquiry-based learning, and understanding of STEM concepts. Similarly, a mixed-methods case study by Isabelle et al. (2021) explored Engineering Design Process through inquiry and play-based learning using blocks scaffolding building skills, critical thinking, and problem-solving in kindergarten children under the guidance of teachers.

In all the above studies it is evident that play-based learning is employed as the pedagogical approach to teaching STEM concepts, but educators need support in incorporating STEM lessons through play-based experiences in their practice (DeJarnette, 2012). The research findings from a two-year independent evaluation of the *Little Scientist* program in Australia report that a community of STEM inquiry learning through play-based explorations was fostered when educators were provided with STEM professional development (MacDonald et al., 2019). As a result, the Early Childhood STEM Habits of Mind Framework by Simoncini and Lasen (2018) was developed to raise awareness of the importance of STEM in the early years and as a guide to planning integrative STEM education in early childhood to promote 21st-century skills and STEM thinking through play-based learning.

Section Two: Play-based learning appropriate for STEM education in early childhood.

What is play-based learning?

According to Zosh et al. (2017, p.12), "Children are born to learn through play," play is an important tool for enhancing children's learning. In many countries, play-based learning (PBL) is developed as the key pedagogical approach to early childhood education (Pyle & Danniels, 2017). However, there is no definitional consensus on PBL which makes it debatable and controversial (Bubikova-Moan et al., 2019). According to a meta-synthesis of 62 studies from 24 countries from different corners of the world, views on PBL were influenced by different theories and terminologies however many early childhood teachers saw it as learning through play (Bubikova-Moan et al., 2019). This view is further supported by Nolan (2015) by considering play as the most appropriate tool for young children's overall learning. Although there are varied definitions of play across different cultures (Rentzou et al., 2018) most literature draw on similar characteristics of learning through play as engaging, interactive, meaningful, iterative, and joyful through both digital and non-digital play that can be either free or guided play (Gray & Thomsen, 2021; Zosh et al., 2017). A cross-cultural study by Rentzou et al. (2018, p.10) across eight countries in Europe and the USA showed that play supported “social/emotional development, learning, creativity, and as an opportunity to explore the world.” Similarly, Taylor and Boyer (2019) also define PBL as child-centered that considers children’s interests and abilities through developmentally age-appropriate learning experiences to support their academic, social, and emotional development. On the other hand, the study also found a lack of a consistent definition of play and its implementation in their classroom with further recommendation for more empirical research to develop clear policies for educators to construct and translate play pedagogies into classroom practice (Rentzou et al., 2018).

Despite the ambiguity of play pedagogy in early childhood, a growing body of studies emphasizes how early STEM practices are observed and developed through play-based learning (Buchan & Cron, 2020; Gray & Thomsen, 2021; Lowrie & Larkin, 2020; Torres-Crespo, 2014; Tunnicliffe & Gkouskou, 2020; Vogt et al., 2018). These phenomena of children learning through play are clearly illustrated by Tunnicliffe and Gkouskou (2020) who claim that children are natural scientists as they observe, ask questions, and solve problems while engaged in free play to demonstrate STEM in action. It is observed and agreed by early childhood professionals that discovery and exploration through play are a cornerstone of STEM teaching (MacDonald et al., 2019; Simoncini & Lasen, 2018). A further contribution has been made in early STEM education with the use of digital technologies through intentional teaching and play-based learning to promote STEM practices (Lowrie & Larkin, 2020).

Types of play used as a pedagogical approach in STEM teaching:

The two most widely used play approaches in early childhood environments are free-to-play and guided play in which free play is initiated by children and guided play is a mix of adult-scaffolded learning or intentional teaching but child-directed (Cohen & Emmons, 2017). To throw more light on the information, there are different terminologies used according to different researchers and are enacted as free or guided play. For instance, Johnston's (2015) play types underpin the principles of Rousseau, Piaget, and Vygotsky for effective science teaching and learning with young children into different play types such as dramatic and exploratory play. Johnston's (2015) comprehensive description of different types of play and its connection with the development of scientific understanding in young children provide guidelines for early childhood professionals to implement STEM practices. Out of different types of play, exploratory play is found often to be associated with scientific and cognitive development, as children explored the world around them with the support of educators (Johnston, 2015). For example, Johnston (2015) describes a case study of guided exploratory play where four-year-old children tested balloons by filling them with air, water, and ice to promote understanding of the concept of forces.

Tunnicliffe and Gkouskou (2020) segregated play into two main categories as free play activities where children chose the activity and planned (guided) science activities by the educators. Some of the activities included water play, construction play, outdoor play, ball games, and slides with scientific concepts embedded in each play when children engaged in these experiences (Tunnicliffe & Gkouskou,2020). With the world going digital, early STEM education has employed digital technologies such as tablets to support STEM learning through exploratory and imaginative play using both on and offline applications (apps) which proved successful in engaging children in meaningful yet playful learning (Lowrie & Larkin, 2020). As a part of Australia's early STEM project, Lowrie and Larkin (2020) developed a heuristic for digital engagement with play-based STEM learning apps that encouraged children to work collaboratively, think critically, and understand concepts such as sorting. This heuristic program through digital engagement had received positive feedback from educators regarding children's responses to the apps (Lowrie & Larkin, 2020). In a study of STEM Summer Camp, assorted materials and activities promoted STEM skills and concepts in four-year-old children through block play, hardware kit, balloons, mixing liquids and colors, and making dough in a free and structured play setting that both proved to be engaging with educators' support (Torres-Crespo et al., 2014). Adding to the variety of play-based learning, the research project by Vogt et al. (2018) with 324 six-year-old kindergarten children indicates that the group having a play-based intervention with card and board games in a guided play significantly had higher learning outcomes in mathematical competencies than the non-intervention group. Similarly, the study by Bose and Seetso (2016) for preschools in Botswana revealed that using local games and rhymes as a pedagogical approach by the teachers helped in teaching science and mathematics concepts to children. Drawing on the literature, play pedagogies support the development of STEM learning in young children with the support and guidance from adults.

The role of the early childhood teachers:

The role of the educators and teachers in the early childhood setting is critical for the development of STEM concepts in young children through planning, supporting, and guiding children in learning (Bose & Seetso, 2016; McClure et al., 2017). For this reason, Buchan and Cron (2020, p.31) call upon educators to be "STEM detectives" to observe children as incidental learning happens when they are playing. Similarly, significant studies (Isabelle et al., 2021; Khales & Meier, 2013) posit that teachers should support and scaffold children’s developmental learning to meet the needs of each child through play-based learning by being a facilitator. Weng and Li (2020) pointed out that the full potential of children’s learning cannot be realized without appropriate scaffolding as children need adults to answer their questions, assist in processing the world around them, and meet their different needs. Most importantly, teachers should motivate and inspire young STEM learners by engaging them in rich STEM experiences and interdisciplinary practices (Ciftci et al., 2020; Zaza et al., 2019). This belief is further consolidated and agreed upon by early childhood teachers in nine European countries emphasizing the need to foster motivation, creativity, exploration, inquiry, and problem-based learning by providing a rich STEM environment (Stylianidou et al., 2018).

To prepare rich STEM lessons, collaboration among teachers is found to be a resourceful way to share STEM ideas (Lamberg & Trzynadlowski, 2015). This is illustrated in data analysis of 91 pre-service early childhood teachers in Turkey where one group collaborated in developing a STEM integrated lesson plan utilizing the engineering design process and Bybee's 5E instructional model that showed achievement of STEM learning outcomes (Ciftci et al., 2020). Educators can also facilitate play-based learning by setting up the learning environment with different materials, props, and activities (Bubikova-Moan et al., 2019) for children to explore and develop STEM understanding from their experiences (Bulunuz, 2013). Another way to provide early exposure to STEM learning in the early years is by finding ways to incorporate scientific inquiry and technological design lessons with hands-on activities (DeJarnette, 2012).

To expand on the role of early childhood teachers, Clements and Sarama (2016) argue that teachers who use research-based STEM approaches demonstrate higher levels of STEM thinking and learning in children. For instance, a qualitative observational study of preschool children to examine their early engineering behaviors while building with blocks using a fundamental design process model in free play found that children exhibited goal-oriented design and problem-solving thinking (Bagiati & Evangelou, 2016). This kind of STEM approach can be used by teachers as a guideline to practice in the classroom. At the same time, teachers must keep children's curiosity and motivation sustained by frequently asking questions and encouraging them to talk about their ideas as "communication can lead to generalization and production of new ideas" (Early Childhood STEM Working Group, 2017, p.15). For effective implementation of STEM education, early childhood teachers need to understand STEM content and thinking that are age-appropriate for instruction to meet children's development, and robust professional development training is recommended for teachers (McClure et al., 2017). Thus, engaging in lifelong learning and STEM professional development is critical for the effective implementation of STEM education (Nadelson et al., 2013). Although the literature reviewed so far presents early STEM exposure through play-based learning as helpful in developing 21st-century skills and scientific concepts in young children, the learning trajectory of STEM education in the early years faces significant challenges (Weng & Li, 2020).

Section 3: Challenges in implementing STEM in ECE

Lack of confidence and self-efficacy in teachers:

Although early childhood professionals perceived STEM education as an important tool for developing early STEM practices and for later success in STEM study through play-based approaches (Simoncini & Lasen, 2018), the desired outcome is not achieved despite various programs and funding invested in STEM education (Blackley & Howell, 2015). One of the factors impacting the effective implementation of STEM in the early years is found to be associated with the lack of confidence and self-efficacy in teachers as discussed in a significant body of literature (DeJarnette, 2012, 2018; Nadelson et al., 2013; Tao, 2019; Weng & Li, 2020). As a result, teachers are unable to engage in robust STEM activities for children (Margot & Kettler, 2019). When teachers have low self-efficacy, it means that they lack the ability to discern their own abilities to teach STEM lessons which also leaves them with low confidence levels (DeJarnette, 2018). McClure et al. (2017) also report that low self-confidence and anxiety in teachers could lead to the transfer of similar effects in their students.

To discuss more on teacher self-efficacy, the data analysis from 150 preservice preschool teachers in Taiwan through survey questionnaires also revealed that STEM self-efficacy correlated with their STEM pedagogical belief, therefore, found the need to engage teachers in STEM professional development (Chen et al., 2021). In another research analysis of various Australian STEM education strategies Murphy et al., (2019) identified the need to build confidence in early childhood educators to deliver STEM education programs with sound STEM content knowledge and pedagogical approaches. For example, a case study of Shanghai early childhood educators reveal that educators were not confident enough to integrate technology into their STEM teaching without receiving relevant training (Weng & Li, 2020). Nadelson et al.,(2013) in the US and Tao (2019) from China were consistent about kindergarten teachers' confidence in teaching STEM education stating that teacher confidence did not correlate with their years of experience or levels of qualification but with insufficient professional development and other contextual factors such as lack of systematic STEM curriculum and big class sizes. Thus, the Early Childhood STEM Working Group (2017) argues that modest interventions in the form of support are required for promoting a positive mindset in early childhood teachers to mitigate teachers' STEM anxiety that could affect children's disposition to engage in STEM learning.

Other contextual factors causing barriers in early STEM education:

As mentioned above, the findings from Tao's (2019) interviews with the kindergarten teachers indicated other barriers such as a lack of systematic STEM curriculum, large class sizes, and insufficient time for STEM activities. Similar views were presented about the lack of time dedicated to STEM as an integrated subject in early childhood settings (Madden et al., 2016) and an absence of structured content curriculum or guidelines for early childhood STEM education (Blackley & Howell, 2015; Weng & Li, 2020). A systematic literature review on teachers' perception of STEM education based on empirical studies by Margot and Kettler (2019) analyzed challenges perceived by teachers in terms of pedagogy, curriculum, structure, student abilities, assessment, time, and STEM knowledge as the barriers to STEM education. Weng and Li's (2020) Shanghai case study findings revealed a lack of a comprehensive curriculum in technology stating teachers found integrating digital gadgets such as interactive whiteboards and tablet computers in teaching challenging as they were skeptical about the negative effects of the technology. Another multi-case study by Wang et al., (2011) also found technology as the hardest discipline to integrate into a STEM practice.

Another barrier discussed in a study conducted in Australia by Murphy et al. (2019) showed that there is a shortage of competent and confident early childhood educators engaging in STEM teaching. On the other hand, a qualitative study of 15 kindergarten classrooms shows that teachers found challenges in teaching curricular expectations through play-based learning (Pyle & Danniels, 2017) which means maintaining a balance between STEM teaching through play-based learning is hard to achieve. A qualitative study by Park et al. (2017) found that teachers' challenges in teaching STEM revealed several themes regarding lack of time, instructional resources, administrative support, parental participation, STEM knowledge, and teachers' collaboration. To support early STEM education, findings from nine European countries' *Creative Little Scientist* project study identified the need to ensure enough resources (school structure) and facilities to support practical STEM learning and to encourage the involvement of parents and the wider community to encourage dialogue and their role in strengthening early years STEM education (Stylianidou et al., 2018). Consolidating all the factors, particularly the lack of self-efficacy in teachers highlights the need to have more attention to STEM-related training and professional development support for both pre-service and in-service early childhood teachers (Early Childhood STEM Working Group, 2017).

STEM Professional Development for early childhood teachers

Providing quality professional development and training to both in-service and pre-service teachers in terms of STEM content and pedagogy will produce more awareness of the importance of early STEM education, increase teacher confidence in STEM teaching, and promote meaningful STEM experiences for children to engage in (Early Childhood STEM Working Group, 2017). Additionally, a study analysis of 150 early childhood preservice teachers from Taiwan revealed the need for PD to promote self-efficacy (Chen et al., 2021). Furthermore, learning STEM concepts and thinking such as scientific inquiry, and design thinking through problem-based and technological activities are to be part of teacher education so that they are prepared to incorporate STEM initiatives in their curriculum (DeJarnette, 2012). Although the need for PD is emphasized for effective STEM implementation, it is found that early childhood teachers have inadequate PD programs and STEM is usually ignored (Clements & Sarama, 2016). In response to these challenges, studies on STEM frameworks and pedagogical practices through PD programs are conducted to inform early STEM education and to increase the self-efficacy of teachers (Brenneman et al., 2018; DeJarnette, 2018; Lowrie & Larkin, 2020; Simoncini & Lasen, 2018).

Brenneman et al., (2019) conducted a professional development (PD) model for early childhood teachers on integrating STEM into preschool classes of children from diverse backgrounds in a Northeast state of the United States and the result revealed more confident teachers with a positive impact in their STEM beliefs and practice after the PD program. Similarly, after conducting workshops and modeling STEAM (integrating Arts with STEM) activities, preschool teachers experienced increased self-efficacy with calls for more hands-on STEM training to be effective teachers (DeJarnette, 2018). A further contribution is made by the Early Learning STEM Australia (ELSA) project (2016-2019) by developing the Experience, Represent, Apply (ERA) heuristic pedagogical framework to integrate digital technologies into STEM activities through play-based learning as it provided STEM concepts and strategies to translate into practice thereby increasing the confidence and self-efficacy of teachers (Lowrie & Larkin, 2020). Likewise, Australia's *Little Scientist* program, an initiative to improve

STEM skills and knowledge in early childhood formed Professional Learning Networks to gain insights about the program and the findings revealed increased confidence in educators to teach STEM through play-based explorations (MacDonald et al., 2020). In summary, the literature points out that teachers' self-efficacy and confidence play pivotal roles in STEM education that ongoing professional development for teachers would facilitate the successful implementation of early STEM education (Margot & Kettler, 2019). Thus, supporting STEM educators in STEM knowledge to engage in quality teaching is the gateway to achieving effective STEM education (Zaza et al., 2019).

Conclusion and Recommendation

This review discussed the importance of early STEM education in developing 21st-century skills through play-based learning to create further awareness in the early childhood community. By raising awareness, the demand for high-quality early STEM education is created by parents, teachers, administrators, and policymakers (Early Childhood STEM Working Group, 2017). Despite the importance of STEM education for children, little attention has been paid to teaching STEM in early childhood settings and this calls for more efforts from different stakeholders to put theoretical findings into action (Park et al., 2017). The review further elaborated on how play-based learning supports early STEM practices and concepts through different types of play approaches and experiences for educators to explore with STEM learning. The literature revealed that play in any form when guided by adults can support the development of STEM concepts and skills in children (Johnston, 2015; Lowrie & Larkin, 2020). Conversely, the research also shows that teachers find it challenging to achieve curricular expectations through play-based learning (Pyle & Danniels, 2017). Additionally, the international literature also indicates that there is a gap in research on translating the theory of teaching through play in classroom practice (Bulunuz, 2013). Further empirical research is required to measure the effectiveness of early STEM education through play-based learning (Blackley & Howell, 2015; Weng & Li, 2020). The review also discussed the role of early childhood teachers in translating age-appropriate STEM learning into practice and the challenges faced in the implementation of early STEM education. The review reported low confidence and self-efficacy of teachers as the main challenge in implementing early STEM education. To overcome this barrier, the review analyzed the impact of STEM professional development on teachers' self-efficacy and synthesized that STEM professional development is key to the success of integrated STEM education as it increased teachers' self-efficacy and confidence to teach STEM lessons in early childhood settings (Nadelson et al., 2013).

A large body of literature indicates that STEM education is important in early childhood to develop early STEM practices and to develop 21st-century skills through play-based learning. To realize the benefits of early STEM education, a call for stronger action from policymakers and early childhood professionals is expected for the effective implementation of STEM learning in young children (Clements & Sarama, 2016). The

Early Childhood STEM Working Group (2017) recommends that high-quality STEM education in early childhood can be achieved through an awareness of the importance of STEM to all the stakeholders, and the need for investment in teacher preparation and STEM resources for practitioners.

Competing interests

"Authors declared no competing interests exist."

Author's Biography

Author 1: Tshering Sydon started teaching service in 2006 and since then has taught in several schools in four Dzongkhags teaching English, Maths, and Science for primary classes. Her first post as Vice Principal was at Wamrong Lower Secondary School, Trashigang in 2014. Currently, she is a Vice Principal at Changzamtog Middle Secondary School, Thimphu. She did her master's degree from the Queensland University of Technology, Australia in the Early Years and has deepened her interest in early years education (0-8 years). She loves reading children's books and enjoys experiences with little young minds.

Author 2: Sonam Phuntsho, is currently the Principal at Changzamtog Middle Secondary School, Thimphu Thromde. He has a master's degree in Educational Administration and Management from Paro College of Education. Prior to his current post, he has served in various capacities in Education Ministry as a Principal, Assistant District Education Officer, and teacher in different schools.

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