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Contributing to SDGs through Conceptual PlayWorlds: Changing the STEM story for children, families and teachers

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Abstract

Encouraging young children's interests in learning Science, Technology, Engineering and Mathematics (STEM) concepts has been key focus of educational research across countries. However, there has been less focus on how early childhood children, educators and families engage in STEM through play and how this can be sustained through programmatic research. The chapter discusses emerging findings from the Conceptual PlayLab on a large-scale national study aimed to test the evidence-based model called Conceptual PlayWorlds (Fler, 2018). Founded on cultural-historical theory, Conceptual PlayWorlds is an innovative, evidence-based model of learning STEM concepts through play (SDG 4) consisting of five characteristics- selecting a story, designing the Conceptual PlayWorld space, entering and exiting the Conceptual PlayWorld, planning the play inquiry and problem scenario and planning adults (parent/carer/teacher) interaction (Fler 2018, <https://www.monash.edu/conceptual-playworld>). The focus is to create a collective imaginary situation where children and adult engage in problem-solving and STEM learning. With its focus on closing the gap for girls in STEM and mentoring a largely female early childhood workforce (SDG 5), this innovative programmatic study provides a better understanding of how educators, parents/carers, and policymakers can support future generations to pursue science-related careers and address the shortages of STEM qualified professionals.

Keywords: STEM education, play-based pedagogy, early childhood education, imagination, teacher education, family pedagogy

1. Introduction

Governments around the world have identified the need for increasing conceptual learning outcomes in early childhood (Fleer and van Oers, 2018). The United Nations Sustainable Development Goal (SDG) 4 aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Meanwhile, SDG 5 aims to achieve gender equality and empower all women and girls. In Australia, our federal government has recognised the need for enhancing innovation by engaging young children in Science, Technology, Engineering, and Mathematics (STEM) at an earlier age. There is an urgent need to address the skills shortage in STEM due to decreasing rates of STEM enrolment, low female participation, and reduced mathematics performance (Australian Industry Group, 2015). Diversity in STEM professions is now a priority.

It must be noted that early engagement in STEM translates to greater potential for involvement in the broader STEM workforce in later years. Therefore, developing innovative and appropriate STEM experiences for the early childhood period is key to creating a strong foundation that supports continued access to STEM education throughout schooling and beyond. More equitable access to education - particularly for girls (SDG 5) - is crucial for addressing the big issues in science such as tackling climate change and preserving oceans and forests (SDG 4). The impact of the COVID 19 on educational gains and the resultant crisis in early childhood and pre-primary education and care (SDG Report, 2021) serve to emphasise the importance of this endeavour. Underpinning all of this is also an urgent need to build capacity in researching STEM in early childhood settings to ensure ongoing access to STEM education through the pipeline towards STEM careers is well-preserved.

Founded on cultural-historical theory, Conceptual PlayWorlds is an innovative, evidence-based model of teaching and learning STEM concepts through play that addresses the needs identified in both SDG 4 and SDG 5. In a Conceptual PlayWorld, adults and children construct an imaginary world based on a dramatic children's story and together solve highly engaging STEM problems that arise in the imaginary situation. The Conceptual PlayWorld model consists of five characteristics (Fleer, 2018, <https://www.monash.edu/conceptual-playworld>) and provides a social purpose for engaging with STEM in the context of the shared imaginary situation that is created. This wholistic framework to play aligns with

UNCRC's imagination of children rights, where play also facilitate children's wider and independent participation in cultural life and arts (article 31, UNCRC, 1989).

The longstanding international research into young children's science concept formation has focused on children from the age of three, but not on the birth to three age period (O'Connor et al., 2022). Empirical evidence from the Conceptual PlayLab is creating new understandings about how infants and toddlers engage with STEM concepts in collective contexts when supported by adults in Conceptual PlayWorlds within centres, schools and family homes. Findings are also showing that girls play important roles in ensuring the social purpose of STEM investigations (Stephenson et al., 2021). This early engagement in STEM is crucial for later STEM interest in school and participation in STEM careers.

The Conceptual PlayWorld model is being tested in the field through a 5-year programmatic study conducted by the Conceptual PlayLab at Monash University in Australia. It is significant that the Australian Research Council Laureate Fellowship scheme has funded this programmatic study - the first to be awarded in the field of early childhood education. This research aims to create a shift in the way STEM concepts are taught in the early childhood period in Australia and internationally. There are 3 pillars in the research program: Pillar 1 investigates how infants, toddlers and pre-schoolers form concepts in STEM in play-based early childhood settings; Pillar 2 focuses on STEM learning in family homes; and Pillar 3 measures educators' confidence and competence in STEM.

2. The Five Characteristics of the Conceptual PlayWorld

A Conceptual PlayWorld is an imaginary scenario created by an educator or parent where young children are invited to go on imaginary journeys, meet and solve challenges, and learn STEM concepts – all while playing. A Conceptual PlayWorld can be inspired by a children's book or a fairy tale, and it can be set up in an average room, classroom or outdoor space. There are five characteristics to consider when setting up and developing a Conceptual PlayWorld (Fleer, 2018, <https://www.monash.edu/conceptual-playworld>):

- i) Selecting a story: Early childhood educators or families are encouraged to choose a story that is enjoyable to both the children and adults. The story should have a plot with dramatic moments that lend themselves to introducing a problem situation to the children. For example, in the story of Alice's Adventures in Wonderland, the main character, Alice, might get stuck in miniature form and need help from the children to return to normal size (Fleer, 2021). This lends itself to investigating a range of STEM concepts as a team in order to generate potential solutions to the problem. Empathy for the character(s) in the story is central to the children wanting to help research and resolve the problem situation. Through repetition and joint imaginative play, children are encouraged to build empathy for the main character, or they may be drawn to a different character in the story. New scenarios can be added to the story as the Conceptual PlayWorld progresses to maintain engagement and incorporate developing interests. It is important that the story has scope for all five characteristics and that it is dramatic with emotional tension.
- ii) Designing the Conceptual PlayWorld space: Educators design different opportunities for collective play and child-initiated play in ways that develop the play plot further and support the learning of STEM concepts so that they become personally meaningful. The available indoor and outdoor spaces should be evaluated for their potential to help develop the collective play of the group. They can be designated through the use of signs (e.g. This way to Wonderland). Props can be helpful for adults and children to enter into the imaginary world together (e.g. a key, or phial for the "shrink me" potion, a hat for the Mad Hatter).
- iii) Entering and exiting the Conceptual PlayWorld space: It is important to highlight the difference between the real world, e.g. the mat space at group time, and the space of the shared imaginary world that will be created during the Conceptual PlayWorld. A routine is created so that the whole group enters the Conceptual PlayWorld together, and each chooses a character as they enter into the imaginary space together (e.g. going through the tunnel to Wonderland). Returning as a group from the imaginary world is important too, to help children to distinguish between reality and imagination.

- iv) Planning a problem scenario that is dramatic and engaging: Planning is key to developing an effective Conceptual PlayWorld. The problem scenario should not be “scripted”, but rather a general idea of the problem should be planned, and STEM concepts that may help in solving the problem should be researched. Adults need to strike a balance between preparation through researching likely STEM concepts and being flexible to respond to spontaneous developments as the Conceptual PlayWorld unfolds. For example, the children may not empathise with the main character in the story as expected, but instead may relate more closely to an animal in the story (e.g. the White Rabbit; Fler, 2021).
- v) Planning adults/teacher interactions: Educators or parents plan for a range of roles in the PlayWorld, both in relation to the children and in relation to the other adults. They can choose to be equally present with the children, to model practices in their role, or to need help from the children. Their role can also be as together with the child, leading (where they cradle the child or hold their hand and together act out the role or solution). This is particularly the case with infants and toddlers and children who need extra help to engage in the imaginary situation.

The five characteristics of a Conceptual PlayWorld are not sequential, but should be planned iteratively in relation to each other. The following sections discuss the theoretical background that underpins the Laureate Fellowship Programmatic Research followed by evidence from the three Pillars of the programmatic study in relation to SDGs 4 and 5.

3. Cultural Historical Theory and Conceptual PlayWorld

The Conceptual Playworld model draws upon Vygotsky’s conception of play (1966), development (Vygotsky, 1987; 1998) and imagination, emotions, and creativity (Vygotsky, 1971; 2004). The focus of Conceptual PlayWorlds is on children’s meaningful learning of concepts in play-based settings. In a Conceptual PlayWorld, learning is in the service of the children’s play. Conceptual Playworlds is the outcome of research into the play and learning of concepts in science (Fler, 2017) for the development of executive functions in play-based programs (Fler et al., 2017) and in learning engineering principles (Fler, 2020).

There are four theoretical assumptions underpinning the Conceptual PlayWorld model. First, a cultural-historical conception of play focusses on imagination as the key psychological function that is developing in the early childhood period. Imagination develops through play (Elkonin, 2005). In play, an imaginary situation is created where children change the meaning of actions and objects to give them a new sense and work creatively to build new meaning through different levels of abstraction (Vygotsky, 1966). Play itself develops in relation to the experiences afforded by the child's social environment, from changing the meaning of an object in toddlerhood (the pencil becomes an airplane), to image play (the child is a character), to role play (where children play characters and there is a plot to the play) to play with rules (games) in the preschool and early school age period (Kravtsova, 2014). Vygotsky (2004) noted that play is dialectically related to learning and development through broadening the field of experience available to the child. Second, concepts to be learned are usually historically developed (science as a body of knowledge), culturally defined (Western science), and given meaning in everyday life through interactions with others (early childhood curriculum in action). When children use concepts in the service of their play, they have new possibilities in play and different ways of thinking. Third, play is a creative and imaginative production by the child. Children bring insights and practices from everyday life to their play, and in doing so are imagining and creating actions in new ways. Children produce new play scripts and negotiate these with their play partners. In the Conceptual PlayWorld model, play plots are introduced through the narrative of a story or through non-fiction play inquiry, both of which develop the group's collective imagination. Fourth, a cultural-historical view of child development suggests that it is important for dramatic moments to occur in the child's social situation of development that support children to think and feel more consciously about a particular phenomenon. In a cultural-historical conception of play, drama (or crisis) brings about development (Vygotsky, 1998).

Finally, the cultural-historical conception of motives, motive orientation and institutional demands (Hedegaard, 2002) is important for understanding children's development of imagination and learning in their play. Teachers inside of a Conceptual PlayWorld with a group of infants can help their motive orientation towards collective imagining. In the following sections, partial findings from the Conceptual PlayLab's empirical research in early childhood centres (Pillar 1), family homes (Pillar 2) and with educators (Pillar 3) are presented.

4. Pillar 1: Early Childhood Settings

The research that underpins the Laureate Fellowship Programmatic research makes an important contribution to SDG 4. Changing the conditions in early childhood programs to support inclusive and equitable quality STEM education promotes lifelong learning opportunities for all, particularly in regards to girls' aspirations to succeed in STEM professions (Fleer et al., 2022). This has been realised through researching how infants, toddlers and pre-schoolers engage in STEM activities in group settings (Fleer, 2021a).

Our research has noted ongoing inequitable access to STEM resources and activities for girls, arising from longstanding practices in early childhood centres, where for example, the block corner and construction areas are often dominated by boys. Girls have shown reluctance to enter those areas or are even held back from entering those areas by the boys, and sometimes inadvertently by teachers who are not aware of the gender bias. A different story emerges in Conceptual PlayWorlds, where two key changes are evident.

First, the motive to solve the problem that arises in the imaginary situation takes centre stage, and all areas of the preschool become repositories of materials that are seconded to solve that problem: The blocks in the block area change their meaning, becoming part of a crane, or a simple machine that is needed to rescue a character in distress; the outdoor area becomes a place to find a safe space to build a burrow to shelter the native animal who is under threat; climbing equipment becomes a mountain to conquer on the quest. As the participants in the Conceptual PlayWorld build their collective understanding of the changed meaning of the resources in the traditional areas of the preschool, the traditional gender biases associated with those areas fade to the background. The traditional structures of the preschool no longer reinforce the unconscious biases and associated ways of being that keep girls from accessing STEM materials. Girls feel more empowered to access STEM materials, move them to new areas and use them in new ways to serve the needs of the imaginary situation of the Conceptual PlayWorld. Consequently, our research is showing that the girls are building competence, especially in STEM, simply because they have access to STEM resources and are supported to be STEM active (Stephenson et al., 2021).

The second change in practices is in relation to the role of the teacher. Traditionally, teachers position themselves outside of the play, observing, providing materials and equipment, and making suggestions from the sideline. However, in a Conceptual PlayWorld the teacher takes on a role in the play, becoming a character (or object) in the story, rather than passively observing the children playing. The positioning of the teacher as an active play partner brings them closer to the child's perspective, in tune with the developing imaginary situation. From this new position, the teacher can in turn position the girls as STEM capable and STEM knowledgeable. For example, as the need to build a new burrow for a homeless animal in the story becomes imperative, the teacher positioned with the children can say to a group of girls, "Let's put on our engineers' hats and design a new burrow. I wonder what we're going to need?"

Another benefit of being positioned inside the imaginary play is that teachers can more easily identify incidents when more dominant children try to exclude less assertive girls from STEM areas. Being in a position to notice such microaggressions and intervene immediately from within the imaginary situation, e.g. "Let's make a space for Gemma to get the lever for the crane to rescue the dragon. We all need to help our chief engineer and save the dragon," helps create experiences in which girls come to see themselves as STEM capable. The STEM competence and confidence of girls begins with and grows from these early experiences in the changed conditions created by Conceptual PlayWorlds.

The outcomes of our research in early childhood settings actively support the aims of SDG 5 in achieving gender equality and empowering all women and girls. When the studies are collectively examined, we have shown how infants and toddlers who are followed over time engaged in Conceptual PlayWorlds are building early STEM competence (Fleer et al., 2020) before gendered stereotypes have time to emerge or become solidified with a belief system (Utami et al., 2021). Infants and toddlers therefore become oriented to STEM (Fragkiadaki et al., 2022) contributing to the aims of SDG 4 in ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all.

5. Pillar 2: Conceptual PlayWorld in home settings

One of the prime goals of Pillar 2 research at the Conceptual PlayLab is to generate scholarly knowledge about how families can create new motivating conditions for their children's STEM learning. Our work uses educational experiment methodology (Hedegaard, 2008) to create emotionally amplified collective imaginary situations (Fleer et al., 2020) where parents/carers and children can use their everyday home practices to create learning demands that could facilitate their children's STEM learning. Over the last three years of our programmatic research, this work has been done with families using digital tools such as Zoom (especially during the Covid-19 pandemic) and in-person workshops with families in playgroups and their home settings. Given inequitable access to early care and learning services, we also wanted to target hard-to-reach families, especially those with young girls. Our collaboration with Playgroup Victoria offered us an expansive network and we utilised Zoom during the COVID-19 pandemic to aid in designing a novel way of data collection as well as supporting families and children. Aligned with SDG 4, this collaboration offered an opportunity to work with culturally and linguistically diverse families from multiple socio-economic backgrounds. There are three key findings emerging from this research as outlined below.

First, drawing on Wartofsky's (1979) work on artefacts and Fleer's (2017, 2019) conceptualisation of 'digital coadjutant', we make a case that digital technology similar to Zoom could be used to create new STEM learning motives in the home setting. To achieve this high-quality learning environment there is a need to follow a pedagogical model that works with children's leading motive of play and the family's demand of teaching robust concepts to their children. This is achieved by theorising digital tools from a non-binary perspective which values the mutual constitution of the person and digital (Rai et al., 2021). Our digital educational experiment using Conceptual PlayWorld model (see previous section for the planning characteristics of Conceptual PlayWorld) introduces families to an innovative pedagogical model that values children's imagination and their love for stories and play to create a space within their home, backyard or playgrounds where families could go on exploratory journeys together and teach STEM.

Second, a set of concepts from cultural-historical theory - social situation of development, motive and motive orientation and institutional demands - are used to understand children's everyday life situations and evaluate their maturing psychological functions. This helps to create a responsive approach to teaching and learning where children and their families' everyday realities are central to thinking about their education. The design of the educational experiment is not limited by material conditions but a detailed understanding of the social situation of development contributes in creating new transformative opportunities for STEM learning (Rai et al., 2022). The important point worth noting here is that this approach offers a fundamentally different model for thinking about quality education as per SDG 4. Quality as a concept thus is not about objective universal criteria or certainty and ranking order but refers to working with complex everyday realities, family values, and perspectives of children and parents/carers to develop a responsive model of education. Seen in this way, this approach challenges the age and stage-based developmentalism concept, one of the prime theoretical positions guiding curricula worldwide.

Conceptual PlayWorld demands a collaborative approach to working with families.

Following an educational experiment methodology, the detailed planning for teaching is done to create “optimal conditions for the learning and development of the participating children” (Hedegaard, 2008, p.185). In our more recent writings, we unpack the collaborative aspect of the educational experiment to show how researchers, consultants, external organisations and families used Conceptual PlayWorlds to support families to work together. The main aspect of this approach is that the researchers offered conceptual orientation and guiding principles for the practice, while families provided an understanding of their children's development and how Conceptual PlayWorlds could work in their home setting. The methodological focus thus sees families and children not just as a site of data collection but a site in which researchers, families, and children co-create new opportunities for learning and development to fulfil their intentional purposes.

6. Pillar 3: Professional Development for Early Childhood Educators and teachers

High-quality early childhood education is paramount for the future of our nation. Children participating in high-quality early childhood programs has led to policy and educational

reform (e.g. Organisation for Economic Co-operation and Development [OECD], 2017). Many governments aim to support long-term educational and life gains by providing high-quality early childhood education. In Australia, the National Quality Framework (NQF) provided a significant and systematic change to the national provision, law and regulation of early childhood care and education. The Early Years Learning Framework (EYLF) highlights the important role of educators to ‘provide young children with opportunities to maximise their potential and develop a foundation for future success in learning’ (DEEWR, 2009, p. 5). The framework also emphasises the pedagogical practice of ‘intentional teaching’ (DEEWR, 2009). Professional development programs are necessary to provide educators with the significant knowledge, skills, experience, and mentorship to implement intentional teaching practices in play-based settings (Ryan and Northey-Berg, 2014). In Australia, there is a need for the teaching and learning of STEM concepts, particularly on how to teach these concepts in play-based settings. Existing models were primarily developed on research from school classrooms and not play-based settings. Therefore, it is crucial to empower early childhood educators’ confidence and competence of teaching young children STEM concepts (Fleer, 2009).

The Conceptual PlayWorld as a model of intentional teaching is targeted at building the capacity of early childhood educators, parents/carers, and families to use intentional teaching strategies for supporting children’s learning and development in STEM, which will directly improve children’s social-emotional wellbeing and communication skills. At the completion of the Conceptual PlayWorld professional development, participants gain confidence in teaching STEM concepts and implementing strategies to engage young children in social-emotional learning. This creates the appropriate conditions to enable children to be school-ready. Additionally, it is expected that educators will become skilled in providing support for any challenges and difficulties faced by the children and their families while teaching STEM concepts to children in play-based settings through continuous reflection and collaboration with colleagues and families.

7. Conclusions

Through presenting the Laureate Programmatic Research of the Monash Conceptual PlayLab and the innovated, evidence-based model of Conceptual PlayWorlds, this chapter contributes to a better understanding of how educators, parents/carers, and policymakers can support future generations to pursue science-related careers by engaging children in STEM early in infancy, toddlerhood and early childhood and homes and play-based settings, thus supporting SDG 4. Through improving equitable access to STEM resources for girls and therefore potential access to STEM education and careers, Conceptual PlayWorlds is proving to be a promising model to achieve gender equality and empower women and girls, which supports the aims of SDG 5.

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