Working paper number 22 –

https://www.monash.edu/education/research/projects/conceptual-playlab/publications

This is an article published in *Research in Science Education* on 29th April 2021, available online: https://rdcu.be/cjCTQ /[Article DOI: https://doi.org/10.1007/s11165-021-10003-z].

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Stephenson, T., Fleer, M., & Fragkiadaki, G. (2021). Increasing Girls' STEM Engagemen t in Early Childhood: Conditions Created by the Conceptual PlayWorld Model. *Researc h in Science Education*. https://doi.org/10.1007/s11165-021-10003-z

This work was supported by the Australian Research Council [DP180101030] and [FL180100161].

Increasing girls' STEM engagement in early childhood: Conditions created by the Conceptual PlayWorld model

- Stephenson, T., Fleer, M., & Fragkiadaki, G.

Abstract

As societal needs change and STEM solutions are offered, an increasing concern for the participation of girls in STEM has emerged. Research has consistently shown the unintended preferential treatment of boys by teachers during STEM teaching, and although well recognized, has seen limited change over the past decades. Gendered interactions, including microaggressions, influence girls' identity formation from a young age, leading to a decrease in girls' STEM participation, continuing the trend of underrepresentation of women in STEM fields due to underlying gender equity issues. To improve this gender gap, is important to consider the beginning of the STEM pipeline, the early stages of education. Drawing upon the system of concepts from the cultural-historical theory, this study explores the motivating conditions created by the Conceptual PlayWorld model for girls' engagement in STEM in the early years. Using a holistic study design, video observations of interactions and experiences within and outside the Conceptual PlayWorld were gathered from 2 preschool teachers and 13 children aged 2.3 - 3.2 years. Findings support previous research surrounding the accumulation of microaggressions in free play settings that position girls away from STEM activity, which are minimised inside the Conceptual PlayWorld due to the changed role of the teacher. It is argued that the possibilities afforded by this model positively shift interactional patterns to create motivating conditions for girls in STEM so that both girls and boys can have a strong engagement and interest in STEM from the very beginning.

Keywords: STEM; gender; early childhood; identity; science; engineering

1. Introduction

While there is growing demand for greater understandings of science, technology, engineering and mathematics (STEM) within communities, and the need for STEM literate citizenship (Prinsley and Johnston 2015), there appears to be an increasing unwillingness of students to participate in STEM. Alongside recommendations on engaging students through different forms of STEM education, the growing necessity of introducing children to STEM opportunities early in their education is highlighted (National Research Council

2011). Additionally, international statistics highlight ongoing concerns about the gendered occupational participation and underrepresentation of women in STEM-related professions, including girls' disengagement with STEM and the lack of interest by girls in pursuing STEM careers (Department of Industry, Innovation and Science 2019). A science achievement gap appears by kindergarten, with girls at higher risk for their STEM skill-development (Morgan et al. 2016). Government reports focus on underrepresented cohorts, unconscious gender biases and early childhood as the origin of this issue (e.g. Education Services Australia 2018 p. 50).

Positive early STEM engagement is vital to ensure that children are well prepared for future STEM challenges (Campbell et al. 2020). It is important to understand how the divergence begins in girls' STEM identity and how it may be disrupted before becoming ingrained and guiding girls' future careers (Corrigan and Aikens, 2020). Literature on identity has increasingly recognised the social and cultural construction of identity, including the gendered identity of an individual (Campbell et al. 2020). While we recognize that gender is a cultural construct and non-binary in nature, in this paper we focus on children with the gender identity of a girl, and examine existing literature surrounding barriers to girls becoming scientists and engineers.

The focus of this research is the conditions created by a play-based STEM teaching model for girls' STEM engagement. We begin by outlining what is known regarding early childhood STEM education and gender followed by the cultural-historical conceptual framework guiding the study. We discuss the study design and findings from an educational experiment following 2 teachers and 13 children across a play-based setting as they engaged with the Conceptual PlayWorld. We conclude with insights into if and how this model can create motivating conditions for young girls to develop a positive STEM identity.

2. Gender and early childhood STEM education

Children develop attitudes and ideas about STEM as they reach the early primary years of schooling, co-constructed with simultaneously developing ideas regarding gender (Corrigan and Aikens 2020). It is important to consider the early stages of education to understand the source of children's engagement. Three key themes emerging from the literature over time have been discussed – a) gender-stereotypes b) microaggressions in STEM c) a play-based STEM teaching model. These are discussed in turn.

2.1 Gender-stereotypes

The social world that girls experience plays a significant role in their developing identity and views of what it means to be a girl (Campbell et al. 2020). The lower probability of girls pursuing STEM-related careers can be connected to a lifetime of traditional gender stereotyping, where what it means to be a girl is constrained and influenced by cultural stereotyping from an early age (Hobbs et al. 2017).

Gender distinctions arising from socially constructed roles and attributes that society considers appropriate for men and women can lead to the creation of stereotypes (Ridgeway 2011), shaping the choices and beliefs of individuals. Cultural histories associated with gender strongly influence the cognitive, social, and emotional development of children, impacting identity formation (Ferrari and Mahalingam 1998). Existing stereotypes can act as barriers preventing girls from developing STEM interests, with stereotypical beliefs that STEM is a boys' field negatively impacting girls' STEM experiences (Campbell et al. 2020). A combination of negative experiences, including microaggressions (Moroz 2015), can result in girls' disengagement with STEM.

2.2 Microaggressions in STEM

Significant for this paper is the concept of microaggressions, playing a crucial role in the conditions for girls' STEM engagement. These are the gendered exchanges in society including minor but substantial acts of hostility towards girls in STEM (Grossman and Porche, 2014). Research on gender diversity in STEM shows a lifetime of microaggressions which together contribute to girls believing that STEM is not for them (Moroz 2015). Various microaggressions have been recognized based on verbal, non-verbal, and environmental occurrences.

Microassaults are usually conscious and explicitly offensive behaviours while microinsults may suggest second-class citizenship. Microinvalidations indicate the assumption of traditional gender roles, denying gender individuality (Capodilupo et al., 2010). Prejudiced actions, including distributing resources differently for girls and boys, or forms of evasion including not engaging girls in STEM experiences form a part of microaggressions, implying that the recipient does not belong (Fleer 2019). These small experiences in preschool have a cumulative effect on children (Moroz 2015), influencing identity formation and becoming so integrated that future choices are considered as innate (Gullberg et al. 2017). Frequent and

persistent microaggressions can negate, exclude, and deny equal and authentic access to STEM, leading to girls' building an identity that STEM is not for them (Fleer 2019).

Although studies have explored the effects of microaggressions on minority adolescents and adults, few investigate gender-based microaggressions for girls in preschool STEM practices (Fleer 2019). Microaggressions can be particularly influential for young children as they are in the midst of identity formation. Investigating how and when these begin in education has become increasingly important to understand when girls engage/disengage from STEM, to better understand how girls begin to imagine themselves included in, or excluded from, preschool STEM practices (Fleer 2019). The sociological studies above build our understanding of microaggressions, but only illuminate part of the problem. Few cultural-historical studies contribute to this area (Fleer 2019), and further research is needed to dialectically explore how children enter into their *social situation*, the *social situation of development* they bring and how conditions around them create a motive orientation towards STEM.

2.3 Gender and the Conceptual PlayWorld Model

Girls' access to STEM areas is a significant challenge to their engagement (Fleer 2020). Several studies have identified construction areas (e.g. block play) as areas where engineering thinking most commonly occurs (Gold et al. 2015). Research demonstrates that boys often dominate, and significantly challenge girls' entry and accommodation into these spaces (Bagiati and Evangelou 2016). There is a gap in understanding young girls' STEM opportunities as gendered interactions in these spaces have rarely been reported (Fleer 2019). Importantly, gendered differences are noted in how and what children chose to play with, e.g. girls enjoy dramatic play with narratives, constructing with a social purpose (Hallstrom et al. 2015).

The Conceptual PlayWorld model, based on the original Playworld model (Lindqvist, 1995) and developed from the Scientific PlayWorld model (Fleer 2019c), introduces the teacher's role in play, and the significance of play inquiry introduced as a problem to develop play narratives (Hakkarainen et al. 2013). This gives children a social purpose to engage with STEM as they enter an imaginary situation based on a story-book, suggesting an orientation towards developing STEM competence (Fleer 2020). Further, teachers adopt an active role within Conceptual PlayWorlds, contrasting previous perspectives which do not position adults within children's play (Hallström et al. 2015) where many microaggressions are reported (Fleer 2019), bringing them closer to the children's narrative.

Conceptual PlayWorlds therefore appears to create conditions bringing teachers closer to children's play where microaggressions occur, while orientating children towards STEM. This paper further investigates these conditions in relation to the possibility of increasing girls' STEM engagement in early childhood.

3. Conceptual Framework - A cultural-historical perspective

To better understand the conditions created by Conceptual PlayWorlds for girls' STEM engagement, this study adopts the cultural-historical concepts of *social situation (SS), social situation of development (SSD)* and *motives*.

Firstly, it is important to examine the significant role of the individual's environment, or *SS,* and its relationship with development, by exploring the individual's participation within everyday settings and how environmental occurrences are experienced (Vygotsky 1994). Even where the *SS* itself remains unchanged, because of the changes within an individual during development, the individual's relationship with particular environmental factors or *SS* changes, leading to the same environmental factors holding different meanings and playing different roles (Vygotsky 1994). This paper examines the changes created by Conceptual PlayWorlds in the *SS* of teachers and children.

Secondly, the *SSD* is the unique relationship between an individual and their social reality, shaped by their environmental engagement (Vygotsky 1998). To understand an individual's *SSD,* it is important to explore their participation in everyday settings and how they experience occurrences within the *SS* that they participate in (Fleer and Hedegaard 2010). Changes in the *SS* created by Conceptual PlayWorlds alter how girls experience STEM, changing their *SSD*.

Finally, in cultural-historical research, contrary to asking how a child behaves within a group, it is important to analyse how the group develops the child (Vygotsky 1997). *Motives* are shaped by the *SS* through an individual's engagement within activity settings (Hedegaard 2014). Motive development occurs through activities with collective engagement and orientation in social interaction between participants (Hedegaard, 2008). When a learning motive is created, it is important to recognize the engaging activities (Hedegaard 2008), and motivating conditions created. In this paper, by examining how a child participates in a Conceptual PlayWorld as a part of collective imagination, and the interactions occurring inside and outside a Conceptual PlayWorld, we gain an understanding of the motivating conditions that could support the development of girls' motives towards STEM.

4. Study design

The methodology of an educational experiment was adopted, implying "a cooperation between researchers and educators" (Hedegaard 2008 p. 200). This was done as they engaged in planned preparation of teaching, using the story *Room on the Broom* to introduce engineering concepts. A stimulating motive for STEM engagement was introduced by the problem of the dragon being too big for the broom, unable to join his friends for a space picnic. This engaged the children, leading them to become characters including engineers building a flying-machine to help the dragon.

4.1 Participants and Context

This paper follows 2 early childhood teachers - Ling and Pei – and 13 children (6 girls and 7 boys) aged 2.3 - 3.2 years. Only pseudonyms have been used. The teachers introduced aerodynamic principles including lift, weight, thrust and drag through the dramatic problem in the Conceptual PlayWorld narrative.

4.2 Data Collection

To achieve a holistic perspective, one hand-held camera followed a smaller group of children as they entered into and engaged with the activity setting, allowing focused observations of interactions amongst the children and teachers. A second camera was positioned on a tripod near relevant STEM activity settings that developed over the 2-week observation period. Collected data includes 13 hours of digital video recordings of planning, Conceptual PlayWorld sessions, related activity settings, and interviews, along with field notes for supplementary information.

5. Analysis

From a cultural-historical perspective, it was important to draw upon a holistic analytical framework (Hedegaard 2014) enabling deeper analysis of gendering in teachers' STEM practices. Data was logged, coded and stored as tagged raw digital data, copied and analysed using Hedegaard's three-level analytical framework (Hedegaard and Fleer 2008).

Common-sense interpretation involved tagging digital files as instances of gendered interactions and linking them to literature (e.g. microaggressions). *Situated practice interpretation* involved repeatedly viewing the data to divide single situated practices into a

series of related clips, e.g. instances of microaggressions such as girls unable to easily access STEM areas, were copied into a "microaggressions" folder. *Thematic interpretation* involved data-analysis in relation to the complete data-set, coding and nuancing interpretations, linking underpinning theoretical concepts. The set of cultural-historical concepts (*SS*, *SSD* and *motives*) were used to more deeply understand interaction patterns and motivating conditions in relation to findings from literature. Microaggressions form a significant part of the conditions for girls' STEM engagement, forming an important aspect of our analysis while building a broader understanding of the dialectics between *SS*, *SSD* and how motive orientation to STEM emerges in some conditions but not in others.

6. Findings

The focus of the research is the motivating conditions created by Conceptual PlayWorlds for girls' engagement with STEM. We observe how Conceptual PlayWorlds as an activity setting is continually in dynamic flux and draw attention to two things – a) the changing role of teacher within and outside the Conceptual PlayWorld, and b) as the teachers are developing, the girls' simultaneously evolving STEM play practices. Three activity settings emerge, with changing motivating conditions for girls – a) *collective imaginary play* within the Conceptual PlayWorld where teachers and children are in character together, collectively working with the STEM problem, b) *outside the Conceptual PlayWorld where the collective imaginary play continues* due to the children still imagining and wanting to solve the STEM problem, but teachers are no longer in character, and c) *free play settings in relation to the Conceptual PlayWorld* where the children and teachers are not in character but interest in the STEM problem continues. Table 1 presents a conceptual roadmap encapsulating these changing conditions, analysed with two lenses – actions of the teacher and actions of the children, along with what it means for the girls.

Table 1: A conceptual roadmap encapsulating the Conceptual PlayWorld activity settings and motivating conditions.

Theme	**What the teachers are doing**	**What the children are doing**	**How the girls are being positioned**

1. Collective imagination within the Conceptual PlayWorld (Vignette 1)	Teachers are in character with the children	Children are in character and engaged in collective imagination, following the teachers' actions to take-off, fly and land.	Girls and boys are positioned equally in play, taking on story characters to engage with the concept of aerodynamics. No microaggressions faced.
2. Outside the Conceptual PlayWorld activity setting but within collective play (Vignettes 2, 3)	Teachers are no longer in character but support children and offer resources.	Children continue to engage with the engineering concept, pretending to be engineers building a flying-machine.	The girls' interest in STEM continues outside the Conceptual PlayWorld as they actively work on building the flying-machine. Microaggressions reappear and girls are positioned as helpers.
3. Free play in relation to the Conceptual PlayWorld (Vignette 4, 5)	Teachers are back in their traditional supervisory role, no longer in character or engaged with the children's play	Children are still engaged with the idea of aeroplanes and flying-machines within different activity settings	Girls are actively interested in aeroplanes and building flying-machines. Microaggressions continue in free play.

The following vignettes demonstrate this in further detail as we examine the motivating conditions created by the teachers in each activity setting, followed by interview extracts.

6.1 Theme 1: Collective engagement in STEM through imaginative play

Vignette 1: After reading the story, the teachers introduced the concept of aerodynamics, and its principles of thrust, drag, weight and lift. The teachers and children chose different story characters (e.g. birds), displaying shared excitement and engagement within the Conceptual PlayWorld. The teachers used actions including holding both hands in an inverted-V to demonstrate the streamlined shape to fly (Figure 1), running forward to demonstrate acceleration and thrust along with explicitly modelling language such as "lift" and "drag". The children followed these movements to take-off and land.

Figure 1: Children follow the teachers' actions to pretend take-off.

As they pretend-fly, a problem arises. The teacher, Ling, says, "Oh no! My witch's hat has fallen down!" The children flap their arms and slow down, demonstrating a decrease in speed while landing (Figure 2). One of the girls points to the sandpit saying, "The hat is in there!" A boy picks up the pretend-hat announcing, "I got it!" Another girl shouts, "and now my one is gone!", continuing the narrative.

Figure 2: Everyone flaps their pretend-wings to decrease speed and land.

Vignette 1 demonstrates the boys' and girls' collective engagement in the STEM experience, being introduced to engineering concepts within the story's narrative. Here, the teachers' and children's *SS* has changed, where they are no longer identified as boys or girls, but are story characters (e.g. birds), with no explicit gender connotations. Similarly, teachers are transformed into characters, changing their relationship with the *SS* and how they experience STEM with the children. As Vygotsky (1994) writes "…the same environmental factors which may have one meaning and play a certain role…begin to have a different meaning and play a different role" (p. 339). While the presence of the same children remains unchanged, the teachers' relationships with the girls and boys change and carry a different meaning.

Being in character frees teachers from their typical roles (Lindqvist 1995), enabling them to see the world differently. Here, teachers play active roles with children and can pay attention to microaggressions. Due to the new roles offered to teachers and children by Conceptual PlayWorlds, there is a change in the *SS* without the focus of gender, where children are not seen as boys and girls but are engaged in collective imagining as characters free from assumed gender limitations, altering interactions within the *SS.*

This offers possibilities for teachers to let go of any unconscious gender bias regarding girls, creating an inclusive and engaging environment where children can freely explore STEM. This changes the girls' *SSD* as they experience STEM differently and are visibly involved within imaginary play, actively engaging without microaggressions. Such motivating conditions created by the change in teachers' roles established a strong position for the girls throughout the Conceptual PlayWorld sessions that followed.

6.2 Theme 2: Outside the Conceptual PlayWorld but within collective play - Girls' extended STEM interest

Vignette 2: The teachers subsequently introduced the problem of the dragon being too big for the broom, unable to join the space picnic. This narrative with a social purpose (Hallstrom et al. 2015) oriented the girls towards STEM even outside the Conceptual PlayWorld. Here, while they were not specifically inside a Conceptual PlayWorld, they continued to problem-solve as engineers building a flying-machine for the dragon. Teachers were no longer in character, but played an active role supporting the children such as helping to construct the machine's 'nose' and wings. Girls were actively involved in the construction, working with materials and brainstorming ideas for appropriate sizes and shapes (Figure 3).

Figure 3: Girls are actively involved in building the flying-machine

Vignette 2 demonstrates the girls' active interest in STEM, sparked during their Conceptual PlayWorld experience, continuing into imagination outside where they furthered their exploration of aerodynamics. The teachers created this new *SS*, leading to the development of the girls' motive orientation towards STEM. While all children gain a positive experience, here the girls are equally involved due to their changed *SSD* and the new way of experiencing STEM. However, as evident from the following vignettes, as the teachers shifted their role from being in character back to being outside the collective imagination, microaggressions seem to reappear.

Vignette 3: The teacher, Ling, repeatedly asks Nick if he was the pilot, involving him in construction while unintentionally disregarding Chloe's ideas about seat sizes for herself and

for the dragon, demonstrating her developing ideas about size (Figure 4). Ling asks Nick to sit inside the machine and discusses additions to the cockpit to help him fly. Chloe appears very interested, repeatedly sharing ideas and bringing things for the cockpit. As she attempts to sit inside, Ling stops her, saying, "I think there is room only for one person. It's a bit tight in there Chloe." Chloe stops trying to be the pilot.

Figure 4: Chloe attempts to share her ideas with the teacher

As discussed in the literature, such small occurrences received by girls are internalized, influencing identity formation, creating a divergence away from STEM. Vignette 3 demonstrates that Conceptual PlayWorlds sparked the girls' interest through the social narrative, and they continued to actively problem-solve. However, as teachers are no longer in character, they are distanced from the children's characters and the microaggressions reappear. The *SS* here is very different from that of Vignette 1 as the conditions were not created to give girls the space or agency to be who they wanted to be. Although the girls engage as engineers in the construction, they are positioned into supporting roles, while the leading roles are occupied by boys. This is evident when Chloe tells Nick, "we're going to cut a big, big hole so you can see [as the pilot]", taking on the role of the helper instead of continuing her original desire of sitting inside the machine herself to be the pilot. The conditions here include frequent and persistent microaggressions, which can dismiss and deny equal and authentic access to STEM, resulting in girls' developing an identity that STEM is not for them (Fleer 2019). Similar occurrences were frequently visible throughout the machine-building process.

6.3 Theme 3: Free-play outside the Conceptual PlayWorld

In free-play settings, the teachers were back in their traditional supervisory roles, no longer in character or engaged with free-play. The children were also not in character but continued to engage with the idea of aeroplanes and rocket-ships across activity settings.

Vignette 4: Rose and Nick use blocks to build a flying-machine together in the Block-Corner (Figure 5). Ling approaches asking, "Is he building…is Nick building a machine?" Nick responds, "Yeah, the rocket-ship." Rose listens and stops building, moving away to sit and watch instead.

Figure 5: Nick and Rose build a flying-machine together

Although Rose and Nick were constructing together, Ling's question specifically asks if Nick is building the machine. This interaction is heard by Rose, who immediately stops building, moving away from the blocks to watch Nick instead. The *SS* now includes such microaggressions, unintentionally sending an excluding message. This instance of microinvalidation appears to change Rose's attitude towards the construction and changes her *SSD* from that of within Conceptual PlayWorlds as she now experiences STEM with microaggressions. Similar occurrences were observed throughout free-play settings.

Vignette 5: A Science-Table was set up (Figure 6) with airplane models. While the girls were curious to explore, they were quickly pushed aside by the boys, aligning with previous research around challenges for girls when entering into areas traditionally dominated by boys (Fleer 2019). They were guided by the teacher towards the Art-Corner, from where they continued to look at the Science-Table.

Figure 6: The Science-Table with airplane models

The girls reapproached the table when most boys had left, engaging with take-offs and landings as they had experienced inside the Conceptual PlayWorld (Figure 7).

Figure 7: Girls reapproach the table when it is less crowded

Vignettes 4 and 5 demonstrate a shift in the motivating conditions for girls' engagement STEM. While they still have a motive orientation towards STEM, the interactions have shifted, creating a change in their *SS* and *SSD* as they are no longer being actively encouraged to participate in these settings. Instead, they are diverted to the Art-corner, and they continue to look over until feeling safe to reapproach. Such microaggressions continue to hinder equal and authentic STEM access, diverting girls' developing STEM identity (Fleer, 2019). Vignettes 1-5 demonstrate the changing role of teacher within and outside the Conceptual PlayWorld and the consequent shift in motivating conditions for girls' STEM engagement.

6.4 Interviews

This section examines follow-up teacher interviews in relation to girls' engagement.

> The girls in the group are…actually more excited than some of the boys are in the group about the STEM concepts in the story…and it's funny because… the boys…usually play with the…construction and the trucks…it's really interesting to see…I haven't seen the girls in our group so excited…[about] building and construction and interacting with these materials with the focus of…learning about a STEM concept before, so this has been really incredible.
>
> The girls in the group were so involved in the STEM concept… I've relayed that message to the parents and…the reception from the families has been phenomenal…they think it's such a fantastic experience for them.

Rose's father shared his personal experience where she initiated a discussion about flying-machines:

> …I asked her what she had done [at the early childhood centre] and…she went on to tell me…it was about *Room on the Broom* and we went onto talking about how things fly…we spoke about an aeroplane…she was just infatuated by how things fly up and even looking at cars, 'that not fly away', she said.
>
> She wouldn't be as excited [about STEM]…and the fact that she could make a connection to a car and said, 'that not fly away,'… you could see that little brain ticking over going, 'what can fly away?'…From what I've seen in just that small snippet with her is that depth of knowledge and that she's thinking about it...she's not hitting…a maximum of learning…it's creating a synergy…where it just opens up a whole new opportunity for them to continue to explore.

The interviews confirm evidence from the vignettes regarding the motivating conditions created by Conceptual PlayWorlds for girls' STEM engagement. A shift from the teachers' traditional understandings of gender-stereotyped roles towards a developing conscious awareness of girls' STEM engagement is visible. The girls' excitement towards building activities linked to the story's narrative opened up girls' engagement with and access to these spaces where engineering thinking most commonly occurs (Gold et al. 2015). Rose's STEM interest extending at home further demonstrates that girls can be highly interested in STEM, and that the conditions created by Conceptual PlayWorlds gets them connected to, excited about and engaged with STEM.

Discussion

The findings show how Conceptual PlayWorlds creates motivating conditions for girls' STEM engagement. Table 1 illustrates the varying motivating conditions across the three activity settings due to the shifting interactional patterns in each setting caused by the changing role of

the teacher. Vignette 1 demonstrates that when teachers and children are together exploring STEM concepts as characters in a story, microaggressions seem to disappear. By creating a collective imaginary situation where everyone is in character, the Conceptual PlayWorld liberates teachers from their traditional, supervisory roles (Lindqvist, 1995). This alters the *SS*, where children are not identified as boys or girls but are characters in a story, without the presence of gender and its seeming implications, changing how teachers themselves experience STEM with the children, positively altering their relationships.

Further, when in character themselves, the teachers are closer to the children's narrative, therefore more in tune with the occurrences within the play and with each child, allowing them to more closely observe and counteract microaggressions. This new form of interaction between the teachers and children created by Conceptual PlayWorlds, free from gender bias, allows teachers "to feel one's way into a role, imagining worlds that have not been experienced as possible worlds, and sympathizing with others in ways that foster collective action towards possible social future" (Vadeboncoeur 2019 p. 244). This plays a crucial role in teacher development as teachers of STEM where microaggressions are minimised and girls are actively encouraged towards STEM. The Conceptual PlayWorld model therefore enables teachers to create these motivating conditions for girls and changes their *SSD* as they experience STEM differently.

The Conceptual PlayWorld provided new ways of using resources and spaces within the early childhood setting, positively positioning girls to have access to learning areas. It allowed possibilities of disrupting existing interactional patterns of using materials as the girls were actively involved in construction, a space typically dominated by boys (Bagiati and Evangelou 2016), overcoming previously identified problems of traditional spaces positioning girls away from STEM-related areas, repositioning girls in STEM, positively influencing their STEM identity formation and development.

The girls' active interest in STEM experiences ignited through Conceptual PlayWorld narrative continued and extended into free-play, where they actively furthered their exploration of STEM (Vignettes 2, 3, 4). Teacher interviews demonstrate a developing conscious awareness of the girls' increasing engagement with STEM, leading to a shift in teachers' orientation towards girls in STEM, challenging the traditional position of boys being more interested in construction. Words such as "incredible" and "phenomenal", further highlight the positive shift

from existing gendered positioning towards the possibility of girls being equally interested as boys in STEM.

However, with the teachers' roles changing from being actively in character inside Conceptual PlayWorlds to taking on supportive or more traditional supervisory roles outside Conceptual PlayWorlds, microaggressions reappear (Vignettes 3, 4, 5). In free-play, children continue aspects of the imaginary situation, however, small but frequent and repeated occurrences negatively alter the *SS* and their *SSD*, shifting girls' positioning with STEM as the microaggressions received are internalised, influencing their identity formation away from STEM. This was visible when the girls shifted their focus towards taking on supportive roles for boys, displaying early signs of gender stereotype conformity. Such trends of girls taking on helper roles in STEM have also been observed in previous research (Hallstrom et al. 2015). As attitudes and ideas about STEM are developed by the time children reach the early years of school, co-constructed with their parallelly developing ideas about gender (Corrigan and Aikens 2020), it is important for teachers to consciously disrupt such patterns.

Therefore, we can see that Conceptual PlayWorlds gives teachers a new position by bringing them closer to the children's narrative where these microaggressions occur, allowing them to actively counteract these occurrences, creating motivating conditions for girls. However, unless teachers are conscious about gendering issues in STEM, the positive difference caused by the Conceptual PlayWorld will be limited. It is important for teachers to be constantly mindful of gendered interactions and to develop a gender lens towards STEM engagement, without which, boys are continually being positioned as STEM leaders while girls are positioned as helpers.

7. Conclusion

The possibilities created by the Conceptual PlayWorld model positively alter interactional patterns to create motivating conditions, offering a positive, engaging and safe space for girls to freely engage with STEM experiences from as young as 2.3 years old - a crucial stage in children's identity formation (Campbell et al. 2020). Transforming the teachers' role through this educational experiment offered numerous possibilities, making a significant difference for girls' STEM opportunities. While several positive outcomes have been observed regarding the motivating conditions created by teachers through this model, it is important for teachers to continue these positive shifts in interactions even when outside the Conceptual PlayWorld.

Girls are very interested in STEM experiences as evident from their continued engagement with the problem, however, they face more microaggressions as teachers return to their traditional roles. This suggests that there is a possibility for further positive outcomes to be achieved if teachers were conscious of barriers to girls' STEM engagement as a significant problem and a consistent issue further up the STEM pipeline (Education Services Australia, 2018).

As the Conceptual PlayWorld model appears to create an enabling process for young girls in STEM, it is a promising model of practice for shifting the current situation of underrepresentation of girls and women in STEM. Considering the sample size, this study provides potential and positive direction. There is an urgent need for a larger number of participants in similar research. Finally, findings suggest that practice can be supported and policy informed by this model as it is evident that adopting such an inclusive model allows teachers to actively encourage girls in STEM through their critical years of identity formation, and therefore, it is anticipated that there will be an increase in girls' STEM interest, engagement and participation.

Acknowledgement:

Research assistance for data collection in this paper was provided by Sue March (field leader) and Rebecca Lewis. Special acknowledgment is made of the teachers who participated in the study. This work was supported by the Australian Research Council [DP180101030] for data collection, and [FL180100161] for subsequent analysis.

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