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Conceptual PlayWorld for infant-toddlers: The unique nature of becoming a science learner in the early years of life

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Abstract

In recent years limited research attention has been directed to what happens in science education before the age of 3 years. We present the findings of a study that followed 13 infant-toddlers aged 0.1-2.2 years (mean 1.8 years) and their educators from a childcare centre. Under the conditions of an educational experiment, the results of our study identified how scientific experiences build empirical knowledge in the context of an imaginary play problem, where infant-toddlers are resourced with content about the phenomenon, and in the drama of the play, build a relationship with a science concept. Early forms of scientific investigation processes were identified, problematising the current low expectations of what might be possible in science education for this age group. Our findings add to understandings about the earliest forms of learning in science in group care settings and introduce a model of practice called a *Scientific Conceptual PlayWorld for infant-toddlers*.

Keywords: cultural-historical infants - toddler imagination play science education

The author declares that they have no conflict of interest.
Ethics approval (Number:19778) was gained and informed consent for all participants was acquired.

Introduction

Over the past 15 years we have seen a strong interest in researching early childhood science education (Andersson and Gullberg, 2012). Important understandings about children's thinking in science have resulted, such as insights into children's knowledge of astronomy (Hu, Gordon Yand and Ren, 2021), physics (Ravanis, Christidou and Hatzinikita, 2013), chemistry (Adbo and Carulla, 2020) and biology (Frejd, 2019). We now know a lot about how to set up learning for children in the preschool years, where inquiry models (Eshach and Fried, 2005; Peterson and French, 2008), resource rich contexts for science engagement (Siry and Max, 2013) and child-led science learning (Blake and Howitt, 2012; Roth, Goulart and Plakitsi, 2013) are reported as making an impact on outcomes in science learning (Fleer & Robbins, 2003). However, much of this research has been based on the learning of the preschool child (O'Connor et al 2021). We know very little about the nature of learning and models of teaching in science for infant-toddlers. In this paper we take up this challenge by adding to what we know about the nature of the infant-toddler learner in science (Fragkiadaki, Fleer and Rai, 2021; Sikder and Fleer, 2015; Yonzon et al., 2022) in relation to

an educational experiment where educators and researchers introduced a planned intervention (Hedegaard, 2008) to study what might be possible for infant-toddler learning of science under the conditions of a scientific playworld that was developed from research with preschool aged children (Fleer, 2019).

What we know about infant-toddlers learning in science

In a scoping review of what is known about infant-toddlers learning in science by O'Connor et al. (2022), it was identified that there were two broad categories of understandings relevant to the focus of this paper. The first was centered about the product of science learning, such as what children understand about specific science concepts at particular points in time. This was in keeping with constructivist studies and the longstanding research in science education generally, where researchers systematically documented what is known about children's thinking in science. The other area they identified was the process of science learning, where researchers found how children learn science concepts in everyday life and in institutional settings, such as childcare. O'Connor et al. (2022) argued that this aligned with cultural-historically oriented approaches to researching, which traditionally sought to capture the process, rather than the product of children's thinking in science. But these two categories were based primarily on research dominated by children aged 4 to 6 years where there is an expectation of higher forms of conceptual learning when compared with infant-toddlers.

There were some studies that specifically focused on infant-toddlers. For instance, Klaar and Öhman (2012) studied natural phenomena by exploring how infant-toddlers aged 22 months form science concepts through their actions in nature. This in-depth study of one child in Sweden looked at non-verbal, bodily actions to investigate toddler's physical nature experiences. They identified bodily experiences of physical experiences were fundamental for infant-toddler learning about natural phenomena and processes. They found "that toddlers actually learn a lot of things about nature in their play and in their physical encounters with their surroundings" (p. 452). Their surprise is suggestive of a lower cognitive load in relation to the learning of science concepts when compared with preschoolers (Eshach and Fried, 2005).

Everyday encounters through physical exploration were shown to be important for learning science concept of friction in another Swedish study by Larsson (2013) of 4 children aged 2.1 to 5.6 years whilst playing. They determined that play brought children into direct contact with the phenomenon of friction (swinging a tomato, sliding down different surfaces of a slope), but found that educators did not support these everyday encounters by directing children's attention to moments of friction during their play. Rather they actively re-directed them to protect the surface of the slide and stop their explorations, and to follow conventions by not playing with food. Everyday routines rather than opportunities for science learning appear to dominant practices of educators working with the under three-year-olds. This is different to the learning opportunities found in preschools, such as in physics (Ravanis, Christidou and Hatzinikita, 2013). In another study in Sweden, Gustavsson et al., (2016) followed the educators' intentions and infant-toddler actions (Project 1: 1-3 years) and noted that interactions between children and educators were oriented to group cohesion and working together, and the science content was lost to the 1-3 year olds. More science content was observed for the preschoolers (Projects 2 and 3 for 4-6 year olds) in their study.

Research in Australia and Singapore by Sikder and Fleer (2015) also took a naturalist approach to identifying infant-toddler scientific learning opportunities in everyday life situations, but rather than centre-based settings, they examined home contexts. Like the

studies undertaken in Sweden, they followed 4 children aged 10 to 36 months in their everyday family homes and found that there were opportunities for them to experience and learn concepts associated with Force, water properties, and heating/cooling. Sikder and Fleer theorised their results as "small science". This concept of small science captures the idea of toddlers' attention and accompanying adult narration of scientific moments in everyday life. They suggest these science-based interactions draw attention and make conscious the science being experienced/observed during collaboration between adults and infant-toddlers (Sikder and Fleer, 2014; 2018). What these studies of infant-toddlers in science show, is how the learning of science occurs in everyday interactions in family practices, as well as when playing with materials whilst attending preschool settings. However, when compared with preschoolers (Blake and Howitt, 2012; Roth, Goulart and Plakitsi, 2013), these studies did not intervene in the everyday experiences of infant-toddlers. But research in England by Lloyd et al., (2017) did. Their study aimed to support 19 families in identifying and building science related experiences for 26 children aged from birth to 5 years. The families received instruction on how to introduce scientific thinking about Forces, materials and their properties, as well as the living world. They showed through a *stay and play* approach that families increased their confidence and their infant-toddlers' moments of rich science-based experiences. Intervention studies were also used in Australia by Fragkiadaki et al., (2020) who specifically sought to increase the amount of science teaching in childcare settings. Their research sought to follow the learning experiences of 13 children aged 5 months to 2 years and 3 months under the conditions of a Conceptual PlayWorld (CPW). In their case study, the educators introduced the infant-toddlers to the concept of sound through imaginary play. It was through the drama of a story and a play inquiry of a possum hunt, that the infant-toddlers role-played the dramatic and noisy clutter of the possum crashing through different rooms in the family home. The story book created the narrative, and the objects and actions of being the characters from the book gave a context in which to consciously explore sound. In a follow up analysis (Fleer et al., 2020) it was determined that the use of props, the embodiment of the experience, and the shift from physical objects and concrete spaces into a shared intellectual zone with abstraction (Fragkiadaki et al., 2021a) took place in collectively oriented imaginary play (Fragkiadaki et al., 2021b) in a CPW. Different to the CPWs of preschoolers who communicate verbally, was the importance of props for infant-toddlers communicating their intentions and the need to actively orient infant-toddlers to the group during moments of science teaching.

In another study in Australia that was designed under the conditions of a CPW, Yonzon et al., (2022) identified props as key for infant-toddler role-playing during science-based experiences. But in their study, it was found that over time the infant-toddlers drew more on their imagination to relive the narrative of the story. The differentiated use of props supported infant-toddler transitions into imaginary play. Unlike Larsson (2013) where opportunities for learning science in play were lost, the imaginary play featured many examples where educators were active in leading learning in play. This was consistent with those studies that examined imaginary play and science learning of preschoolers (Siry and Max, 2013; Blake and Howitt, 2012; Roth, Goulart and Plakitsi, 2013). Although limited in number, the studies of naturally occurring opportunities for science learning of infant-toddlers in childcare settings show that the possibilities for science were often missed (Gustavsson et al., 2016; Larsson, 2013). However, intervention studies appear to support the place of science education for infant-toddlers in childcare centres (Fragkiadaki et al., 2021a,b; Yonzon's et al., 2022).

Taken together both the intervention studies and the naturalistic research of infant-toddlers collectively show that the learning of science is possible with this age group. But the number of studies is relatively small when compared with the research with children aged four years and above. This would suggest that more research into the teaching of science before the preschool period is needed. To build confidence in this emerging area, more insights are needed into what might be unique about the learning of science by infant-toddlers, and what could be a teaching model for this age period to systematically guide practice.

Theorising the problem of learning science at such a young age

There are robust theoretical concepts available to guide research in science education that previous researchers have worked with for understanding infant-toddler development of scientific concept formation in naturalistic settings (e.g., Sikder and Fleer, 2015) and as part of a planned intervention of a CPW (Fragkiadaki et al., 2020; Yonzon et al., 2022). We add to those studies that draw on cultural-historical theory, and specifically those where a planned intervention into infant-toddler scientific concept formation was adopted. In this section our interpretation of the theorisation of a dialectical relation between everyday concepts and scientific concepts specific to infant-toddler thinking in science is theorised in relation to the central problem of this paper. Our research question centred on identifying foundational knowledge of educator intentionality in interactions in play-based settings that support the emergence of scientific thought of infant-toddlers with the goal to build a model of teaching science specific for this age group.

The theoretical foundations that have guided researchers in science education generally bring forward the individual and their construction of the world (constructivism), with later theoretical frames contextualising the individual in social relations (social-constructivism). The premise of this conceptualisation is the building of empirical knowledge one block at a time, where previous understandings are brought into tension with new insights, and old understandings replaced with new knowledge. Cognitive dissonance in social contexts acts as the driver within constructivist and social-constructivist theorisations of concept formation in science. In the context of our study of infant-toddlers, this theoretical framework would position the infant-toddlers as having already formed scientific concepts. But infant-toddlers have limited life experiences and this framing limits how we might understand the process of infant-toddler development of scientific thought and a scientific consciousness of understanding the world in which they live. Rather than replacing what infant-toddlers know, and moving forward on that foundation, we draw upon Vygotsky's conceptualisation of the relations between everyday concepts, such as the phenomenon of a rainbow, and the scientific concept, such as light. We bring forward six key theoretical ideas that we drew upon in our study of infant-toddlers learning of science concepts.

First, Vygotsky (1987: 177) argued that, "The boundary that separates these two types of concepts [everyday or scientific] is fluid. In the actual course of development, it shifts back and forth may times". This back-and-forth movement is important for studying the process of concept formation of infant-toddlers, as they participated in an educational experiment of a CPW where the story narrative of a book (Follow that Tiger by Joyce) and the planned intervention iteratively introduced infant-toddlers to theoretical thinking of the core concept of ecosystem (habitat, food sources, characteristic of the organism). Children's everyday concept of animals, such as their names; do they have eyes, tails? where do they live? (the water, a tree) and the scientific understanding of animal characteristics in relation to their habitat was conceptualised in the educational experiment as being in constant relations with each other – rather than conceptualising the process as one of replacing old knowledge with

new concepts. This is in keeping with Vygotsky's (1987: 177) conception that "the development of spontaneous [everyday] and scientific concepts are in closely connected processes that continually influence one another".

Second, Vygotsky (1987: 177) argued that regardless of which type of concept (everyday and scientific) is being foregrounded in the educational experience at a particular moment, "we are dealing with the development of a unified process of concept formation". In contrast to the idea of empirical knowledge being built through the process of replacement of old with new understandings, Vygotsky (1987: 177) suggested that the two types of concepts, "are not separated from one another by an impenetrable wall nor do they flow in two isolated channels". This dynamic conception of concept formation is a theoretically helpful framework for understanding how infant-toddlers enter into, and experience, an educational experiment of a CPW. In contrast to constructivist and social constructivist perspectives, "It is not a function of struggle, conflict, and antagonism between two mutually exclusive forms of thinking" that is foregrounded (Vygotsky, 1987: 177).

Third, Vygotsky (1987) argued that there is a different relationship between a child's personal experience of an everyday concept acquired in everyday life, and their relationship with a scientific concept acquired at school. His theorisation of the latter was primarily in relation to formal educational settings with older children, and therefore what this means for infant-toddler scientific thinking and the development of concepts has received less theoretical attention. Sikder and Fleer (2015) in bringing forward the idea of 'small science' experiences in everyday life at home for infant-toddlers have sought to capture how adults draw attention to, and make conscious through their narrative, interpretations of the child's world when building a scientific foundation. But their theorisation does not extend to early learning centres, such as childcare, which is the focus of our educational experiment. Therefore, we suggest a theoretical gap associated with this age group in a context of childcare is still to be considered further.

Fourth, important for our study of infant-toddlers, Vygotsky (1987: 179, original emphasis) suggested that "*the formation of scientific concepts is not completed but only begun at the moment when the child learns the first meanings and terms that function as their carriers"*. How words hold meaning, but also how objects can act as carriers of scientific concepts are both particularly pertinent to the resource rich learning environments of childcare where infant-toddlers are still developing their oral language. Thereby, generalisation through word meaning being consciously realised in action has its beginning in the word rather than being completed through its expression. This word-scientific meaning suggests that it is not tied to simply the intellectual effort of the child but is embedded in social relations with others as words, actions and objects become personally meaningful in an infant-toddler room.

Fifth, related to the theoretical arguments above, is the question of how conscious awareness of a scientific concept is realised by infant-toddlers in social relations. Vygotsky (1987: 187-188) offers some insights:

> Conscious awareness develops as a whole. …Development is not a sum of the changes occurring in each of the separate functions [e.g., perception, memory, imagination, will]. Rather, the fate of each functional part of consciousness depends on changes in the whole.

It was suggested by Vygotsky (1987) that during infancy there is a lack of differentiation of functions, but during early childhood perception becomes differentiated, and later Vygotsky (1998) argued that imagination develops in play, and, later still, as children enter school, memory dominates, leading to formation of pre-concepts at school where "comparatively mature forms of attention and memory at his [sic] disposal" (Vygotsky, 1987; p. 189). The augment that Vygotsky puts forward is that it is only during and towards the end of primary school age, that children can think consciously with concepts because they have at their disposal generalisations that have developed through iterative and dynamic relations between everyday concepts and scientific concepts through instruction in school. However, Vygotsky wrote in a time when childcare did not have educational programs using curriculum documents, as occurred in the context of our study, when the principle of intentionality in play-based learning was being promoted. So the question of how educators create conditions to support conscious awareness of scientific concepts for infant-toddlers remains.

Sixth, Vygotsky argued that although scientific concepts have a unique relationship with objects, concepts are also localised within a system of relations, which produce generalisations. For example, habitat, structural features of an organism, and food source are part of a system of relations that make up the core concept of an ecosystem. Vygotsky (1987, p. 193) argued that "concepts must be seen as part of the entire system of the relationships of generality that define its level of generality, just as a stitch must be seen as part of the fibers that tie it to the common fabric". Poignantly, he found in his research that "the source of the lack of conscious awareness of concepts not in egocentrism [as Piaget theorised] but in the absence of system in the child's spontaneous [everyday] concepts".

Whilst the characteristics associated with everyday and scientific concept formation within a system are well established in Vygotsky's writing, how they change in relations to each other, and how they then act as part of the child's conscious realisation of scientific concepts as tools for thinking differently about their everyday world during infant-toddler period remains elusive.

Study design

Research question: This study sought to identify infant-toddler learner in science under the conditions of a Conceptual PlayWorld in a group setting of a childcare centre.

To answer this question, we designed an educational experiment (Hedegaard, 2008), which involved researchers and participants collaborating on a theoretical problem and not just a problem of practice. A theoretical problem in an educational experiment is understood from a subject matter perspective (science to be taught) and the development of the child (what is unique about infant-toddler learning in science). This dialectical perspective brings forward a particular theoretical orientation that both researchers and educators discuss. For instance, the relations between everyday concepts and scientific concepts as proposed by Vygotsky (1987). In our educational experiment we collaborated with educator Karen and educator Mya from an infant-toddler room in a childcare centre on the problem of our research. We wanted to know if a CPW could be used with infant-toddlers to support science teaching and learning of such young people. The goal was to identify what kinds of pedagogical characteristics allowed for the emergence of scientific thinking and action of infant-toddlers in imaginary situation of a CPW. Ethics approval (Number:19778) was gained and informed consent for all participants was acquired.

The CPW model was developed from research with preschool aged children and has five pedagogical characteristics (Fleer, 2010). They are: selecting a story, designing an imaginary space for role-play, developing a routine for all the children and educators to enter and exit the imaginary space, planning a science problem to solve, and educators acting as play-partners with children to bring science concepts into the play problem.

Participants: A total of 13 infant-toddlers aged 0.1-2.2 years (mean 1.8 years) from a childcare centre from a middle-class suburb in southeast Melbourne participated in our educational experiment. The background of the children were British, European, Latin American, East, and South Asian.

Data generation: The digital recording of 23 observation visits (13 data log sets) was the main source of data. Two cameras were used. The handheld camera followed the children as they entered into the different activity settings, giving close up details of children's and educators' play. The second camera was mounted on a tripod and was located in the room to give a holistic capture of the different activity settings (story reading area on couch; main room with tables of activities; small table with figurines of zoo objects and enclosures). The study generated 13 hrs of digital data. The data set included in situ interviews (i.e., educator responses to questions at the end of teaching period) and pre-arranged interviews designed around questions such as, what were your intentions, what worked, what concepts were you teaching, what is unique about CPW for infant-toddlers? This constituted 2.08 hrs of digitally recorded and transcribed data.

Analysis: All digital data were organised into digital folders related to each of the 23 sessions, and these were analysed using Hedegaard's (2008) 3 levels of interpretations: common sense organisation; a situated practice level of interpretation; and a theoretical analysis. A common sense organisation of raw data involved logging digital videos and organising them into folders with descriptions, where a sense of the data related to infant-toddler play and educator practices were determined. A situated practice level of interpretation was then undertaken by examining the patterns across the data. Specifically, the phenomenon of snakes within a conceptual system of an ecosystem, was tagged and summarised across the data (see Appendix 1). The digital folders were integrated for common themes emerging from the data set (intentions, phenomenon, relationship with the concept).

Finally, the analytical concepts of everyday and scientific concepts, and imitation (Vygotsky, 1987) were used to examine *how educators created conditions for science learning for infant-toddlers.* The concept of imitation is relevant for analysis because infant-toddlers imitate social gestures in their world. Vygotsky (1987) said,

> It is well established that the child can imitate only what lies within the zone of his [he] own intellectual potential…. In collaboration, the child turns out to be stronger and more able than in independent work. He advances in terms of the level of intellectual difficulties he is able to face" (Vygotsky, 1987: p. 209).

Imitation by infant-toddlers is therefore not a mindless act, but rather it becomes an important source of scientific learning. How a child enters a CPW and imitates the actions of the educators and relives the narrative of the play plot could give insights into children's intentions and their learnings of scientific concepts. The actions and embedded scientific problem that are a feature of the CPW in which the educators have "prepared the structural formations necessary of the mastery of the higher characteristics of the everyday concepts" are brought into play that "scientific concept begins not with an immediate encounter with

things but with a mediated relationship to the object" (p. 219). Paying attention to how educators create the conditions for infant-toddler imitation was a core part of our analysis.

Results

The results show how narrative, empirical, and theoretical knowledge were associated with the building of a system of scientific thought about animal characteristics, habitat, and food source. These acted as the core aspects of a simple relational system of an ecosystem for the snake and other animals from the role-play and story. The iterative process of different knowledge forms and ways of thinking appeared to create the foundational relational system in which conceptual development for infant-toddlers in play-based setting was being pedagogically supported. To explain this finding, we draw on typical examples of practices of the educators and actions of infant-toddlers, alongside of interview data to support the intentionality of the educators in the practice setting of a childcare centre. The presentation of the findings with typical examples is supported by Appendix 1 where a condensed summary is shown and where the phenomenon of snakes is featured (grey rows). Snapshots of vignettes follow under three headings. They show how the phenomenon of a snake was iteratively brought into close relations with the concept of a simple ecosystem:

- Building a relationship with the scientific concept
- Consciousness of concepts in the traditional learning areas in the centre room
- Conscious awareness of concepts in the imaginary situation
- A scientific problem arises

In this section we begin with an overview of how the *phenomenon of snakes* emerged as an inquiry within the practices of the educational experiment of a CPW, followed by how this phenomenon iteratively created conditions for infant-toddler experiencing of different knowledge forms.

Building a relationship with the scientific concept

The study found that the children had many opportunities to build a relationship with the scientific concept of an eco-system. This was done through populating the regular areas in the centre with science content. For example, in Appendix 1 Column 2 the everyday practices of the centre of book reading, educator-child play in the main room, table activities, and music and movement, were used as activity settings for introducing the phenomenon of the animals in the story living in the jungle. The storybook reading of *Follow that Tiger* and later jumping into the story and going on adventures (Column 3), was found to give a context in which the regular activity settings became saturated with scientific content about the animals (Column 4). This is in keeping with Vygotsky's (1987: 177) theorisation that "we are dealing with the development of a unified process of concept formation". In the vignette below, the visual field of the reading couch with the props of animal headbands and tails becomes the gateway into the imaginary situation of the jungle (main room) where the infant-toddlers go on an adventure (phone rings – call from the Tiger asking for help) to look for the snake from the storybook:

> *Reading couch:* Everybody is reading the book "Follow the tiger". All the children are making animal sounds. Peter points to the monkey and makes monkey sounds. They all make the snake and parrot sounds. They all say roar when the Tiger comes up in the book.
>
> *Reading couch becomes the entry into the jungle:* The infant-toddlers turn into animals by putting on ears and tails.

> *Problem arises:* The telephone rings. It's the Tiger calling again. Tiger needs their help to find the missing snake.
>
> *Main room becomes the jungle:* The Zebras and the Tigers, Lions and the Bear set out on a mission to find the snake. They discuss that they need to look underneath the rock to find the snakes. They look on the ground, they look up in the trees to see if the snake is up in the tree. They keep looking! They keep going, Educator Karen says "c'mon Zebra, come on help us look Zebra. Are there any snakes under the trees and bushes? Can you lift the leaves? Are there no snakes?"

The learning areas in the centre collectively became the CPW, each acting as a resource for solving play problem rather than as traditionally intended. In the imaginary situation of the jungle the infant-toddlers explored the phenomenon of a snake with all of its characteristic, as well as the sounds they make, all whilst going on an adventure to find the snake by examining possible habitat of a tree (jungle tree snake) or living on the ground under leaves (ground snake). Regular entry into CPWs gave possibilities for building a relationship with the concept (concept of simple ecosystem of organism structure, movement, and habitat). This is illustrative of practices that build a relation between everyday concept (phenomenon of snakes) and the scientific concept (snake within their habitat) where "The boundary that separates these two types of concepts is fluid" (Vygotsky, 1987, 177).

Consciousness of concepts in the traditional learning areas in the centre room
The program also brought forward explicit science content in the regular activity settings as moments of scientific content, such as book reading on a one-to-one basis or through small group experiences at the tables. For example, by placing non-fiction books into the environment, Karen and the infant-toddlers could explicitly bring into an interaction, information about snakes to support thinking and playing. For example:

> Sully, Tiana and Karen are seated on the reading couch exploring books about snakes. Sully is looking at different animals in the book. Tiana is looking at snake fangs. She shows Karen the Snake's mouth. They look at the teeth and tongue. The snake is eating on the next page, and baby snakes are coming out of the eggs, they look at the eyes. Tiana shows Karen the snake figurines that she has on the couch with her. She shows Karen the mouth and the eyes. They try to poke out their tongue like a snake. They explore the hissing sound the snake makes. Karen asks if the snake says roar or hiss. Sully says 'hiss' (C1R2007).

In this example, Karen draws attention to the different parts of the body of a snake in relation to the children's body features (Figure 1). In response to this Tiana smiles and points to each part of the snake's body (Figure 2) as well her own body suggesting a connection between herself and the features of the snake. In the example Karen also points to the snake's tongue. After looking at the snake's tongue, Karen asks Sully to show her his tongue (Figure 3). This practice is potentially the earliest form of Vygotsky's (1987: 179, original emphasis) suggestion of "*the formation of scientific concepts" as not yet being "completed but only begun at the moment when the child learns the first meanings and terms that function as their carriers"*. Exploring physical features and making links between the children's tongue and that of the snake's tongue is being framed *in the word tongue*. There are very different structural features, and this conscious awareness of the *word as a carrier and a discriminator* is foundational for building a relationship with the scientific concept associated with the

structure and form of the organism, habitat, and food source (ecosystem). This is illustrative of how educators create conditions to support conscious awareness of scientific concepts for infant-toddlers.

Figure 1. Talking about the physical characteristics of snakes

Figure 2. Finding the physical characteristics of snakes in the figurine

Figure 3. Physical characteristics of snakes in relation to human characteristics

Conscious awareness of concepts by regularly being in the imaginary situation

We identified that the source of conscious awareness of concepts also appeared in the social and playful relations between the infant-toddlers and educators when regularly being in the

imaginary situation of role-playing the story of Follow that Tiger. We know from previous research that a CPW builds a collective narrative and focus for preschool children, and that early forms of a collective inquiry are possible for toddlers (Fragkiadaki, Fleer and Rai, 2020; 2021; 2022; Yonzon et al., 2022). The results of our study build on this foundation because we identified that there was a constant association being made between the phenomenon of the snake and the scientific concept in the imaginary situation. Karen refers to this as bedding down.

> It's that bedding down time. Making sure you have given them knowledge and then you are listening to them, in their play, then see where it goes. Even like Tiana. …But the interest, and it is almost like they spend a lot more time on the experiences, because they are looking deeper. I can see so much going on (Interview, 20191204 Folder – clip 2).

The science content being introduced to the infant-toddlers in relation to the snake was seen through both populating existing areas in the childcare centre room with science content and introducing the narrative of the story with a problem of looking for the snake. Both approaches supported consolidating or bedding down the relationship with a concept.

Figure 4. The phenomenon of "snake" in the imaginary situation is populated with science content to build a concept over time

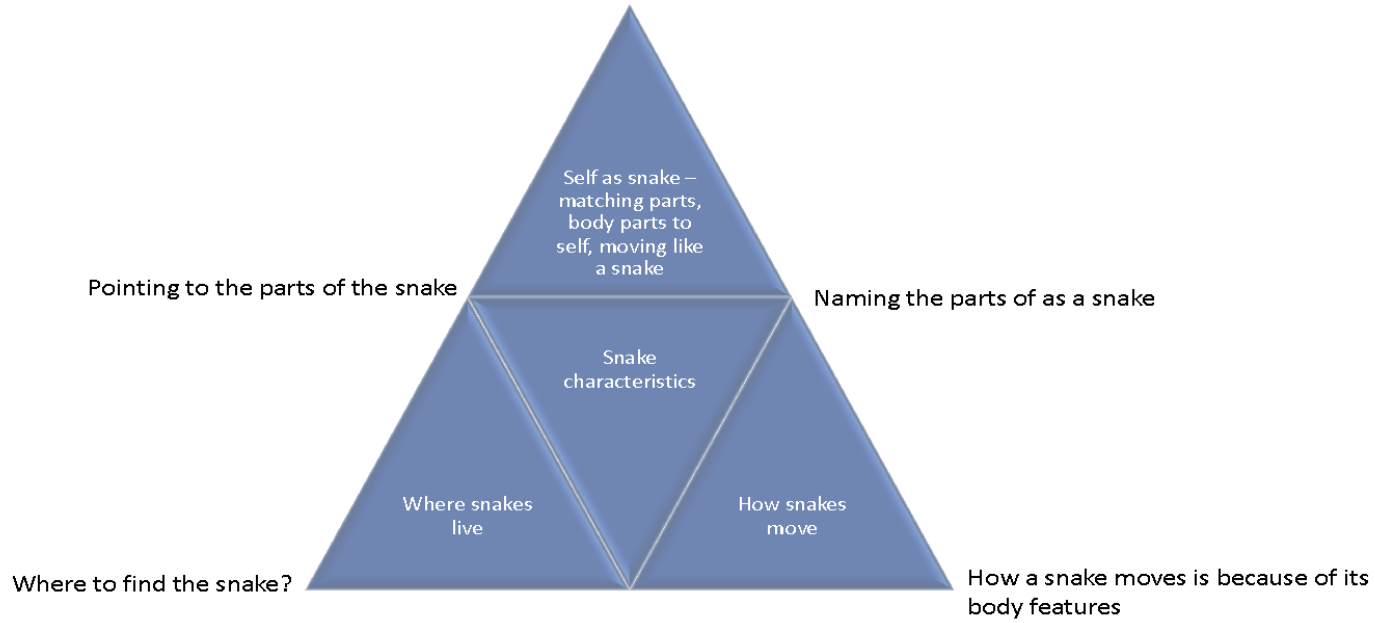


Figure 4 captures the many dimensions of the phenomenon of the snake that were being explored with the infant-toddlers over time. They appeared both in the imaginary situation of being in the jungle looking for snakes (and other animals), and when exploring the physical features of the snakes in books and their own body. Other resources available to support connecting the phenomenon of the snake and the concept of an ecosystem were the figurines and soft toys (e.g., python) in relation to self (see top triangle). The imaginary situation gave possibilities for exploring how to move in the jungle when you are a particular character (animal) from the story (triangle bottom right), and when going through the different habitats in the jungle (e.g., river – to swim; the rocks – to scramble over; the tree – to climb; triangle

bottom left). Figure 4 is illustrative of the practices associated with how educators create conditions to support conscious awareness of scientific concepts for infant-toddlers. Whilst Vygotsky (1997) suggested that only towards the end of primary school do children use true concepts (suggesting that younger children work with pseudo concepts), these practices by the educators show early forms of science activity as building a unique relationship with objects in the childcare centre. The practices in Figure 4 collectively bring forward a system of relations, which have the potential to produce generalisations which we know are foundational for thinking and working with scientific concepts.

In implementing a form of a CPWs for infant-toddlers brought out new pedagogical conditions for the teaching of science to such young children, as Karen explains:

> With infants and toddlers, you have got to put the CPW away for a bit, and make sure you have given them enough resources in themselves, knowledge, to then be able to step in there, so you can see what's going on. There is so much going on that you can't see, we don't always know what's going on for them. I am seeing questions, and even the interest, with babies, we have to be very aware of the layers to learning (Interview, 20191204 Folder – clip 2).

In summary, the bedding down time for consolidating a relationship between the phenomenon and the concept was undertaken by 1) a consciousness of concepts through populating the existing areas (table activities, reading couch) with science content, and by 2) embedding science content into the imaginary situation of looking for the snake in the jungle - the children had to think about habitats when looking for the snake. These explicit science practices appeared to support the children's building of a relationship with the concept that was being consciously explored. This aligns with Vygotsky's (1987: 187-188) claim that "Conscious awareness develops as a whole".

A scientific problem arises

The study also identified that in the CPWs it was possible for a question to arise. Karen said:

> … even that question that Chloe had about "Why do snakes live in trees?" …we could be looking at "How do we find a snake?". Chloe has got a bit of knowledge now. We could look in a tree. What other animals live in trees? We could find a bird (Interview, 20191204 Folder – clip 2).

Chloe's question not only suggests a deep engagement with the narrative of the story, but a curiosity that brings the phenomenon of the snake into an active relationship with the concept of an ecosystem. For example, Karen said:

> …with the question that came from Chloe about why do snakes live in trees, why do all the animals live the way they live, so then looking at habitat, but you have got to then give them a bit of that knowledge, let it sink in and let it, then see where they go with that, it might not be about snakes at all, that was the question that we started with, it might turn into what are our houses like? I don't know. And then I am wondering, I am reading the [additional fiction] book, *The Tiger who came to tea*, it's about a tiger not in his natural habitat, has that prompted for Chloe that question of where do animals live? We are showing her tigers in the wild, in a way, but I have also introduced this idea of a tiger in a house. So, there is the questioning coming up (Interview, 20191204 Folder – clip 2).

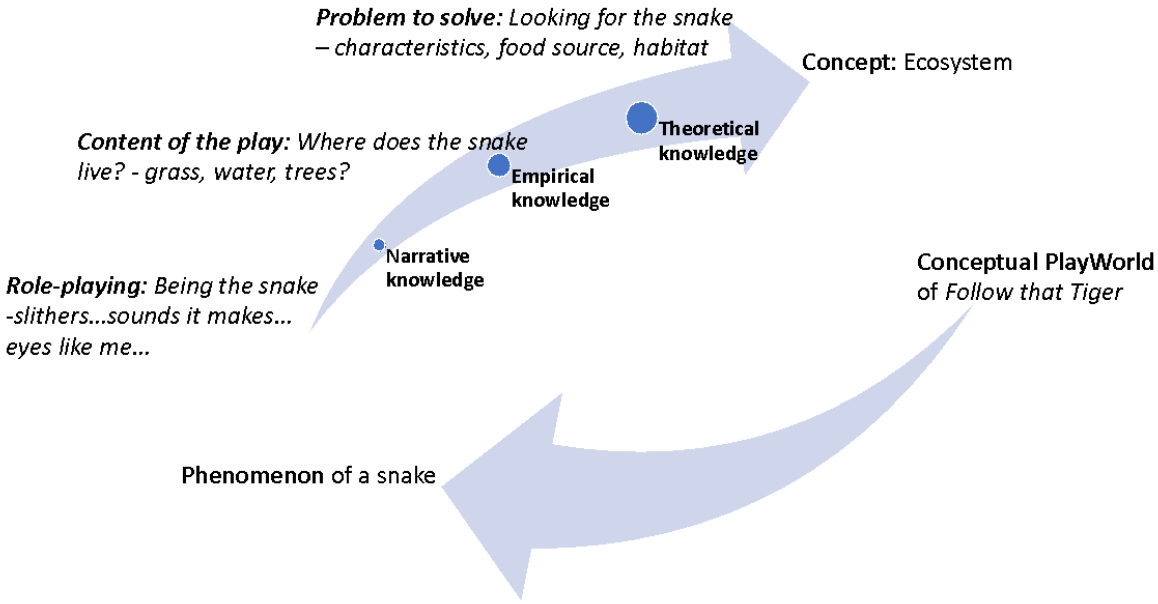
Discussion

The study found there were two types of ways that a system of concepts emerged in the practices of the educators that were different to preschoolers in a Conceptual PlayWorld: 1) The centre room is turned into an imaginary situation of a CPW where the learning areas resourced narrative knowledge associated with the phenomenon of a snake; 2) The traditional learning areas were imbued with science content through bringing into the reading couch, tables, shelves of science related resources to bring different kinds of interactions between educators and infant-toddlers that supported empirical knowledge development. The iterative process of different knowledge forms that were presented, and ways of thinking appeared to create the foundational system in which conceptual development for infant-toddlers in play-based setting was being pedagogically supported. A synthesis of these practices and knowledge forms can be expressed as:

- *Constant relation between the phenomenon and the concept*
- *Play frames the conceptual system of the scientific concept*

Constant relation between the phenomenon and the concept
We learned from our in-depth analysis of the data that there was a constant relation between the phenomenon and the concept in the planning and practices of the educators which meant the infant-toddlers were continually exposed to many different dimensions of the core concept in their role-play, such as when looking at books on snakes and studying their tongues. This exposure also sat within the narrative of the story that was always cycling and being amplified by the play (see Figure 5: Narrative), such as when looking for the snake in a tree because that was presented in the book of Follow that Tiger. In addition, the constant iterative introduction of content into the play was featured in the practices, such as when the educators placed rubber snakes under the carpet for the children to find, or when slithering like snakes, or when retrieving the soft toy snake from a tree and studying its features. Together, these examples show how each play session could become more complex over time (see Figure 5: Empirical). This pedagogical practice brought the infant-toddlers closer to the core dimensions of the science concept (see Figure 5: ecosystem: food source, habitat, and animal characteristics). The educators created a way of seeing and being the animals from the story of *Follow that Tiger* and this was important for iteratively re-engaging infant-toddlers each day over a period of time.

Figure 5. Building a relational conceptual system for infant-toddler science learning of Follow that Tiger



The interplay between the phenomenon and the concept builds over time. It was through the imaginary situation that adventures could be developed, with new kinds of phenomenon-concept relations being strengthened when role-playing the characters in the jungle. New curiosities become scientific questions (as we saw with Chloe) to be solved in the imaginary world of *Follow that tiger.*

Playful relations between infant-toddlers and educators become the routine for learning concepts. Vygotsky argued that it was through others that the conscious awareness of concepts emerges for the child. But this social and playful relationship was not simply a narrative experience of being characters from the story living the everyday concepts of animals, such as their names; do they have eyes, tails? where do they live? (the water, a tree?), but it was a new conceptual system being built where a scientific concept was being introduced, explored, and used during role-play. We found the infant-toddlers were role-playing with their educators within a system of everyday concepts that were interconnected. This is symbolised as a dynamic pedagogical relation between the phenomenon of the snake and the scientific concept of the jungle ecosystem (two outer relational arrows). In the imaginary situation the relationship between phenomenon and concept begins.

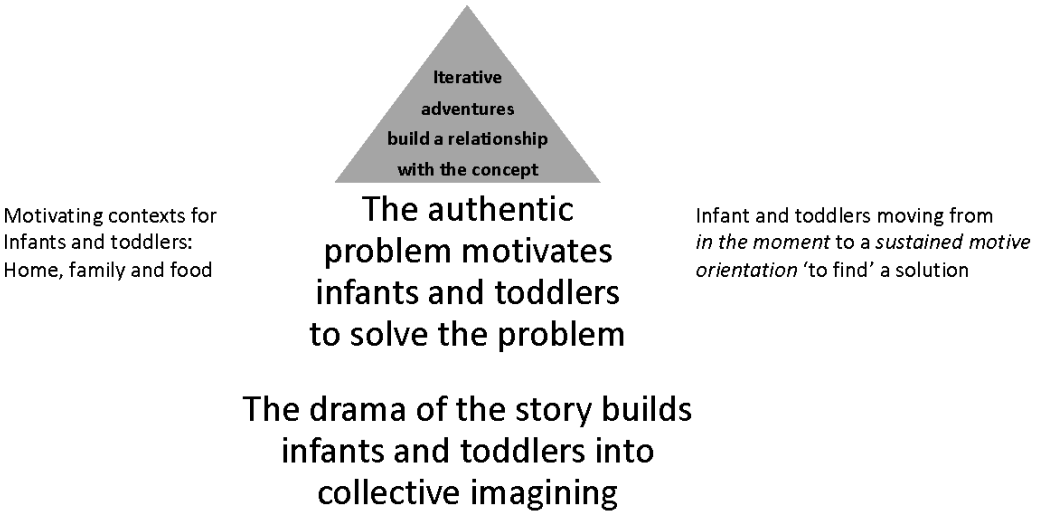
Play frames the conceptual system of the scientific concept under study

The study identified that a planned program of play built a conceptual system in which scientific thinking was being framed for infant-toddlers. The repetition of the story narrative and the role-playing gave possibilities for infant-toddlers to imitate with understanding the movements and sounds of the animals, at the same time as being brought closer to the concept of an ecosystem as they moved through the different habitats in the imagined jungle with the adventure of looking for the snake (and other animals). It was through the educators creating the system of interconnected everyday understandings about phenomenon of snakes that the infant-toddlers experienced a relationship with the scientific concept. Concepts were

being introduced by the educators to frame the interactions in the play. Vygotsky (1987) has suggested that the "Concepts do not lie alongside one another or on top of one another with no connections or relationships…. without well-defined relationships to other concepts, the concept's existence would be impossible... By its very nature, each concept presupposes the presence of a certain system of concepts. Outside of such a system, it cannot exist." (p. 224).

The concept and the phenomenon sitting within a scientific system could be amplified through the imaginary play. The play framed the conceptual system in which the phenomenon of the snake was present. Figure 6 shows how the motivating conditions for learning science developed – the dramatic story (layer 1 of triangle) for imaginary situation where Chloe's curiosity of why snakes live in a tree emerged (Layer 2). The iterative adventure brings infant-toddlers into a relationship with the scientific concept. The drama of the story becomes the drama of the problem to solve that is personally meaningful. We identified that the model brought infant-toddlers from an *in the moment* to a more *sustained motive orientation* to find a solution – thereby experiencing early forms of a scientific investigation. Whilst preschool children are likely to sustain their engagement in the imaginary situation with one or two readings of the story (Fleer, 2019), with infant-toddlers the educators enacted shorter sessions with more story reading sessions, repetition of words, sounds, and embodied actions of the animals.

Figure 6. Early forms of a scientific investigation by infant-toddlers



A Conceptual PlayWorld for supporting infant-toddler learning of science

In our educational experiment we were also interested to know if a scientific playworld could be used to teach science to infant-toddlers. Based on the research reported above, we found that all the characteristics identified for preschool children (Fleer, 2019) supported infant-toddler learning of science. But there were also some important differences.

The first section of Table 1 captures what is unique for infant-toddlers learning science, and builds on previous research (Fleer, 2019). Based on the results of our study, we determined that story selection needed to be nuanced in relation to the actions it afforded, because pre-

and emerging verbal children show their intentions physically through actions (Table 1, Row 1). We also noted that it was important for the educator to re-tell the story with actions in the imaginary situation. The transition from many readings of the book with actions and sounds, into being a character and living the story in the imaginary situation, was only possible later in the program. With preschool children, this story reading/telling allows for almost immediate jumping into the story through role-play.

We also found that the infant-toddlers needed to have knowledge of the characters they were to role-play, and this meant bringing with the story reading non-fiction content as well (Rows 2, 3 and 5). This was achieved by bringing into the existing learning areas resources to support new kinds of interactions about the animals in the storybook.

We also noted that props were important for supporting the role-play, as this allowed the infant-toddlers to initially identify and signal to others what character they were, and later to become the characters simply by using sounds and actions (Row 4). These features are unique to a Conceptual PlayWorld for infant-toddlers who are building a relationship with science concepts in group settings. See Appendix 2 for details of a Conceptual PlayWorld for preschool children.

Table 1. *Unique features of a Scientific Conceptual PlayWorld for infant-toddlers*

Pedagogical characteristics	Pedagogical practices
Selecting and animating a story for the CPW	■ A story that has repetition and potential for action and sound that educators can amplify, and infant-toddlers can imitate. ■ **Building the play plot:** Reading the story, animating the characters with sound, action, and repetition. ■ **Consolidating the play plot and characters**: Many readings of the story, continuing to amplify the actions and sounds associated with each character, inviting the infant-toddlers to do the same actions during story reading. ■ **Re-telling the story in the imaginary situation:** Narrating the story with actions in the imaginary situation, using same animated sounds, action and repetition, and inviting the infant-toddlers in to be with you living the story through action.
Traditional learning areas are resourced with science content	■ Non-fiction books to explore. ■ Cards and images
Building knowledge of science content to resource infant-toddler imagining and role play	■ Building knowledge about the characters – for example, what they do, where they live, what they eat?
Imaginary play is resourced with props associated with the selected story	■ Figurines, headbands, or soft toys to support infant-toddlers **co-experience** the phenomenon through **acting 'as if'** the characters from the storybook.
Building a relationship with the scientific concept	■ Phenomenon and concept progressively align and then act in unity, for example: ■ Characteristics of self (ears, eyes) and animals being made. ■ Characteristics of animals and how they move in relation to their habitat. ■ Personally meaningful questions arise in this unity – "Why do snakes live in trees? Do hippos poo in a potty?"

Conclusion

The educational experiment sought to identify the nature of the infant-toddler learner in science under the conditions of a Conceptual PlayWorld in a childcare centre. The model (Table 1) that was developed from our research is different to that of a CPW for preschool children (Fleer, 2019) because we identified the need to create particular conditions for *building a relationship with the science concept*. Rather than design an inquiry (Eshach and Fried, 2005; Peterson and French, 2008), the science learning was framed within imaginary play situations. The model is also different to those studies undertaken in naturalistic settings (Klaar and Ohman, 2012), where educators respond *in the moment*, rather than plan for *sustained science learning* over time. The provision of resources was framed within a play problem, rather than being introduced to inspire children to design their own inquiries in science (Siry and Max, 2013). Whilst play-led learning was evident (Blake and Howitt, 2012; Roth, Gourlart and Plakitsi 2013) the science framing was led by the educators because the infant-toddlers had less experience with play resources. We noted that the educators had to give some information so that infant-toddlers had content to bring into the imaginary play. The content provided by the educators was aligned with building a relationship with the science concept over time. Finally, our study was located within a childcare centre rather than set up in family homes (Lloyd, et al., 2017; Sikder and Fleer, 2015). This matters because educators are charged with designing educational programs and families are not. Drawn from a sample of one childcare centre, further research is needed to determine if the model can support the teaching of science to infant-toddlers more broadly.

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APPENDIX 1

Condensed overview of data set foregrounding phenomenon of snakes within a conceptual system of an ecosystem

Educational experiment log reference	**Activity setting**	**Phenomenon**	**Building a relationship with the concept**	**Infant-toddler intentions**
C1R2001	Reading couch	Listen to Karen (educator) read the story 'Follow that Tiger".	Karen reads the story making gestures and noise throughout.	At times the children imitated the movements and sounds.
C1R2002	Reading couch acts as transitioning area to jump into the story in character	Explore animal costumes.	Karen talked about the different patterns of the animals, how the tiger and the zebra had strips.	The children wore animal costumes. Wynn became the elephant. Peter became the zebra and Sully became the tiger.
	Main room becomes the jungle	The children explore the room in their costumes.	The children pointed to the lion and Karen asked, if the lion had strips.	Wynn in particular was interested in the zebra's tail.
	Table with books on animals	They explore the features of the elephant - head, eyes, tusks, big ears; later zebra; later a jaguar.	They discuss different tails.	Wynn and Peter were interested in the tusk.
C1R2003	Table with animal figurines	They are exploring animal figurines.	Chloe shows a rhino to Karen and Karen asks what noise does a rhino make.	Wynn asks if it is the hippo and what sound does the hippo make. Tiana is exploring the rhinoceros and Chloe inquires about the elephant.
	Reading couch	They move to the reading corner, where they read the elephant book.	Mei and Karen talk about the	Chloe wants to know where the

			elephant tusks, and swimming in the water.	elephants are stampeding to. Chloe asks if elephants poo in a potty.
C1R2004	Drawing table	Karen recites phrases from the Follow that Tiger story as the children draw.	As the children draw, Karen points out the various characteristics of each animal. Mya looks at a non-fiction text about animals with Madison, Oliver and Mei.	Children visit the animal table to fetch more animals throughout the session. Mya and Peter make animal noises and play with the animals together at the animal table.
C1R2006	Pictures of animal parts activity sheet on the table.	Karen reads the story.	They used the animal toys and picture cards to identify the various animal characteristics.	Wynn approaches the table with the *Follow that Tiger* storybook.
C1R2007	Reading couch	Sully, Tiana and Karen are exploring books about snakes in the red sofa reading corner.	Karen asks if the snake says roar or hiss.	Tiana is looking at snake fangs. She shows Karen the mouth.
C1R2008	Table with books and cards of animals	Tiana, Alden, Mei, Peter and Oliver are reading the book "Follow that tiger" with Karen.	They are discussing features and sounds of animals, **such as the snake;** trying to match to the pictures on the table.	
	Transition into the CPW	After the book reading, they put on props.	Walk like zebras, lions and tigers; looking for the	Karen discusses Chloe's question – and asks,

			tiger and later snake.	"Was the snake in a tree or on the ground?".
C1R2009	Transition into main room (jungle)	The children and Karen are putting on animal ears. Mya talks about matching the figurine to the animal ears.	Karen asks the children to find the lion head from the animal figurines on the table.	The children imitate the roar.
C1R2010	Reading couch	Karen reads the book "Follow that tiger".	They talk about the animal's tail, paws, nose.	Peter and Sully imitate the actions.
	CPW transition – phone rings	Karen tells the children the telephone is ringing? The flamingo is missing.	Karen says, "Let's go and find the flamingo?".	Children follow Karen and imitate her gestures and actions.
C1R2011	Reading couch	Karen reads book and children do actions.	Karen helps the children put on their headbands and tails, asking which animal they would like to be.	Chloe closely imitates the gestures.
	Transition into CPW – phone rings	The telephone rings and it is tiger calling. Karen tells the children they have to go and find the Flamingo.	Karen becomes the bear, and says, "We have to walk through the long grass". .	Children make climbing actions for rocks, trees, and swimming actions when crossing the river.
C1R2012	Main room CPW jungle	Karen revisits the story in action in the jungle, and the children follow her lead, going over the rocks, climbing up a tree, and swimming across the river. They find flamingo feathers, and later when the phone rings they tell the tiger they have not yet found the flamingo.	In the cave Karen asks if it is dark, and if they need a light.	Chloe is gesturing and acting to hold on to branches with her hands as she climbs along with Karen up the big tree.

C1R2013	Main room CPW jungle	The animals are swimming across the river looking for the flamingo.	They find the flamingo feathers; they explore the feathers, and wonder where the flamingo could be.	Peter brings some more zebras, lions and a tiger to look for the flamingo.
C1R2014		Everybody is reading the book "Follow that tiger" The telephone rings. It's the tiger calling again, he needs their help to **find the missing snake.**	They discuss that they need to look underneath the rock to find the snakes. Karen says, "The snake says hiss… hello everybody".	Ming waves at the snake. "We found a snake up the tree".
C1R2015	Reading couch, transitioning into the main room jungle	Everybody is reading the book "Follow that tiger" The phone rings "It's the tiger calling, he tells the children: "Hello we need to **go find the snake and Flamingo**?" And there up in the tree they **find the snake**. "	Karen says, "I am paddling with my big paw".	Sully has already started crawling and swimming across the river looking to find the snake.

APPENDIX 2 A Conceptual PlayWorld planning proforma for Preschool Children (copyright PlayLab)

Planning a *Conceptual PlayWorld* in STEM

Five Characteristics of a Conceptual PlayWorld to support imaginary play and Science, Technology, Engineering and Mathematics (STEM) thinking and learning

Pedagogical characteristics	Pedagogical practices that are planned	Conceptual PlayWorld in action
Selecting a story for the *Conceptual PlayWorld*	■ Selecting a story that is enjoyable to children and	■

Pedagogical characteristics	Pedagogical practices that are planned	Conceptual PlayWorld in action
	adults. Summary of the story. ■ Building drama for the characters in the story. ■ Building empathy for the characters in the story. ■ A plot that lends itself to introducing a problem situation. Overview of the problem. ■ Being clear about the concept(s) and its relation to the story and play plot to be developed ■ Adventures or journeys that spring from the plot (e.g., chapters).	
Designing a *Conceptual PlayWorld* space	■ Finding a space in the classroom/centre/outdoor area suitable for an imaginary *Conceptual PlayWorld* of the story. ■ Designing opportunities for child-initiated play in ways that develop the play plot further or explore concepts and make them more personally meaningful.	■

Pedagogical characteristics	Pedagogical practices that are planned	Conceptual PlayWorld in action
	■ Planning different opportunities for children to represent their ideas and express their understandings.	
Entering and exiting the *Conceptual PlayWorld* space	■ Plan a routine for the whole group to enter and exit the *Conceptual PlayWorld* of the story where all the children are in the same imaginary situation. ■ Children choose characters as they enter into the imaginary situation. ■ Adult is always a character in the story.	■
Planning the play inquiry or problem scenario	■ Problem scenario is not scripted, but a general idea of the problem is planned. ■ The problem scenario is dramatic and engaging. ■ The problem invites children to investigate solutions to help the play in the *Conceptual PlayWorld.*	■

Pedagogical characteristics	Pedagogical practices that are planned	Conceptual PlayWorld in action
	■ Being clear about the concepts that will be learned from solving the problem situation. Concepts are in service of the children's play.	
Planning adult interactions to build conceptual learning in role	■ Adults are not always the same character. Roles are not scripted. ■ Planning of who will have more knowledge and who will be present with the children to model solving the problem. There are different roles adults can take: Adults plan their role for the *Conceptual PlayWorld* to be **equally present** with the children, or to **model practices** in role, or to be **needing help** from the children. Their role can also **be together with** the child leading (primordial we), where they literally cradle the child or hold their hand and together act out the role or solution.	■ There are different roles adults can take: Adults plan their role for the *Conceptual PlayWorld* to be equally present with the children **(e.g. "")**, or to model practices in role **(e.g. "")**, or to be needing help from the children **(e.g. "")**. Their role can also be together with the child leading (primordial we), where they literally cradle the child or hold their hand and together act out the role or solution **(e.g. "")**. ■ Conceptual intentions are planned: Planning of who will have more knowledge and who will be present with the children to model solving the problem.

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