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The hidden and invisible: supporting science learning in infants'-toddlers' group settings

Science concept formation has a long history in early childhood educational research. Most of the studies in the field focus on the way children form science concepts as preschoolers. However, less is known about the nature of science concept formation for children under three years of age. This study explores how early childhood teachers create the conditions for the formation of science concepts for infants. The research design drew on the *Conceptual PlayWorld* model, a collective form of practice for learning and development through imagination and play. Thirteen infants with a mean age of 1.2 years (1 year and 3 months) participated in the study. Visual methods were used for digital data collection and analysis. The analysis drew upon the cultural-historical concepts of the interrelation between everyday and scientific concepts and the concept of real and ideal forms. The analysis foregrounded four key elements for introducing science concepts in infants' everyday educational reality: a) making meaningful interrelations between the everyday concept and the scientific concept, b) consistently using scientific language, c) using appropriate analogies, and d) using early forms of a scientific method. The overall findings open new understandings about the nature of science concept formation of infants, informing pedagogical practice in this under-researched area.

Keywords: infants, toddlers, early childhood, science education, concept formation, play, pedagogical practice

Introduction

Limited policy attention and even recognition of the place of early childhood science in educational contexts for infants is not only evident in Government reports in Australia and many western countries (e.g., Australian Industry Group, 2017; Johnson, Mohr-Schroeder, Moore & English, 2020) but it can also be seen through a lack of research in this area (English, Adams & King, 2020; Fler, Fragkiadaki & Rai, 2020; Fragkiadaki, Fler, & Rai, 2022). Sikder & Fler, 2014, 2018). Reviewing the literature in the field, O'Connor, Fragkiadaki, Fler, and Rai (2021) have highlighted that empirical research on science concept formation in the early years has focused primarily on children aged

three to six years while a lack of empirical understanding of science concept formation in children from birth to three is evident. What is not known is how science and scientific thinking can and does begin from birth. Whilst some speculate about how to introduce science to infants and toddlers (Early Childhood STEM Working Group, 2017) and indeed recognize its place through national/local curricula (Campbell, Speldewinde, Howitt & MacDonald, 2018), there is a surprising lack of empirical evidence to give directions to teachers and systems who wish to turn around the current and predicted shortfalls that will emerge in the future (Johnson et al., 2020).

The purpose of this paper is to study how early childhood teachers introduce science concepts into everyday practices within childcare centres and how they support the formation of science concepts during infancy. The typical age range of infants discussed in the literature is from birth to approximately one year or one year and a couple of months. Science concepts are conceptualized here as basic and fundamental abstract formations that are compatible with the scientific knowledge used in education and allow children to systematically approach phenomena in order to interpret and understand the surrounding natural and technical world and their experiences in it. To form a science concept everyday practice and understandings need to be dialectically interrelated to science-related knowledge in a child's thinking. The paper focuses primarily on the early formation of the concept of sound. It is argued that the mediating role of the early childhood teacher is the key asset of a rich and quality learning environment for very young learners in science as well as that early learning in science is feasible and effective when it becomes meaningful for the young child.

The paper begins with an overview of what is known about infant concept formation in science. This is followed by a theoretical discussion of the central concepts driving the study. The findings unpack key elements in early childhood teachers' practice for introducing science concepts in infants' everyday educational reality and supporting their learning in science. The paper concludes by pointing to new directions in what until now, has been hidden and invisible in practice, and which we argue is foundational for understanding science thinking and concept formation of children entering school settings.

Infants' learning and development in science

When we look into the crib, we often “see a picture of innocence and helplessness, a clean slate” (Gopnik, Meltzoff & Kuhl 1999, p. 1). The capacity of children in the early years to investigate and make meaning of a very complex world is often underestimated (Baldwin, Adams & Kelly, 2009). Following the works of Piaget and other stage and age-based theories the teaching of science also suffers from an approach where it is often considered inappropriate for certain grades and especially in the early years (Roth, Goulart & Plakitsi, 2013). A common view is to consider children, especially in infancy as deficient in some manner (Gelman & Baillargeon, 1983). The comparison is largely with fully developed human cognition, resulting in a focus on what children cannot do rather than what they can do. In their book “*The scientist in the crib: Minds, brains and how children learn*”, Gopnik et al. (1999) highlight that we miss the brilliant capacities young children have and the special capacities children develop very early on in their lives. Keil (2011) makes a similar claim that science and causal inference starts as early as infancy in children. Evidence also suggests that infants do have the capacity to integrate information and draw causal inferences very similar to adults (Keil, 2011). This is linked to children’s sense of wonder and curiosity about their environment (Anderson, Martin & Faszewski, 2006; Fragkiadaki, Flee & Ravanis, 2019; Fragkiadaki & Ravanis, 2021; Peterson & French, 2008; Ravanis & Pantidos, 2008; Zales & Unger, 2008). Dueschl, Schweingraber & Shouse (2007) reported that even pre-verbal children have a great deal of science concept reasoning. Children develop quite a sophisticated sense of mechanic causality that is intrinsic to the motion of simple physical solids by the preschool years. In the case where two events precede another one, children usually determine which is more physically plausible and then prefer it as the cause (Bullock, Gelman & Baillargeon, 1982; Dueschl et al., 2007; Gelman & Lucariello, 2002).

Going even a step further Siry and Max (2013) showed that children do not just have initial wondering but from the very early years they have the capacity to “conduct investigations, explain their observations and plan new investigations” (p. 899). Gopnik (2012) has also highlighted that very young children have advanced learning mechanisms in science and are capable scientific learners from the very early beginning of their lives. That means they are able to develop early forms of abstract and causal structures (Gopnik et al., 2004; Gopnik & Wellman, 2012) early in life and make sense of the surrounding world.

Young children's sophisticated understandings of science do not develop autonomously but are dialectically interrelated to the child's everyday reality and real-life needs. Sikder (2015, 2018) has argued that small science concept formation draws on children's everyday experiences, and this means that scientific thinking is not an extra burden on an infant-toddler's life but a way of being in the world. According to Sikder, young children engage with science concepts as part of their play, and it is through play that they manage to form their first understandings in science, make sense of and master the surrounding world. Sikder and Fleer (2014, 2018) have also shown that a supportive learning environment in everyday family life is critical for young children's early learning and development in science. In their research, Sikder and Fleer followed a set of families with infants and toddlers over two years and used visual methodologies to capture science experiences in home settings. Their research has revealed a broad range and number of science concepts, such as force, light, sound, and insulation that infants explore and form as part of everyday practice in family contexts. Their overall research has confirmed the importance of quality child-parent interactions in infants' early engagement with science. It was shown that simple practices such as crafting a scientific narrative and actively engaging the child in that narrative can lead to a child's conscious realization of the concepts being deployed. In addition, the research has also pointed to the dialectic interrelation between the motive of play and the motive of learning in science highlighting the critical role of play in engaging infants with science.

The above shows that very young children not only can learn science concepts during infancy but also can learn ways of knowing in science impressively early in their lives. This is no longer a surprising finding or a rarity. The literature suggests that "science isn't just the specialized province of a chilly elite; instead, it's continuous with the kind of learning every one of us does when we're very small." (Gopnik et al. 1999, p. 3).

The above understanding suggests that teaching and learning of science should be systematically supported pedagogically within infants' group settings. Surprisingly, although empirical studies for teaching science later in the early years are mounting (Eshach & Fried, 2005; Ravanis, 2017) and the critical role of adult's engagement in science with young children in preschool settings is extensively highlighted (Andersson & Gullberg, 2012; Areljung, 2019; Garbett, 2003; Stephenson, Fleer, Fragkiadaki, & Rai, 2021), we still do not have enough empirical evidence about how to organize a pedagogic practice that can support the development of science conceptual knowledge from infancy.

The limited empirical evidence highlights the critical role of the early childhood teacher in unpacking the multiple capacities infants have in science. Byrne, Rietdijk, and Cheek (2016) argued that when the teacher provides infants the autonomy and the opportunities to explore the surrounding world, skills are promoted that come in line with inquiry-based learning requirements, such as wondering, experimenting, gathering evidence, and using evidence to draw conclusions. Within a flexible and rich environment like that, children can be actively engaged with science and start forming science concepts. Their study concludes by suggesting that infants' group settings pedagogies are flexible and dynamic science learning environments and can also be used as a model for promoting inquiry-based learning in primary school settings. Fler, Fragkiadaki, and Rai (2020) have also highlighted that guidance and support for early childhood teachers on how to engage very young children in science are much needed in the field. These authors examined some initial evidence and the practices for supporting science thinking, learning, and development for infants. The study suggests that promoting pedagogical practices that increase wonder and imagination as well as create a collective sense of being a science thinker through play-based settings can engage infants with science and lead to important learning outcomes. More research has to be done to make visible and more systematically study pedagogical practices that can construct a robust pedagogical framework for supporting science learning in early infancy. The study reported here seeks to address this gap by unpacking and defining a range of practices through which early childhood teachers create motivating conditions for introducing and incorporating science concepts in infants' everyday educational reality.

The real and ideal forms of development and the interrelation between everyday and scientific concepts

Vygotsky (1994) wrote about the importance of the presence in a child's environment of what someone would expect a child to be able to do at the end of the process of his/her development. Vygotsky introduced the concept of ideal form to describe what might be what one would want to develop, and he introduced the concept of the real form (also seen as 'primary or rudimentary' in Vygotsky's texts) of a child's development and understanding to describe what might be the current form of development one is experiencing. These concepts capture both the environment and the child and are in

constant relation with each other (Vygotsky, 1994). Thus, it is this relation that must be studied if we are to understand a child's development. To understand this dialectical relationship Vygotsky used an example of learning to speak, and this is particularly relevant for the focus of this paper where infants are learning not only to speak the language of their community but as will be shown later in this paper, the language of science. He argued that an infant will only learn to speak if he/she is in environments where language is spoken. Even though infants may not say the words or even understand them at the beginning, they still need to be in language-rich contexts if they are to communicate with the people around them. He theorized this as the ideal form of language that had to be made available to the child in their environment. Accordingly, even though infants may not understand science explanations at the beginning of their engagement with science, they still need to be in contexts rich in scientific narratives if they are to start forming science concepts in their early years.

Vygotsky also recognized that the real form of a child's development is always interacting and changing as a result of how the child interacts with this ideal form of development. For example, in the context of childcare centers where teachers are talking to infants, they narrate the world around them, as they undertake routines such as washing hands or heating bottles and discussing microbes or temperature. This means that the ideal form of scientific language is made available to the child and the child interacts with this ideal form of language development as part of his/her everyday educational reality. From this standpoint, we get a better insight into the findings of the present study by using these concepts to better understand and theorize the way early childhood teachers introduce science concepts into everyday practices in infants' group settings.

Vygotsky (1987) also introduced the interrelation between everyday and scientific concepts to explain how concept formation takes place. Conceptualizing this dialectic interrelation helps us to better understand the findings of the present study by providing a deeper interpretation of the processes teachers used to support the formation of science concepts by infants. Everyday concepts are those children embody or use spontaneously when engaging in the world, such as putting on a jumper when they are cold. Scientific concepts are abstract concepts, such as the concept of insulation for explaining the reason for putting on a jumper. These two lines of conceptual development lay the foundations for each other, because experiencing the scientific concepts as a narration gives a story to what children are noticing, and this means that the practices being introduced in everyday

life, become understood in scientific ways. Only discussing scientific concepts in an abstract way devoid of everyday practice makes it difficult for a child to understand how the scientific concept can help them with thinking about their world and their everyday experiences. Similarly, only ever engaging in everyday practices without a scientific explanation, that is the use of a scientific concept, means that a child is locked into practice context only. It is when both happen together and over time, that the practice and the concept enrich each other. To fully form a science concept the child's thinking needs to repeatedly move back and forth between the everyday and scientific aspects of the concept and understand the way these two aspects are related.

Methodological framework

In line with the above, this paper seeks to explore how early childhood teachers who work with infants introduce science concepts into everyday practices within childcare centers and how they support the formation of science concepts during infancy.

Study Design

As an *educational experiment* (Hedegaard, 2008), the study followed a group of early childhood teachers over 10 weeks. An *educational experiment* is a planned intervention based on the collaboration between researchers and teachers where “The educational experiment can be said to represent a form of action or intervention research, where everyday situations are systematically intervened and an educational perspective is combined with a research perspective” (p. 67). As Hedegaard (2008) argues, an educational experiment has significant methodological differences from a traditional experiment or action research. It takes place in everyday normal conditions rather than in controlled conditions and it is a theoretically informed endeavor within a context of practice rather than an intervention informed only by practice. What is significant about an *educational experiment* is that not only does this process bring forward the idea of a core concept being something to be discussed with teachers, but the study design becomes cooperation between teachers and researchers in creating conditions for orienting infants to conceptual development. Teachers discussed the science concepts and the conditions they wished to introduce to the infants to support a science orientation in a way personally meaningful for infants. The researchers supported this process through professional

development (5.3 hours of recordings) and ongoing support of the teachers in situ about both the concepts and the inquiries (3.9 hours of recordings).

During their participation in professional development, the teachers learned about implementing a *Conceptual PlayWorld* (Fleer, 2017, 2018, 2019) and used this as the framework for science learning of infants. A *Conceptual PlayWorld* is a collective model of practice created to support the teaching of concepts through play-based settings in early childhood. There are five key characteristics of a *Conceptual PlayWorld*. The first characteristic is selecting a story for the imaginary play. The second characteristic is designing indoor or/and outdoor imaginary spaces inspired by the chosen story to enhance children's imaginary play and explorations. The third characteristic is entering and exiting the imaginary situation getting into a role and pretending to be the characters of the imaginary situation. The fourth characteristic is planning a problem to be solved based on a problematic situation introduced by the story. At this phase, concepts are needed for solving the problem. The fifth characteristic is planning the role of the adults to be within children's play as play partners, taking the position of investigating along with the children, leading an inquiry, or asking children for help.

In this study, the teachers designed a *Conceptual PlayWorld* using the children's book "*Possum in the House*" written by Kiersten Jensen and illustrated by Tony Oliver. This narrative was used to create an imaginary situation where problems arise that need science solutions. The story plot is based on a possum, an Indigenous Australian mammal, who enters a child's house and creates a mess across all the rooms of the house. In the *Conceptual PlayWorld*, the problem to be solved was how to remove the possum kindly and relocate it where it would normally live in the outdoor area of the center, which meant learning about possums, tracking possums, knowing what sounds they make so they can be identified, etc.

A wide range of science concepts related to the story was introduced. The concepts were related to the biological nature of the possum such as a) *external biological characteristics* (i.e., fur, tail, nose, feet, marsupial), b) *heredity* (i.e., a family of possums with the same external characteristics), c) *basic biological needs* (i.e., sleep, nutrition, self-protection), and d) *conditions of living* (i.e., habitat, nocturnal living). Additional science concepts such as the concept of sound (i.e., diverse materials produce different types of sound) and the concept of force (i.e., the force can make things move) were also explored.

The case example of the implementation of the *Conceptual PlayWorld* in one infants' room led by one teacher from the early childhood teachers' group is presented in detail in the findings section. The empirical data generated in the room was the first complete data set collected and thus, analysed in this preliminary study. In this paper, we focus primarily on the results relating to the concept of sound and additionally, to the concept of force.

Participants and Data Generation

Data sets were taken from one childcare centre located in Victoria, Australia. Thirteen infants (8 girls and 5 boys) and 1 early childhood teacher participated in the study. Infants were aged between 6 months and 2 years with a mean age of 1.2 (1 year and 3 months). The teacher, named Mei, is Diploma qualified and has 10 years of teaching experience in early childhood settings. No previous training on teaching science concepts in infants' rooms was reported. Mei is of Chinese heritage background and an Australian citizen. Ethics approval and permission were granted by Monash University Human Ethics Committee and the Victorian Department of Education and Training. Parents' informed consent was given to document children's participation within the CPWs for scholarly purposes. Teachers' voluntary and informed consent was also given. All participants were named with pseudonyms. A total of 17.8 hours of digital video observations were collected over 10 weeks. The visual data arose from the video recordings during the implementation of the *Conceptual PlayWorld* in the infants' group setting. The data collection process was held by the research team and research assistants. The qualitative data captured infants' and teacher's engagement with the concept of sound within the *Conceptual PlayWorld*. Field notes, detailed logs, and research protocols were prepared after each data collection visit.

The analysis

Three different levels of data analysis, as formulated by the *dialectical-interactive method* (Hedegaard, 2012) were followed. The first level of analysis was *common sense interpretation* based on the researchers' comments on infants' and early childhood teachers' experiences. This meant viewing all the raw data and extracting the moments where science concepts were evident in the everyday practices in the centre as part of the *Conceptual PlayWorld*. All these moments were noted and logged. For example,

moments when infants were exploring the concept of sound by using a saucepan and a small hummer one day or by squeezing and shaking a packet of cornflakes as being possums another day, were foregrounded. The research team reflected and commented on our understanding of infants' engagement with the science concepts during each of these moments (e.g., "Olin is tapping on the saucepan. He pays attention to the different sounds the metal and wooden parts of the hummer are making. The teacher expands the infant's activity by placing the saucepan differently (upside down)". Or, "Anna shakes the cornflakes packet quickly and hard and then, slowly and smoothly. She is noticing the different sound the packet makes in each case and tries this again and again for some time. The teacher suggests she do the same with other objects too, such as a piece of fabric to listen to the different types of sound.'). The second level of analysis involved *situated practice interpretation* based on the emergence of conceptual links and correlations between the results obtained from the analysis at the first level. This meant clustering all those moments of science in everyday practices to determine a density of data in relation to practices and science concept formation. For example, the main themes that unfolded in relation to the aim of the present study were: a) the number, the range, and the aspects of science concepts that were introduced by the early childhood teacher, b) the early childhood teacher's practices within the Conceptual PlayWorld and c) the interaction patterns between the infants and the early childhood teacher. Data sets that emerged and which were deemed to link with the overarching question of this study were then analysed about the theoretical concepts discussed previously (everyday and scientific concept formation; the ideal and real form of development). This constituted the third level of analysis. At this level, a theoretical analysis was carried out to find *a conceptual pattern* that explains how science concepts are introduced to infants and how infants' scientific thinking is supported through everyday practices. For example, it was shown that by making meaningful interrelations between the everyday concept and the scientific concept the early childhood teacher supported infants to reflect on their everyday experiences and think differently about their surrounding world. Along with the other interpretations made at this level of analysis, this realization allowed the formulation of new insights into the role of the early childhood teacher in supporting science learning in infants' group settings. In the "Findings" section that follows three indicative vignettes are presented. The specific vignettes were chosen because they are representative of the range and the depth of infants' engagement with the science concepts within a Conceptual

PlayWorld as well as illustrate how the choices made by the early childhood teacher (e.g., Mei chooses to introduce the ideal form through her narrative and consistently uses scientific language within the Conceptual PlayWorld) shaped the infants' experience in science.

Findings

The analysis focused on and unpacked the processes through which the early childhood teacher created the conditions for infants' motive orientation towards science. Findings from three indicative vignettes are presented below.

The everyday concept: different animals are making different sounds

Vignette 1: Different animals are making different sounds



Figure 1. Using digital means to explore the possums' sounds

In vignette 1, Mei is reading the “*Possum in the house story*” story with three infants, Anna, Megan, and Olin. The infants are familiarized with the story as Mei has read the story a couple of times ago as part of introducing the *Conceptual PlayWorld*. As reading the story, Mei is emphasising the sounds made by the possum mentioned in the story (e.g., “Screech-screech!”, “Squick-squick!”). Mei suggests using an iPad to have a look at

possum images (Figure 1). She mentions that they can listen to recorded sounds of possums, too. Together they listen to the sounds of possums using the iPad. Mei is commenting on the sounds making connections to the story (e.g., “Someone is making really really anxious noises. I think a possum mother is worrying about where her baby went! Who is hiding in a tree?”). The infants focus their attention on the iPad and listen carefully to the sounds of possums. Mei poses questions to the infants (e.g., “What’s that?”). Anna responds with some bubbling. Mei brings a possum puppet close to the infants. Infants are already familiarized with the puppet during previous imaginary play situations within the *Conceptual PlayWorld*. Mei puts her hand into the puppet and pretends to be in the role of the possum mummy (e.g., “That’s me! I am looking for my baby...”). Mei makes connections with the imaginary situations of the *Conceptual PlayWorld* explaining that the possum is making grumpy noises because she cannot find her baby (e.g., “Mummy sounds really nervous!”). Mei is introducing a set of possum puppets. When Megan sees the possums, she makes an expressive and extensive sound similar to the sound possums make. Mei moves the mummy possum puppet saying that this is the one who is making the odd sounds because she cannot find her baby. The infants begin handling the set of possum puppets. Mei suggests the infants help the mummy find her baby. Being in the imaginary situation, together they begin searching for the possum baby.

Vignette 1 showcases how the teacher supports the infants to approach the concept of sound as an everyday concept. Infants are already familiarized with sound as an everyday phenomenon in naturalistic settings as part of their daily reality and their everyday experience at home and in the wider community. According to Vygotsky (1987), the realization and engagement with the everyday concept are critical as they lay the foundations for the development of the scientific concept. In this example, it is shown how the teacher builds on infants' early spontaneous understandings and knowledge about sound to introduce possums as a sound source and underscore the distinct and unique qualities of a possum's sound that differentiate it from other animals' sounds. For example, Mei emphasizes the possum is making grumpy noises. What is important here is that within the imaginary situation, the everyday concept of sound is developed through the social exchanges between the infants and the teacher. This could be seen for example when Mei imitates the possums' sound or when Megan is trying to do the same. What is also critical is the cultural exchanges between the infants and the teacher. A cultural

medium, such as an iPad, appears to be motivating for the infants and its mediating role allows infants to advance their understandings of the concept. The whole experience focuses on the specific situation of a possum making sounds (common sense interpretation). The overall experience is indicative of the real form of the infants' learning and understanding of the concept of sound within the Conceptual PlayWorld (situated practice interpretation). The way the teacher brought together the real and the ideal forms to support the formation of science concepts by infants is theorized in the discussion session (interpretation on a thematic level).

The scientific concept: sound as vibration and acoustic wave

Vignette 2. Vibration and acoustic waves can make the chalk dust dance



Figure 2. Using vibration and acoustic waves to make chalk dust move

After five weeks Mei is reading again the story with the infants. Mei suggested that since they are talking a lot about sounds, they might try something new. She gets some chalk dust and puts it on a drum (Figure 2). She proposes to make the dust 'dance' using an analogy from infants' everyday life. Mei mentions that this is going to happen because of the sound wave. Three infants watch Mei closely. Mei talks about sound waves and how they transmit through the air (e.g., "Different sounds coming from (the characters) in the book, from different objects. How can we hear those sounds?"). Gilly, another infant that is sitting on the floor a couple of meters away from Mei and the three infants, makes some

loud sounds. Mei responds by commenting: “How can we hear Gilly talking? Because of them (the sound waves) transmit through the air!”. Mei develops a narrative about what the children are watching, in much the same way as adults do when they introduce infants to many things in their everyday life, such as talking about the temperature of the food or turning on and off lights (Sikder & Fler, 2014, 2018). All infants watch Mei putting the different chalk dust colours on the drum. Mei mentions that she would like to have a second drum to make loud sounds so the infants can see the results of the sound waves more clearly, but this is not possible because some of the infants are sleeping in the next room. Thus, Mei claps her hands to create sounds and make the dust move on the surface of the drum (vibration and acoustic waves created by the sound). The dust on the surface of the drum begins to move. Then, expanding the infants’ science experience, she taps underneath the drum making the dust on the surface of the drum move again (vibration created by force). The different colours of the chalk start merging because of the vibration caused by the acoustic wave and the force. Anna moves closer to the drum. The infants focus their attention on the drum. Mei consistently explains what is happening (e.g., “Look, it is dancing!”). She talks about how when she knocks the drum harder the chalk jumps higher. Mei suggests infants hit the drum by themselves. Anna has a turn holding the drum. Gilly is making some sounds of excitement herself. Mei takes the drum with Anna to show Gilly the ‘dancing colour’. Mei continues the activity with the infants focusing both on the concept of sound and force (Figure 3).



Figure 3. Motivating collective participation in the science experience

Mei asks: “How did it dance without being touched?”. Mei mentions: “That’s because of the sound wave”. Anna has another turn. Mei continues talking to the infants about movement through vibration. Anna watches Mei tapping the drum while she holds it. Mei encourages Anna to pat underneath and helps her to do it by holding Ann’s hand. Mei comments “Can you feel it? Can you feel the vibration?”, “Give it a little shake. See? It still moves. But it is not because of the sound now. It is because of the vibration. The move of your hand.”, “But, if you tap the drum it goes (the chalk dust) upside down. A different movement”, “The louder you tap and pat, the higher they jump!”. Anna and the other infants are watching closely. Mei encourages infants to try it themselves.

Vignette 2 is illustrating how the teacher supports infants to approach the scientific concept of sound as vibration and acoustic wave also combining the concept of force. What is important here is the way the teacher introduces the ideal form of the concept within the infants' environment. This is realized in two ways. Firstly, the teacher introduces the ideal form through her practice. She shares with the infants this joint science-oriented experience and she handles the material in an efficient way that allows the observation of the phenomenon. Mei facilitates infants’ exploration in several ways. She positions herself and the material in proximity to the infants, initiates interactions between the infants and the material, she motivates infants to actively engage in the

experience. Secondly, the teacher introduces the ideal form through her narrative. Mei uses scientific language. This could be seen for example when she explains that they can hear each other's voice because of a transmission medium such as the air (e.g., How can we hear Gilly talking? Because of them (the sound waves) transmit through the air!). The way Mei consistently crafts the narrative through informative sentences orients infants' focus on the critical aspect of the science experience and motivates them to wonder about these aspects (e.g., "How did it dance without being touched?"). Through her practice and narrative, Mei steps the infants towards a more mature understanding of the concept of sound. In line with Vygotsky's conceptualization (1994), even though infants may not fully understand science explanations yet, it is still critical to be in contexts rich in scientific narratives to start forming science concepts. As part of the everyday educational reality, Mei is creating the conditions for the infants to start thinking about the concept in a more abstract way that goes beyond what is directly observable in the first level toward what can be inferred in the second level of engagement with the concept. This could be seen for example when infants begin to make cause-and-effect connections between sound, vibration, and force as they try to pat the drum to make the dust move. This new way of thinking is critical and suggestive of scientific concept formation. In this vignette, the engagement of the infants with new aspects of the focus concepts is illustrated (common sense interpretation). The very early emergence of the dynamics that can set the scene and lead to a scientific way of thinking about the concepts is shown through the analysis of the vignette and also comes in line with evidence found in the overall data of the study (see for example Vignette 3) (situated practice interpretation). That overall experience is indicative of the importance of the ideal form of development in science in infants' environment that is further unpacked in the discussion session (interpretation on a thematic level).

Vignette 3. Vibration and acoustic waves can make several objects dance



Figure 4. Testing if vibration and acoustic waves can make several objects move

Vignette 3 is the sequel of vignette 2 presented above. In this vignette, Mei and the infants, continue exploring the concepts of sound, force, and vibration by using the drum (Figure 4). Amy crawls near the drum and puts on it a plastic toy duck. Mei suggests checking if the duck can jump too because of vibration and the acoustic waves. Mei pats the drum. The duck moves (e.g., “Ducky jumps too!”). Mei suggests checking other objects too (e.g., “What about the ball?”) (see Figure 5).



Figure 5. Testing diverse objects

Mei and the infants put a ball on the drum, pat the drum, and watch the ball jump. Mei mentions “You have to pat harder because the ball is heavy”. Mei drops the ball from above to make the chalk dust move too. She suggests infants try this way to make the dust dance. Anna tries this approach and continues to drop the ball on the drum while the other infants watch carefully. Together Mei and the infants try a range of objects such as different colour balls, harder balls, and bigger balls to see what happens. Mei encourages Anna to drop the ball from a standing position to see what happens in this case. All together continue testing objects for a while. Anna goes away to get the possum puppet to put on the drum too. Mei says that it won’t fit. Anna then goes away again to get the possum book. The team continues with everyday routines in the room.

Vignette 3 illustrates how the infants and the teacher are engaged with testing if vibration generated by acoustic waves and force can make several objects move. What is important here is the way the teacher creates the conditions for the infants to start thinking about the concepts independently from specific objects and situations. The teacher is introducing to the infants the practice of trial and error and supports them to build early trial and error skills to test how diverse objects interact with vibration and sound waves. This practice motivates infants to try each one of the available objects to observe how the object will react in the same conditions; that is vibration generated by acoustic waves and force created by clapping hands and tapping the drum. Through her narrative, Mei points

out the interrelations between the objects and the phenomenon and makes these interrelations noticeable and more visible to infants. For example, she underlines that the effort to move an object is related to the weight of the object. This could be seen when she comments that “You have to pat harder because the ball is heavy”. At the same time, Mei supports the infants to follow regularities related to the concepts. For example, she underscores that the objects have a similar reaction to the vibration. This could be seen when she mentions “Ducky jumps too!”. Through her overall practice the teacher is introducing infants to an early form of a systematic way to explore the surrounding world. In line with Byrne’s, Rietdijk’s, and Cheek’s (2016) argument, the autonomy and the opportunities to explore the surrounding world, seemed to promote infants’ wondering, experimenting, gathering evidence, and using evidence to draw conclusions. This early form is a precursor and a prerequisite for using a scientific method in exploration and experimentation in science. The vignette provides evidence of infants’ systematic exploration with the focus concepts (common sense interpretation). Moments of infants’ intentional and systematic explorations of science concepts were also noticed beyond this single activity setting within the “Possum in the house” Conceptual PlayWorld (situated practice interpretation). The overall experience is also indicative of the presence of an ideal form of the development of the scientific concept in the infants’ environment with is theorized and discussed in the following section (interpretation on a thematic level).

Discussion

The study sought to capture and explore the processes through which the early childhood teacher introduced to the infants’ environment the scientific concept of sound and supported the early formation of the concept. The engagement with the concept of force as part of infants’ explorations within the Conceptual PlayWorld was also explored and discussed. The study did not aim to test the efficacy of a particular teaching intervention or measure the learning outcomes for the infants as this goes beyond the scope of the study design. The overall findings foreground four key elements for introducing science concepts in infants’ everyday educational reality. These are discussed in turn.

First, the teacher appeared to create the conditions for the dialectic interrelation between the everyday concept and the scientific concept. The concept of sound was initially approached as an everyday concept (Vignette 1). In this phase, the focus was on the knowledge that infants experience as an everyday phenomenon, that is, the diverse

sounds animals make. Emphasis was given to what was directly observable by the infants through the sense of hearing. Then, the teacher built on the everyday concept to introduce the scientific concept (Vignettes 2 and 3). In this phase, the focus was on the understanding of the interrelation between sound and movement. Emphasis was given to the non-directly observable aspects of the phenomenon. The analysis made visible how these two lines of conceptual development, everyday concept and scientific concept, lay the foundations for each other. It was because the scientific concepts were related to everyday concepts, that allowed the teacher to incorporate this science-oriented experience within the educational routine and created the conditions for the infants to form early understandings of how the concept of sound as well as the concept of force can help them with realizing aspects of their surrounding world. This comes in line with Vygotsky's theorization (1987) of the development of the two forms of concepts as a unit.

Second, the teacher consistently introduced and used scientific language. The scientific language Mei used included specific terminology (e.g., sound waves), wondering and questioning (e.g., "How did it dance without being touched?"), descriptions (e.g., "The louder you tap and putt, the higher they jump!"), and explanations (e.g., "Because of them (the sound waves) transmit through the air!"). The teacher verbally acknowledged and highlighted what was happening during the science-oriented experience. Scientific language was used to describe the processes (e.g., "Give it a little shake. See? It still moves."), the variables (e.g., "You have to putt harder because the ball is heavy" and the outcomes of the explorations (e.g., "Ducky jumps too.") during the experience. The role of the accompanying narrative appeared to be critical to the infants' engagement with the science experience. It was shown that by listening to the teacher's narrative infants remained motivated and engaged in the experience and managed to focus and actively participated in this as a team over time. The above findings seem to coincide with the fundamental work of Nelson (1974, 1998) on the critical role of language in the concept formation process by the pre-verbal/language-learning child. According to Nelson (1974), to form a concept the child needs first to understand the relations of objects and to extract meaning from these relations. What was shown here is that the teacher supported infants to pay attention to the relations between the objects and the elements (e.g., "How did it dance without being touched?", "That's because of the sound wave".) and shape their meanings about the phenomenon. What was critical is that the teacher consistently translated infants' observations and understandings into words using

scientific language. The language representation of the phenomenon along with the scientific language used stepped the infants through the experience and became the vehicle for their thinking and understanding of the phenomenon (Vygotsky, 1987). This underlines the importance of the mediating role of semiotic systems such as language and speech in learning and development in science during the early years.

Third, the teacher used an analogy from infants' everyday life as part of her narrative. She used the analogy of dancing to explain how the sound waves and the vibration make the chalk move. Although simple, the analogy appeared to draw infants' attention and oriented them toward the joint science experience. The use of analogies and analogic models is a complex element in science education. What is known is that the systematic use of analogic models can transform children's thinking in science (Ravanis, 1999). What is shown here is how basic analogies can be used during infancy to interrelate everyday and scientific concepts.

Fourth, the teacher suggested a basic scientific method to explore how different objects react to sound waves and vibrations. Responding to the stimulus coming from Amy, when she put on the drum a plastic duck, she suggested that they can try and see how several objects will react to the sound waves and the vibration (e.g., "Ducky jumps too!"). This is how the method of the trial was introduced in the infants' environment. The way infants responded to the teacher's suggestion by putting different objects on the drum is indicative of the way infants began to use an early form of the trial skill to test how objects would react to sound waves. The teacher facilitated and expanded children's explorations with diverse objects and she crafted a narrative around each try. This could be shown for example when Mei suggests Anna test the reaction of the object from a standing point to see what is going to happen in this case. Trial skill is realized as a key element in the development of a scientific method to explore, realize, and make sense of the surrounding world. What is shown here is how the teacher creates the conditions for the early development of the trial skill during infancy. We think this is more than small science concepts as suggested by Sikder (2015, 2018) as what happens in everyday life at home between infants and their parents. We believe the difference emerges because the teacher is charged through her professional role to intentionally teach infants.

In keeping with what is known about early learning in science (Bullock, Gelman & Baillargeon, 1982; Dueschl et al., 2007; Gelman & Lucariello, 2002; Keil, 2011; Siry & Max, 2013), the infants in this study appeared to actively explore the concept of sound,

integrate information about diverse qualities and attributes of sound, make cause and effect interrelations between sound and vibration, expanded their explorations and learning on the concept of force, and initiate new investigations using different types of objects. Adding to the limited work in the field (Byrne, Rietdijk, & Cheek, 2016; Fler, Fragkiadaki & Rai, 2020) about the pedagogical role of the teacher in creating science learning experiences for infants, the study suggested four key elements for introducing the science concept of sound into everyday practice within an infants' group setting and supporting the formation of the concept. Although this study focused on analysing how the concept of sounds could be introduced in infants'-toddlers' group settings, there is a variety of scientific concepts that could be introduced and supported during infancy and toddlerhood based on the above four elements. Apart from the concept of force that was also discussed here, indicative scientific concepts could be the concepts of floating and sinking, the kinetic energy of water, magnetism and repulsion, the concept of light and shadow formation or the concept of the biological external characteristic of plants and their circle of life, the concept of animals' habits and habitats, and the concept of the ecosystem.

Conclusions

This study sought to explore how early childhood teachers create conditions for the formation of science concepts during infancy. The study focused on the concept of sound as an everyday concept and as a scientific concept associated with different animals producing diverse sounds where sound as vibration and acoustic waves was featured. The analysis foregrounded four key elements for introducing science concepts in infants' everyday educational reality: a) making meaningful interrelations between the everyday concept and the scientific concept, b) consistently using scientific language, c) using appropriate analogies, and d) using early forms of a scientific method.

The critical role of the presence of the ideal form of development in the infant learning environment in science was illustrated through the overall findings. This comes in line with Vygotsky's (1994) theorization that emphasizes that the scientific concept cannot be developed unless it is present in a child's environment. The present study illustrated how the ideal form of development in science can look like for infants. What was also shown is that although the presence of the ideal form is an essential and a precondition for a child's development, it should not consider that assures development as a matter of

course. Early childhood teachers have a critical role in dialectically interrelating these two forms to create the conditions for the child's development. They are the medium between the real and ideal form in infants' environment. The mediating role of the teacher is the key asset of a rich and quality learning environment for very young learners in science. This realization is also based on previous research in the field of infant-toddlers learning in play-based settings (Degotardi, 2010, 2017). According to Degotardi (2010), quality adult-infant interactions in play contexts inform teachers' understanding of infants allowing them to adjust and advance their teaching practices. Similarly, collaborative learning between infants and teachers, as presented and analyzed in the data set presented here, appears to promote infants' and toddlers' conceptual development (Degotardi, 2017). Therefore, the significance of teachers' role in infants' experiences in science should be highlighted when discussing the advancement of science learning in infancy and toddlerhood.

What is important to note here is that the early introduction of scientific concepts in the infant environment differs from a quick introduction or as something to be discovered without an adult guide. The emphasis is on the improvement of the quality of learning in science and this is different from the acceleration of learning in science. Early learning in science is feasible and effective when it becomes meaningful for the young child.

The overall findings unpack what till now has been hidden in the everyday practice of early childhood teachers and made visible the possibilities and the opportunities of quality learning experiences in science during infancy. This realization adds to the conversation against conceptualizing science learning and development for under-three-year-old learners as a less demanding or inaccessible area (Roth et al., 2013; Gelman & Baillargeon, 1983). The findings of the study add to the current limited and almost non-existing literature in the field of infants' science concept formation in educational settings (Byrne, Rietdijk & Cheek, 2016; Fler, Fragkiadaki & Rai, 2020, Fragkiadaki, Fler, & Rai, 2022) by highlighting practices toward a systematic pedagogical framework for supporting science concept formation in infancy. Further, it is during the first three years, that children are extremely curious and interested in the natural and the technical world that surrounds them. It is therefore important to provide young learners with a learning environment that inspires and supports them to deepen and expand their explorations and understandings, fulfills their wondering, and allows them to make interrelations between what they already know and learn from everyday life, as these understandings lay the

foundations for scientific thinking in science. The findings inform practice further by showcasing the impact of supporting early childhood teachers in situ and the need of organizing professional development programs tailored to the needs of infants' group setting teachers. Understanding and supporting infants' and toddlers' learning and development in science underpin the science thinking and concept formation of preschoolers and children entering school. The above remarks inform policy by suggesting an extended framework and a continuum in promoting the emergence of creative and critical citizens of science beginning from infancy. Future empirical research across a larger sample of children and early childhood teachers may add to what was learned in this study about supporting science learning in infants' group settings through imaginary play.

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