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Science concept formation during infancy, toddlerhood, and early childhood: Developing a scientific motive over time

Abstract

A substantial number of empirical studies in the field of Early Childhood Science Education have explored science concept formation in early childhood educational settings. Most of these studies focus on the process of science concept formation during a teaching intervention or a school year period. However, less is known about how children form science concepts over the first years of their lives. This longitudinal study aims at studying the process of science concept formation during the first five years of children's life within educational settings. Following a cultural-historical approach, the study explored how children develop a science motive from infancy, toddlerhood, and into early childhood and how teachers create the conditions for the development of a motive orientation towards science over time. A cohort of 130 children in Australia participated in the study. Indicative case examples are presented. The research design drew on the Conceptual PlayWorld model, a collective form of practice for learning and development through imagination and play. Digital visual methods were used for data collection and analysis. The findings illustrated that a science motive is developed when the motive of play and the motive of learning in science are dialectically interrelated over time. It was also shown that teachers create a motive orientation towards science by introducing, maintaining, and transforming an ideal form of science in children's environment and by stimulating children to interact with mature forms of science. The study concludes with insights into early childhood science education research methodology. Implications that inform practice are discussed.

Keywords: science· concept formation· motives· infants· toddlers· preschoolers· early childhood

1. Science concept formation in early childhood

Empirical research in young children's engagement, learning, and development about the natural and technical world has a long history. The vast literature in the field covers a wide range of points of interest. Firstly, there has been a focus on exploring children's ideas, representations, (pre-)conceptions about natural phenomena such as thermal phenomena, optical phenomena, properties of the matter, phenomena associated with electricity and solar

energy, meteorological phenomena (e.g., Christidou, Kazela, Kakana, & Valakosta, 2009; Fragkiadaki, Fler and Ravanis 2019, 2021; Saçkes, Flevares and Trundle 2010). Several studies have also suggested teaching interventions and pedagogical frameworks that advance science learning and promote conceptual change during the early years (e.g., Solomon and Johnson, 2000; Vartiainen and Kumpulainen 2020; Vosniadou, Ioannides, Dimitrakopoulou and Papademetriou 2001). The context and factors that affect young children's scientific thinking such as child's and adult's interactions, discursive practices, multimodality, the affective and enactive aspects of science learning have also extensively been explored (e.g., Fragkiadaki and Ravanis, 2021; Hadzigeorgiou, 2001; Siry, Ziegler and Max 2012).

By reviewing the relevant literature, two main points reveal. First, despite the extensive corpus of literature about how preschoolers engage, learn, and develop in science, limited knowledge is gained for under the age of three. This is surprising given that recent ground-breaking research shows that science begins in infancy and infants and toddlers are capable and active learners in science (Byrne, Rietdijk and Cheek 2016; Gopnik, Meltzoff and Kuhl 1999; Gopnik 2012; Fler, Fragkiadaki and Rai, 2020; Keil 2011; Sikder and Fler 2014, 2018; Siry and Max 2013). Second, most of the studies unpack science concept formation in different cultural age periods but do not explore the process of science concept formation over time as the child makes transitions from infancy to toddlerhood, and then into the early childhood period. What is absent in the broader literature is how science concepts are formed and supported across different cultural age periods within early childhood educational settings.

Given the dearth of research, this paper seeks to explore how children develop a science motive across infancy, toddlerhood, and early childhood and how teachers create the conditions for the development of a motive orientation towards science over time. The paper begins by introducing the cultural-historical concept of motive and motive orientation and the interrelated concepts of real and ideal forms of scientific development. These concepts are also discussed in the context of how they are used in the present study. This is followed by an illustration of the methodological choices that determined the study. Qualitative empirical data are then presented and discussed in relation to the above concepts. It is argued that mapping children's pathways in science over time along with capturing the changes in teachers' pedagogical practises allows a better understanding of what matters to children of different cultural age periods when exploring the natural and technical world, the changes in the forms of science experiences and the critical role of teachers in supporting children's engagement with the highly culturally valued science learning in early childhood settings. A

discussion of how institutional practices, children's learning pathways in science, and the collective character of the science experiences orient children towards science is presented. It is shown that a science motive is developed when the motive of play and the motive of learning in science are dialectically interrelated over time. The findings also reveal that teachers create a motive orientation towards science by early introductions, actively sustaining, and gradually transforming an ideal form of science in children's environment and by consistently stimulating children to interact with mature forms of science concepts. The paper concludes with insights into how the findings can advance a research methodology for studying conceptual development in science over time and with a discussion of how the findings can be translated into educational praxis.

2. The development of a science motive and science orientation

Following a holistic perspective on researching children's development Hedegaard (2008, 2014) offers an analytic heuristic that shows "action in activities are nested within institutional practices which are influenced by broader cultural expectations and traditions" (p.188). Central to this framework is the concept of motives and demands. Motives here are not seen as located in the person or social situation, they are culturally and socially determined (Hedegaard, 2002). It can be analytically discerned "in particular substantive relations in which persons are engaged" (Chaiklin, 2012, p.209). From a cultural-historical perspective, motives develop through participation in institutional practices. Hedegaard highlights the dialectical relation between the person and her/his environment. Institutional practices with their objectives create demands on children and thus, shape/influence children's actions. These negotiations lead to motive orientation or ground for the development/expression of new motives. Hedegaard's dialectical interactive approach offers analytical tools, especially the concept of activity setting that helps to unpack dynamic negotiations that happen as children develop new motives/motive orientations. To make the dynamic process of children's learning and development visible it is necessary to analyse "person's (child's) motive orientation and her demands on others when participating in activities in actual settings that may be analysed in relation to the demands directed at them" (Hedegaard, 2014, p.194).

Vygotsky (1994) theorised the role of environment in children's development not in an objective fashion but in a relative yardstick based on the given stage of child's

development. This theorisation is further developed by highlighting the dialectical interrelation between the real and the ideal forms of development. The end result of the developmental process i.e. ideal form or mature/developed form of the practice, exists in the child's environment and creates demands on the child's motives of engagement from the very beginning. The ideal form thus offers a model that can be achieved at the end of the developmental process. To offer a singular trajectory of development where this ideal form which is available from the very first step of development and is in 'direct reciprocal action with the child's first steps along the road of development of this rudimentary or primary form' (Vygotsky, 1994, p.349). The real forms of development are conceptualized as the current or actual level of a child's development at the beginning of a developmental process. These two concepts are described and used by Vygotsky (1994) as a unit, that is, as being in constant relation with each other. This dialectical relationship between the ideal and real form is critical as the environment from the very beginning influences, orients, and guides the developmental process and acts as a source of development rather than merely a setting or context.

Ideal and real form and the concept of motives and demands are central in the present study as analytical tools to theorize how teachers create motive orientation in the Conceptual PlayWorld (CPW) for science learning. CPW offers an ideal form of practice that can dialectically engage with children's primary ways of functioning (real forms) and offers the opportunity for teachers to create demands of science learning in the imaginary situation. Within this framework research questions are formed as follow:

1. How do children develop a science motive across infancy, toddlerhood, and early childhood?
2. How do early childhood teachers create the conditions for the development of a motive orientation towards science over time?

3. Methodological Framework

3.1 Study Design

As an educational experiment (Hedegaard, 2008), the study was a collaboration between teachers and researchers. A group of teachers was followed over ten weeks as they created the motivating conditions for the formation of science concepts in different classrooms of one early childhood center in Australia. The teachers were supported by the research team for implementing CPWs (Fleer, 2017; 2018; 2019). CPWs is a play-based model for conceptual

learning through play and imagination. The model involves five key characteristics: a) selecting a story that engages children and introduces a problem situation regarding a concept or a set of concepts, b) designing a space to allow children to explore in different ways the concepts, c) entering and exiting the imaginary space creating collective experiences, d) planning several inquiries, based on the stories plot, to form the concepts and e) planning teacher's role as he/she joins the imaginary space to support children in concept formation.

To explore a set of science concepts, the teachers along with the researchers firstly created a CPW based on the children's book '*Possum in the House*' written by Jensen. The plot of the story is about a possum, an indigenous Australian mammal that entered a house making mischiefs such as creating loud noises. A problem situation emerged; how to get the possum out of the house? A wide range of science concepts related to the possum's biological nature was introduced: a) *external biological characteristics* (i.e. fur, marsupial), b) *heredity* (i.e. same external characteristics), c) *basic biological needs* (i.e. nutrition, self-protection), and d) *conditions of living* (i.e. habitat, nocturnal living). Additional science concepts such as sound (i.e. diverse materials produce different types of sound) were also explored.

As a longitudinal study, the teachers and the children were followed one year after the first implementation for an additional period of five weeks. At this phase, the teachers along with the researchers implemented a CPW based on the children's book "We're going on a bear hunt" written by Rosen. The story describes the experiences of a family as they go through several sites and locations such as a river or a forest in search of a bear. A problem situation emerges; how to walk through these sites and locations? A wide range of science concepts was introduced. The concepts were the a) *biological external characteristic of a plant and a bear*, b) *plants' circle of life*, c) *hibernation*, d) *ecosystem*, e) *floating and sinking*, and f) *light and shadow*. Science concepts were approached differently in each classroom based on children's interests and cultural age.

3.3 Participants and data collection

In the overall study, we follow 130 children from 4 childcare centres in Australia. In this paper datasets generated within 1 centre are presented. For evidence related to infancy data of 13 infants, 8 girls and 5 boys, and 1 teacher are analysed. The teacher had a Certificate qualification and up to 5 years of teaching experience. The infants were aged between 0.5 (6 months) and 2 years with a mean age of 1.2 (1 year and 3 months). For evidence related to toddlerhood data of 20 toddlers, 11 girls and 9 boys, and 1 teacher are analysed. The toddlers were aged between 1.7 (1 year 9 months) and 2.7 (2 years 8 months) years with a mean age

of 2.1 (2 years and 1 month). The teacher had a Diploma qualification and up to 5 years of teaching experience. For evidence related to early childhood data of 17 preschoolers, 7 girls and 10 boys and 1 teacher are analysed. The preschoolers were aged between 3.9 (3 years 11 months) and 5.1 (5 years 2 months) with a mean age of 4.5 (4 years and 6 months). The teacher had a Degree qualification 11 to 20 years of teaching experience. All participants are named with pseudonyms. Ethics approval was gained from the university and the relevant Department of Education. Visual data arose from the video-recordings. Visual methods were used for digital data collection and analysis.

3.3 Data 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 children's and teachers' experience. The focus was on viewing all the raw data and extracting examples of moments where the emergence of a science motive was evident. Examples were noted and logged. 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. All those moments of the emergence of a science motive were clustered to highlight practices related to the emergence of a science motive. The third level of analysis was the *interpretation in a thematic level* based on the use of a system of concepts of cultural-historical theory as an analytical tool. A theoretical analysis was carried out to find a *conceptual pattern* that explains how children develop a science motive over time and how teachers supported this process.




4. Findings

The study found that children developed a science motive across infancy, toddlerhood, and early childhood, and teachers created motivating conditions for the development of an orientation towards science over time. But this was not straightforward or seen as a linear progression. The findings revealed that a science motive was developed when the motive of play and the motive of learning in science were dialectically interrelated over time. Teachers created a motive orientation towards science by early introducing, actively maintaining, and gradually transforming an ideal form of science in children's environment and by consistently stimulating children to interact with this form.

We present these findings through a set of three vignettes illustrating examples of infants, toddlers, and preschoolers, experiencing science in everyday early childhood settings. We also showcase this more deeply through a fourth vignette by presenting the case of one child experiencing science over time and as she moves classrooms from infancy to toddlerhood.

a. Infancy

In Vignette 1, two infants, Anna and Amy, and the teacher, Mei, are within their imaginary play inspired by the story “Possum in the House”. The story focuses on the diverse sounds created when the possum interacts with different objects. Mei places some coloured chalk dust on a drum suggesting making the dust ‘dance’ by creating sound waves. The infants closely watch Mei’s actions. Mei taps the drum making the chalk jump because of the vibration caused by the acoustic wave (Figure 1). At the same time, Mei crafts a narrative about sound waves and how they are transmitted through the air (e.g., “Different sounds coming from the book, from different objects. How can we hear those sounds?”). Gilly, another infant, that stands nearby makes loud sounds. Mei continues crafting the narrative around the sound waves (e.g., How can we hear Gilly talking? Because of them (the sound waves) transmitted through the air!”). Anna moves closer focusing on the action. Mei expands her narrative by consistently describing the activity (e.g., “Look, it is dancing!”). Mei suggests infants hit the drum. Anna has a turn (Figure 2). Amy places a toy duck on the drum. Mei suggests testing if the duck could also move. Mei taps the drum, and the duck moves. Mei suggests expanding the exploration by testing other objects too such as a ball (Figure 3). The infants and the teacher continue exploring different objects for a while placing them on the drum and creating acoustic sounds to make them move.

Figure 1	Figure 2	Figure 3
		
<i>“The louder you tap and putt, the higher they jump!”</i>	<i>“Can you feel the vibration?”, “Give it a little</i>	<i>“Ducky jumps too!”, “What about the ball?”</i>

	<i>shake.</i> ”	
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Fig. 1, 2, 3. Science concept formations during infancy

This vignette illustrates infants’ early engagement with specific aspects of the concept of sound such as acoustic waves and vibration. The teacher introduces in the infants’ environment an ideal form of development to illustrate a core dimension of the concept of sound. This ideal form is an explanation about the phenomenon that comes in line with the aspects of the scientific concept of sound used in early childhood education, that is, the sound is transmitted through the air like a wave, and the acoustic waves can generate kinetic force. The teacher introduces the ideal form in a twofold way. Firstly, she initiates a science-oriented experience for infants and incorporates this experience in infants’ imaginary play (Figure 1). Secondly, she consistently crafts a scientific narrative to describe and explain the science-oriented experience. The teacher’s scientific narrative is multimodal. It includes the teacher’s wording, gesturing, and body positioning dialectically interrelated to dynamically and effectively communicate the essence of the science concept and support infants to engage with and approach the concept. The data shows evidence that the infants can recognise and respond to the invitation to be in a process of scientific development introduced by the teacher. They focus on the science-oriented experience (Figure 1), engage with objects and materials (Figure 2), and participate for a long time in the experience (Figure 3). They initially imitate the teacher’s activity by tapping the drum and gradually make meaning of teacher’s activity as they start exploring new objects themselves. Three main forms of engagement with the experience are noted: a) observation of the phenomenon, embodiment of the experience, and imitation of the teacher’s and peers’ actions. What is also important is an early form of collectiveness that emerges between the infants. The natural object, that is the drum, orients the infants to join the science-oriented activity and to orient to each other. The infants begin to share a collective intellectual space (Fragkiadaki, Fler, & Rai, in press). This abstract sharing is suggestive of a precursor situation of collectiveness that is a precondition and lays the foundations for more complex collective science experiences in the future when the child will be in a different cultural age period.

b. Toddlerhood

The toddlers are familiar with the story after participating in the CPW for two weeks. The teacher introduces to the toddlers four boxes. The boxes are handmade models representing four diverse ecosystems: the ocean, the desert, the forest, and the city. The boxes are covered with an image from each ecosystem. Inside the box, 3D images represent the flora and the fauna of each ecosystem. The teacher introduces a problem scenario by posing the inquiry of finding an appropriate place to relocate the possum. She stimulates the toddlers to observe the boxes, describe the external figures of each box, and make predictions about what animal might live in each box (e.g., “The dessert kangaroo can leave in the dessert!”). She encourages the toddlers to recall the biological needs of the possum already discussed previously within the CPW (e.g., diet, habitat) (e.g., “Possums can’t leave in the water!”). The teacher supports the toddlers to discuss the appropriateness of the environment for a possum before opening each box. The toddlers open one box at a time (Figure 4 & 5) to confirm or not the adequacy of the environment (e.g., “*I can see a possum!*”). The toddlers conclude that the possum must be relocated to the forest since this environment can address its needs (Figure 6).




Figure 4	Figure 5	Figure 6
		
<i>“What is this place? It is hot during the day and cool during night.”</i>	<i>“Have you seen a possum living in an ocean? Why is that?”</i>	<i>“Is there any food or water for the possum?”</i>

Fig. 4, 5, 6 Science concept formations during toddlerhood

This vignette highlights toddlers’ engagement with the science/biology concept of ecosystem. As in Vignette 1, the teacher introduces into the toddlers’ environment an ideal form of development about the concept. In this case, she introduces the form differently. Firstly, she uses a cultural artifact with a symbolic meaning. The models of the different ecosystems stimulate toddlers to share an abstract intellectual space where they can use their imagination to start forming their understanding and wonder about the concept. Secondly, she uses an

early form of scientific method. She supports the toddlers to start thinking systematically about the concept by a) posing a set of criteria about the adequacy of each ecosystem, b) making predictions about each environment, c) confirming or not their predictions, and e) coming to a conclusion. Toddlers recognize and respond to the invitation to develop scientific thinking related to the concept. Toddlers contribute to the conversation led by the teacher by expressing their understandings and sharing their ideas and thinking with their peers. Three main forms of engagement with the experience are noted: a) observation, b) verbal communication (description, predictions, argumentation), and c) use of imagination. What is also critical is the way the physical object, that is the box, encourages the emergence of a sense of collectiveness between the peers. This comes in line with the role of the object described in Vignette 1. An early form of a collective science experience is noted.

c. Early Childhood

Preschoolers and Andrea, the teacher, read the book. Andrea stimulates children to pretend to be possums by wearing fur tails and constructing new habitats for themselves. Andrea encourages children to think about what materials are needed to make ‘possum homes’. Andrea encourages children to wonder by using their knowledge from everyday life at home (Figure 7). She supports them to use the knowledge and the information gained through the story and the conversations the team previously had about possums characteristics, habits, and way of living. Ideas such as fridge, hammer, kitchen are presented by different children. Andrea orients the children to think about specific criteria such as keeping the possum warm and dry, the availability of materials for the possum, and the properties of materials. Children express their thinking (e.g., “Leaves could be their blanket!”, “We can use bamboo like we do for a tree house...”, “We can use some sticks to hold it right there...”). In several areas of the room, different groups of children begin building their possum homes (Figure 8). They build individual homes connected to create a community of possums. The children share ideas and outcomes (e.g., “I am pretending this is a blanket to stay warm.”, “We need sticks and wood.”, “I used fabric for the roof.”). The next day Laureen, the other teacher, invites some of the children to design the process of building a possum house (Figure 9). Laureen uses an iPad to orient the children to the designing process. The children begin to draw the habitat they created. They craft a narrative explaining the process and the criteria used for the decisions made during the process (e.g., “I put a log so the possum can lay and sleep... and stay warm.”, “I am making a big house for a possum family”, “I made a barrow with leaves and paper in it (for hibernation period).”).




Figure 7	Figure 8	Figure 9
		
<i>“A roof in order not to get wet, something soft so they can sleep on, some sticks to hold the beds.”</i>	<i>“A possum community!”</i>	<i>“Let’s draw the house we made!”</i>

Fig. 7, 8, 9. Science concept formation during early childhood

This vignette maps preschoolers' engagement with the science (biology) concept of environmental conditions in relation to engineering concepts such as stability, tightness, and strength of materials. The teacher creates the conditions for the criteria for constructing a proper possum habitat to be derived from children. She poses some pivots of wondering and allows children to search and find a solution. She consistently attempts connections between everyday and scientific knowledge to support children's thinking about the constructing and designing process. Emphasis is given to the collective aspects of the science experience. Preschoolers appear to be confident in using symbolic forms of expressing and documenting their thinking such as language, 3D constructions, and drawings as they start thinking scientifically about the concepts. Alternations between collective experience and individual action between the preschoolers are noted. What is also important here is that the preschoolers can share an abstract intellectual space independently from the physical presence of the object and the proximity to it. The above elements are indicators of a collective science experience.

d. From infancy to toddlerhood

To better understand scientific conceptual development over time, we now present a case example of one child, Megan. Vignette 4 illustrates how Megan experiences science as an infant and her science experiences as she becomes a toddler the following year. As an infant,

Megan participates in the CPW “Possum in the House”. Within this group activity setting the teacher introduces the concept of properties of matter. Emphasis is given to basic properties such as the property of creating sounds. The teacher makes available to the children a set of diverse materials and objects such as pieces of paper, saucepans, and fabrics and encourages infants to interact with the materials to create and listen to different sounds. Megan stays close to the materials and objects, she observes and pays attention to them and to the way her peer engages with them (Figure 10). She grasps, holds, shakes, and taps on them creating diverse sounds. She repeats the activity several times. The following year, as a toddler, Megan participated in the CPW “Going on a Bear Hunt”. This group activity setting aimed at familiarizing toddlers with differences between diverse ecosystems such as the lake and the forest. The teacher introduces the concept of the ecosystem within toddlers' imaginary play by representing the diverse ecosystems within the indoor space of the classroom and crafting accompanying science narratives related to the diverse characteristics of each ecosystem. Megan enters the imaginary space. She explores the surroundings and begins interacting with the available materials and objects. She notices some transparent ribbons representing grass. Megan picks up the ribbons and explores the material. She shakes the ribbon to create sounds and observes the ribbons closely. The teachers encourage toddlers to shake the ribbons to imitate the sounds made by the grass in an imaginary pasture. Toddlers continue their imaginary play and the teacher places one ribbon close to Megan's eyes asking her: “*What color is the ribbon?*”. Megan notices that some of the ribbons are transparent. She picks one ribbon and places it close to her eyes to see through it. She repeats the action, staring through and away from the ribbon. She refers to the teachers asking: “What?”. The teacher begins crafting an early scientific narrative to explain the phenomenon (e.g., “It is green colour. It makes the light green.”). Although the educator does not go further in explaining that it is only the green light that can pass through the cellophane (something beyond toddlerhood), she brings attention to important preconceptions in understanding light. But rather her focus is in relation to a more concrete conception surrounding materials. Megan explores her surroundings looking through the ribbon. She picks up another ribbon, she places it close to her eyes. When she realises it is not transparent, she throws it away. She finds again a transparent ribbon and continues looking through and away from it. The other toddlers notice Megan's initiative and begin imitating Megan (Figure 11). The group activity setting now focuses on exploring transparency as a property of the materials.



Fig. 10,11 Science concept formation across infancy and toddlerhood

The vignette highlights the different ways the child engages with and explores science concepts over infancy and toddlerhood. In both phases, the child explores the concepts as part of her imaginary play. What is different in each phase is the degrees of freedom in the child's interactions with the surrounding physical, technical, and social world. As the child grows up, the degrees of freedom in her interactions increase. Compared with the infant period, a toddler develops more advanced motor skills that allow her to search, find, and explore the surroundings based on her pace and intentions. The child is also more capable of verbal interactions and this capacity allows her to pose basic questions to the teacher and respond to the scientific narrative. The above conditions allow the child to initiate and participate in more complex and deep explorations. What is also important here is that being a toddler, the child takes the initiative to change the orientation of the joint science-oriented experience and put new demands on the teacher and her peers e.g., other toddlers also begin to explore the property of transparency. This evidence is suggestive of the way the toddler can introduce in the group of toddlers an ideal form of development that motivates her peers to expand their explorations.

5. Discussion

In this paper, the longitudinal aspect in forming science concepts during the early years is elaborated. As Gomes and Fler argued (2019) “A scientific motive goes beyond explaining just a moment in a child’s development, but explains the relationship across institutional practice and the relationships over time where an interest in learning science develops” (p.

629). Exploring how the dialectical interrelations between institutional practices, children's cultural age, and the social situations created within different science experiences key characteristics were noticed. The characteristics were related to the institutional practices, children's personal learning pathways in science, and the collective character of the science experience. These are discussed in turn.

We learned that the teachers appeared to use the dominant motive of play to orient the children to science and support them to develop a science motive through their play. Firstly, following the new practice tradition of the CPW they created the conditions for children's imaginary play (e.g., stimulating the children to stay in role while exploring the science concepts). Secondly, they introduced in children's imaginary play the ideal form of the science concept (e.g., crafting a scientific narrative or posing a set of criteria to reach a conclusion). Thirdly, they kept the ideal form actively present in the child's environment throughout children's play (e.g., continuing crafting a scientific narrative throughout the science experience). Fourthly, they consistently stimulated children to interact with the ideal form (e.g., posing questions to engage children with the scientific narrative). What was different in each cultural age period was the degrees of freedom the teachers allowed in children's explorations. The more children were developing their ability to interact and communicate with objects and peers, the most complex the science experiences were getting as the teachers were highlighting the connections between everyday concepts and scientific concepts. Gradually, the science experiences were shifted from what is observed and described "here and now" towards conceptualizing and designing imaginary spaces and using abstract scientific criteria to form the science concepts. The institutional practices the teachers used shaped the conditions for children's development in science but at the same time, the institutional practices were shaped by children's cultural age.

The findings also illustrated children did not enter the activity settings with a personally formed and pre-determined motive. Their motives were developed during the activity setting and were shaped by the unique social situation created within the activity setting. This comes in line with Hedegaard's (2002) conceptualization of motives as social and cultural formations. However, it is through the social interactions during the activity setting that the scientific motive came in line with the child's motive to play. As Hedegaard and Chaiklin (2005) argued the child develops motives as s-/he participates in institutional practices. This suggests children formed their personal pathways in science in relation to their play and to what was personally meaningful and important to them.

Third, forms of collective science experiences appeared to emerge, established, and develop further as children become oriented towards a science motive. A precursor situation of collectiveness was noted at infants' classroom based on infants' engagement with the object (the drum) that was central for exploring the concept of sound. This was followed by an early form of a collective science experience in toddlers' classroom that was based on a cultural artifact (boxes) with a symbolic meaning of a conceptual system. Characteristics of a collective science experience became more visible in the early childhood classroom where children managed to share an abstract intellectual space independently from the physical presence of objects and the proximity to them. These findings suggest that a sense of understanding and engaging with science as a social practise begins at infancy and dynamically develops across the first four years of a child's life. Simultaneously, a sense of the cultural character of science emerges as children engage with objects and artifacts as part of the science experience. The social and cultural understanding of children about science changes in dialectical interrelation to the child's cultural age. This is also reflected in the degree and the form teachers introduce and exploit objects and artifacts during science experiences.

6. Conclusions

The study sought to understand how infants, toddlers, and preschoolers become oriented to science as they participate in collective play through a CPW. We showcased longitudinally the nature and development of scientific concepts related to the educational reality of infants, toddlers, and preschoolers. By following the same cohort from infancy to toddlerhood, and by simultaneously creating the same CPW conditions, we determined that a motive for learning science concepts can begin in infancy in educational settings.

What appeared as key for the development of a motive orientation for the conceptual learning of infants was a sense of collectively sharing the same experience. A sense of togetherness with proximity within a shared imaginary CPW, meant that infants and the teachers could communicate in relation to the story and to the science concept of sound being introduced to amplify science learning. The CPW gave a common experience and a set of resources that acted as placeholders for the science experience within the play, and it also gave a routine in which the teachers could introduce a mature form of a science concept and the infants could explore through imitation and later through motivating others to collectively explore the materials. Although it is not possible to determine exactly to what degree

conceptual understandings were reached for infants, it is possible to see their motives towards these experiences through how they enter the activity setting, how they contribute to the activity, and how the activity engages their attention. This gives possible new directions for not only data collection in what is the very first period of science learning in educational settings, but it also introduces a framework for studying the conceptual development of infants.

The study also found qualitative differences in conceptual engagement in science between cultural age periods. Examining how the same CPW was created by the teachers for the exploration of sound, and then later in relation to an ecosystem for the toddlers, was directly in line with the toddlers' capacity to go beyond objects tied to the narrative experience of science in the story, and to think more theoretically about their world. Whilst it is not possible from the language of toddlers to determine their conceptual understandings, it is possible to notice their actions, and how they enter the play, and solve problems. Accordingly, the same CPW created the conditions for the preschoolers to further develop their theoretical thinking of the world as well as deepen and expand their conceptual understandings. It is not just to study how infants, toddlers or preschoolers enter the activity settings, what they do and how they shape the activity settings, but it is also to look at the kinds of scientific conceptual development that is afforded by the teachers. In studying children, we have to also study the conditions that teachers create in their educational programs. It is a dialectical relation.

We suggest that the outcomes of this study of scientific conceptual development for infants, toddlers and preschoolers has shown the significance of beginning with narrative knowledge in which empirical knowledge of science is embedded, but that it should not stay at this level. We suggest toddlers should also begin to build theoretical models of thinking for gaining a system view of the world in which they live. This could be followed by preschoolers developing this theoretical knowledge in a more independent way. The study also suggests the critical role of a scientific narrative for the development of scientific thinking. The scientific narrative begins and stays with scientific thinking and is the glue that helps infants, toddlers, and preschoolers to build a motive orientation to science in which empirical and theoretical knowledge can grow.

The findings of this study not only have implications for practice but is illustrative of how science is so fundamental for young children's thinking about their world, as they begin in infancy being introduced to narrative thinking through stories and their own life experiences at home, to empirical thinking as they research, explore and stay curious about

their world, and theoretical thinking as they bring their empirical knowledge into a system of relations and reach more abstract forms of thinking. Not only should we not underestimate infants' capacity to engage in scientific thinking, but we need to recognise the different kinds of thinking that come together for deep conceptual development of the child in science, so we continue to create these conditions for scientifically engaging them in their world systematically over time.

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