Chapter 1
Learning Science in Everyday Life – A Cultural-Historical Framework

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Abstract Vygotsky's conception of the relations between everyday concepts and scientific concepts is introduced in this first chapter through an empirical example of a 6 year old child and an early childhood teacher making a slowmation animation together. The concept of force is examined. Through this example, cultural-historical theory is introduced as the theoretical perspective guiding the whole book. In this chapter, we do not simply introduce the chapters or sections of the book, but rather this chapter provides a theoretical framework and context where the major concepts and themes that are introduced later in the book are presented to give a comprehensive account of early childhood science education. The content of this book is introduced through a discussion of why this particular book on early childhood science is needed for advancing theory and practice in early childhood science education.

Keywords Cultural-historical theory • Early childhood science education • Constructivism • Slowmation • Children's science • Conceptual change • Force

1.1 Introduction: Our Historical Legacy

Sophia (6 years) was at park with her grandparents, two uncles and Chistina (teacher). She led Uncle JJ and Christine to a spinning piece of equipment that she discovered earlier. She sat on it and requested Uncle JJ to spin her.

Sophia:	*Spin!*
Christine:	*How should Uncle JJ do it?*
JJ:	*You should know how to spin it yourself…*
Sophia:	*Hold on tight*
JJ:	*Yes hold on tight (started to spin her) (Sophia grabbed on tightly to the pole)*
JJ:	*Later you'll be very giddy you know*
Sophie:	*Don't worry! (which also means: you can spin fast; I can handle it),(Uncle JJ turned the knob fast and Sophia squealed with excitement)*
JJ:	*Giddy already… Slow… The other way*
Sophia:	*Faster, faster, faster!*

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> *Christine:* *Is your head spinning too?*
> *Sophia:* *No, but the wheel is…*
> *Sophia:* *Faster and faster (squealed with excitement again)*
> *JJ:* *Slower…*
>
> Sophia stood up and next was Uncle JJ's turn. He stood on the spinning equipment. Sophia held on to it with one hand and ran. She gave it a push and observed how it continued to spin without her holding on to it. He squatted down and the equipment slowed down. He exclaimed, "stop!" She helped by using her arm and body strength to bring him to a complete stop (Fleer & Hoban, 2013).

According to longstanding research in science education, very young children's everyday practical experiences of forces have been learned intuitively within specific everyday contexts, such as when Sophia is playing in the park and stops her uncle from continuing to spin (as shown in Fig. 1.1), or when she is spinning and comments (as discussed in the text above). These intuitive everyday practices have been linked closely to the explanations offered about why children do not hold the same views about concepts in science as scientists do. Over the past thirty years a huge volume of research has amassed in relation to children's thinking in science, most of which has drawn from constructivist views for informing learning and development. Even though there exists a large body of literature into understanding what children think, and what kinds of programs support children's learning in science, very little research attention has been

Fig. 1.1 Everyday understandings about *force* learned in the park

directed to children younger than five (Fleer & Robbins, 2003a; Robbins, 2009). This book seeks to redress this dearth in understanding – not by adding to what already exists, but rather by re-analysing this body of work and re-theorising understandings about our youngest scientific learner. To do this, we will draw specifically upon cultural-historical theory for our critique, followed by an examination of cultural-historical studies in science education (including our own recent research) to build our case (see Chap. 7). What is unique about our book is that we will use cultural-historical theory for better understanding the scientific conceptual development of very young children, going one step further than notable works, such as that of Eshach (2006) or Metz (2006). This chapter and the next, pave the way for this cultural-historical understanding of science learning by critiquing the existing literature and discussing those theoretical concepts thought important for the conceptual development of young children.

This chapter begins with a cultural-historical analysis of the longstanding science education research literature so that we better understand the research backdrop that has brought us to this point in time. We begin by an analysis of what is known about children's thinking in science, followed by a critique of the tools that have generated this body of knowledge over the past 30 years. All contemporary research contexts are laced with historically informed practices that contribute to how we currently enact and conceptualise early childhood science research. However, our analysis asks different kinds of questions about the nature of science learning than previous literature reviews because we are interested in determining the conceptual essence of very young children's learning and development in science as a collective endeavour. Our unit of analysis seeks to find the smallest cell that makes the biggest difference to young children's conceptual development (Davydov, 2008). We critique the concept of *children's science* because this work is still prevalent in early childhood science education, and its traces are still keenly felt. Later in this chapter we re-theorise this literature and the tools in relation to cultural-historical concepts.

1.2 Children's Science

Piaget's early work was instrumental in influencing a number of key researchers within the science education community by drawing attention to the explanations children give to natural phenomenon. As is well known, Inhelder and Piaget (1958) made particular kinds of naturalistic observations, and undertook specific conservation tasks, presenting the education community with particular types of interpretations. Some examples are presented, re-analysed and discussed in subsequent chapters.

What is particularly important for the focus of this book is how these ideas were taken up in the science education community in the late 1970s and early 1980s (see

Driver, Guesne, & Tiberghien, 1985; Osborne & Freyberg, 1985; White, 1988). Researchers at the time created specific tasks for children and older students to experience, with the view to ascertaining children's thinking in science for both primary (e.g., Roger Osborne in New Zealand) and secondary students (e.g., Ros Driver in the UK). Sadly, little research was done at the time in relation to children younger than 5 years of age. Examples of the kind of instruments that were designed to elicit children's thinking in science, included, concept maps, word associations, prediction-observation-explanation tasks, Venn diagrams, and a range of forms of interviews (White, 1988). For example, children were interviewed about an everyday incident that they would be familiar with (interview-about-incident) in order to determine their understandings about a concept, such as *force*. The children would be presented with a series of cards, such as the ones shown in Fig. 1.2. The children would be told that the interviewer was interested in their understanding about the concept – *force* – and that they would have a chat about the diagrams. The children

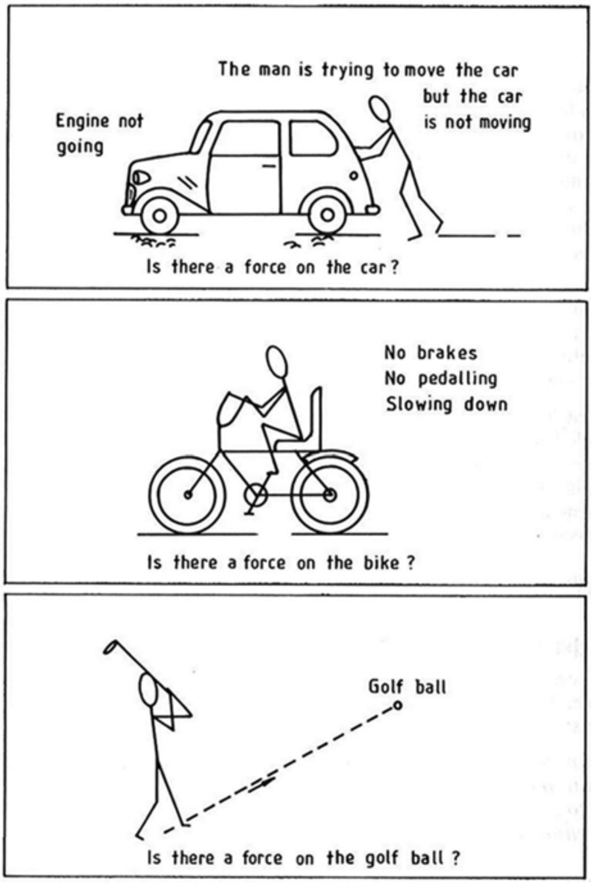

Fig. 1.2 Interview-about-incident (force) cards

would then be presented with a card and asked "Do you consider that there is a force on the …………………., in your meaning of the word force?"; "Why do you say that?"; "Can you tell me more about that?" (Osborne, 1985, p. 43). Interviewers were initially puzzled by comments made, such as when a 9 year old was asked about if there is a force on the car, she replied: "No I don't think so because he is not forcing the car…the car won't move, it would be too heavy…he would be arguing at the car, kicking it…then he would probably start walking…he would do a force, if it was a brand new car…try and save his car instead of leaving it out" (p. 43). Noting the human aspect of the children's responses, as this 9-year-old has conceptualised, is central to understanding the comments children give in these contrived interview situations. Analyses at the time linked children's comments mostly to historical periods in which particular worldviews about the concepts were prevalent, for example, in physics, thinking from scientists, such as, Einstein, Newton and Buridan, who all had different theoretical explanations for the concept of *force*. For example:

Newtonian interpretation: (Is there a force on the bike?: "Yes…because something is trying to slow it down….because something is pushing it the other way so it slows down" (9 year old).

Buridanian interpretation: (Is there a force on the golf ball?: "The force from when he hit it is still in it" (13 year old).

Analyses of children's responses needed to broaden as more studies were undertaken, where findings noted how children associated *force* with an emotional state, like anger or feelings, and as 'something' that makes an object move, rather than causing a change in motion. Here, coercion, or physical movement, or muscular strength were common explanations given by young children – as mentioned in the spinning example of Sophia playing in the park. Frequently, children associated *force* with the object itself – as residing in the object (Buridanian interpretation), or as something that keeps an object moving. Importantly, the early research collectively showed that children generally only considered *force* in relation to the motion of an object and do not give thought to the *equal forces* that are acting to keep an object motionless (e.g., equilibrium situations).

Collectively, this research into children's thinking about *force* suggested that when children think about *force*, they consider it as the *property of an object*, rather than as the interaction between two or more objects. Children who think the former, generally give the following explanations:

- If something is moving, then there must be a *force* acting on it (or has acted on it)
- If an object is still, then there is no *force* acting on the object
- It is not possible to have movement if a *force* has not been applied
- If something is moving, then the *force* has determined its direction
- An object keeps moving because it has *force* inside of it to keep it going
- When something stops, then the *force* has been used up
- For older children, constant speed is associated with constant *force*

The outcomes of these early studies became known as *Children's Science*, and these early studies shaped the way science education research was conceptualized for almost 25 years. In addition, these early techniques used to elicit children thinking, such as the 'interview-about-incident' task, spawned a worldwide frenzy into finding out what children knew about a range of scientific concepts.

This research tells us that for 30 years, research within the science education community has revealed what very young children will express about their thinking for a range of scientific understandings, such as *force*, and this work shows that very young children will usually *explain science concepts at an intuitive level*. But a critique of how these techniques were used to elicit thinking, such as that undertaken by Margaret Donaldson (1978, 1992) when she re-examined Piaget's conservation tasks, is missing from the science education research literature (see also Richards & Light, 1986; Wood, 1988). Rather, the approaches used were deemed suitable for determining how children think about science concepts without questioning the reliability of the tools used for young children. We will return to this idea in Chap. 7 in this book when we look at how children are positioned in research.

The general science education research literature also shows that a range of concepts have been researched in the primary and secondary years, including light, electricity, heat and temperature, force and motion (this chapter), particulate nature of matter, chemical transformations, etc. In addition, more generic topics covering science concepts for younger children were also researched, such as when studying force (Chap. 1), light (Chaps. 2 and 10), geology (Chap. 8), animals and plants (Chaps. 6 and 8), magnetism, the human body (Chap. 11), floating and sinking, and night and day, plus more. We take up some of these science concepts and analyse these further later in this book.

Researchers initially published children's scientific thinking in international handbooks where understandings where discussed in relation to age levels and countries (i.e., see Duit, Treagust, & Widodo, 2008). In addition, most textbooks and scholarly books in science education bring these understandings about children's thinking together as a part of the source material that is deemed useful for informing the work of science teachers or primary and early childhood teachers working with science concepts (see early works such as, Driver et al., 1985; Osborne & Freyberg, 1985; and later publications, for example, Eshach, 2006; Harlen, 2010).

The science education research community has invested a great deal of effort and time into documenting these findings. Some thirty years of research have gone into finding out *children's science* or *alternative views* as they also became known as – due to signaling that children's scientific ideas were not wrong but rather were alternative to that which was accepted by the scientific community at that time (e.g., http://www.education.vic.gov.au/studentlearning/teachingresources/science/scicontinuum/monashdesign.htm). So what has underpinned this body of literature? What has been the basic logic and view of children's development that has guided researchers and educators in science education? Constructivism is the foundational theory that has guided us. Constructivism was informed by Piaget's own theory of child development (Vygotsky, 1987, p. 173). Constructivism is central to *Children's Science*. Children's science is:

- resistant to external suggestions
- deep within the child's thought
- age specific
- maintained in children's consciousness over several years
- the child's first answers

Over the past 10 years, we find that whilst there are still some papers published on children's science or children's alternative views, the quantity has significantly dropped. It is no longer the main area of interest to researchers. During this time, we have also seen more studies directed to the study of how very young children experience science education, including investigating their thinking in science as a result of participating in different kinds of programs, such as *Interactive teaching* (e.g., Kirkwood, Bearlin, & Hardy, 1989), *developmentally appropriate science* and *constructivist approaches* (e.g., Martin, Jean-Sigur, & Schmidt, 2005), a *process approach* (Kirch, 2007), and *cultural constructions* of science and *children's interests* as basis for science instruction (e.g., Siry & Kremer, 2011; Siry & Lang, 2010). We also see fusion between teaching philosophies and science, such as use of Reggio Emilia (Stegelin, 2003), emergent curriculum with science standards (Baldwin, Adams, & Kelly, 2009), Developmentally Appropriate Programs (DAP) and pedagogical practices in science (Hadzigeorgiou, 2001). These ideas will be taken up further in the book.

A careful analysis of the research and the central theoretical frameworks that have progressed the science education field for the past 30 years reveal *a rather one-sided approach to examining children's scientific thinking*. To step back from this plethora of findings, and to think about children's science in a different way, requires another way of considering the traditional view of the process of mental development of children. We need to move beyond *age as a central criterion* for scientific progression (e.g., http://www.deakin.edu.au/arts-ed/education/sci-enviro-ed/early-years/floating.php) or *historical periods in science* for explaining particular types of thinking (see Osborne, 1985), but rather we need to think in new ways about what we already know. Vygotsky (1997) argued that "…it is easier to assimilate a thousand new facts in any field than *to assimilate a new point of view of a few already known facts*" (p. 1; our emphasis). Assimilating another fact about how children think in science does not progress the field, because it would seem that much of the published research has resulted in little progress being made in dealing with the outcomes of these views children hold (Skamp, 1993). That is, what do we do with this expansive knowledge base about children's science or the record of alternative views? How can this help us with understanding the conceptual development of very young children? We need to think about children's science in a different way. We need to move from children's thinking in science, to a cultural-historical reading of the *thinking and learning child,* where we go beyond the lone child's construction of knowledge, and consider the relations between the child and their social and material environment, where the teacher plays an important role.

A cultural-historical reading of science education would position science as a form of cultural knowledge that is historically and collectively formed and understood, rather than as something that is located within the individual. Research into the concepts that children hold, particularly those studies that are framed from a constructivist tradition, would invite the researcher to look closely at what it is an individual child says and believes at a particular moment or point in time. That is, it is an individually held construction of science concepts/knowledge. Here scientific knowledge is broken down into individual concepts, decomposing the whole into parts, as the basis for investigating what a child thinks about an individual concept. Yet we know that children traditionally do not think or learn in reductionist ways. In many respects, this kind of science education research can best be summed up by drawing upon the words of Vygotsky (1997) to say that constructivist research into young children's concepts in science is like a "mosaic of mental life developed comprised of separate pieces of experience, a grandiose atomistic picture of the dismembered human mind" (P. 4). When in fact science is a system of concepts, invented by humans, and which are given meaning through the Western paradigm of science (see Aikenhead, 2006; Aikenhead & Michell, 2011) and enacted with others. These ideas are discussed further in Chap. 6. Knowing about what children think in science is only one side of the '*teaching-learning* coin' for the development of scientific concepts. A cultural-historical reading of conceptual development would suggest that knowledge is not contained within the individual head, but rather it is distributed across people, who collectively contribute to thinking in science, whether this is at a large scale policy level, such as, a Government initiative (e.g., science to inform sustainability by reducing carbon emissions through painting the roof of all CBD buildings white to reduce energy consumption for cooling), or whether it is about how to change family practices in a home for keeping everyone warm in winter (i.e., insulate the walls or close doors and use draft stoppers on the base of doors), or how a child stays warm on their way to preschool by putting on a coat, gloves and hat. Reducing scientific concept formation to the individual as an explanation of 'what they know' or 'think in science' also creates a binary that dates back to Descartes 'mind – body' split. This form of Cartesian logic has been extensively critiqued and found wanting (see Chap. 5 for discussion of forms of knowledge and Chap. 11 on representation in science).

Rogoff (1995, 1998, 2003) has also discussed the *artificial boundary* between the internal mind and external world that is formed when Cartesian logic is used to explain how someone thinks and learns. The binary of externalization and internalization that results is explained by traditional psychology:

> Developmental research has commonly limited attention to either the individual or the environment – for example, examining how adults teach children or how children construct reality, with an emphasis on either separate individuals or independent environmental elements as the basic unit of analysis (Rogoff, 1995, p. 139).

A cultural-historical reading would not separate out individuals, but rather would focus on the interdependence between them, where the unit of analysis would preserve the essence of their social and material interactions, rather than separating out how an individual child thinks about one concept or another. The child, the interactions between others, and the cultural and historical context in which the children/adults are operating does not exist separately. An analogy with the concept of *force* can be made. It would be a nonsense to examine only one source of a *force*, disembedded from the system of forces that were operating, in order to understand the concept of *force. Force* can only be understood within a system of *forces* that are acting, even when the object under investigation is stationary. In a cultural-historical reading of the science education literature, we must consider the mutually constituting processes that are at play when we consider conceptual development of children, and not the individual understandings of scientific concepts. It is incomplete to only focus on an individual's conceptual development, without also considering the social interactions between individuals in coming to speak about or to discuss a particular science concept. A child does not develop in isolation. Importantly, it is also not complete to examine the cultural community within which the conceptual development is being foregrounded, because communities also develop, they are not static. Logically, children's science puts children's thinking in opposition with adult thinking in science, and this is unhelpful as it means in teaching, only the 'replacement of children's thinking to that of the adult' must occur. Rogoff (1995) has used the concepts of *guided participation* and *participatory appropriation*, and the metaphor of *apprenticeship* to explain how development occurs in order to move beyond a model of externalization and internalization of concepts, and this is helpful for thinking outside of the binary that Children's Science has inadvertently created. She shows the binary graphically through the portrayal of the boundary that is formed when first, a behaviourist view is considered, and second, a constructivst view of teaching and learning is featured (see Fig. 1.3).

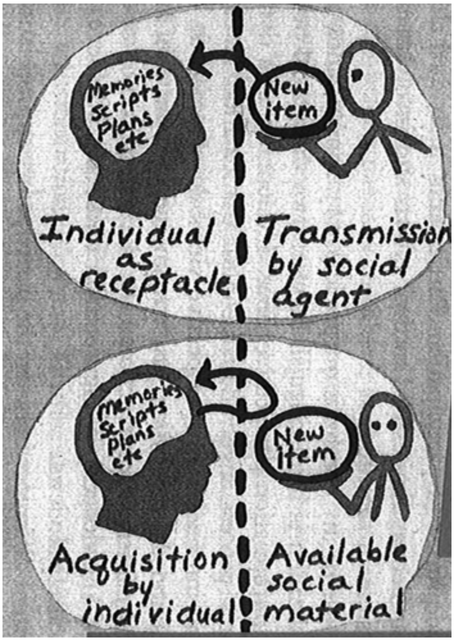

Fig. 1.3 Boundary between internal and external (Extract from Rogoff, 1995, p. 154)

Further to this, we can see in this representation, but also in the critique given by Vygotsky (1987) on Piaget's spontaneous and non-spontaneous concepts which informed constructivism, that children's expression of spontaneous concepts (alternative views) is distinctly different to the accepted scientific concepts. The focus in this line of enquiry is on the *differences* rather than the *connection*. Piaget views "the development of concepts as a mechanical combination of two separate processes, processes which have nothing in common and move, as it were, along two completely isolated or separate channels" (Vygotsky, p. 174). *Children's science* is viewed as completely different to, and disconnected from, the accepted scientific view.

Locating science knowledge within the individual mind is a limited view of science and therefore science learning. Yet, this perspective underpins much of the research that has flowed from *Children's Science* or children's *alternative views*, and into the models of teaching which focus on *conceptual change*. See Chap. 7 for details of how children are positioned in research and how individual understandings of scientific ideas are perpetuated. We now turn to the other side of the coin, and focus on the research into the teaching of science.

1.3 Conceptual Change and Socioscientific Approaches to Teaching Early Childhood Science

The other side of the coin which has steadily gained momentum within the science education literature is socioscientific approaches to teaching. This perspective sees children engaged in a variety of social dilemmas that they must solve. These dilemmas are usually conceptual, procedural or technological. Real world contexts create the conditions for engaging students in science learning as children discuss and debate the products or processes of science. Examples are usually controversial, and often include cloning, climate change, genetically modified food, soil degradation, and stem cell research. From this literature we notice a growing number of studies which focus on how children learn science when a socioscientific perspective is featured. According to Sadler and Zeidler (2005) "the socioscientific issue movement arises form a conceptual framework that unifies the development of moral and epistemological orients of students and considers the role of emotions and character as key components of science education" (p. 113). Through engagement in controversial issues, it is argued that children develop scientific literacy. Scientific literacy entails children being sufficiently informed to be able to make decisions about societal needs and practices. A focus on scientific reasoning and conceptual change of children is central. Examples include enhancing the quality of argumentation in school science (Osborne, Erduran, & Simon, 2004), and argumentation in science (Naylor, Keogh, & Downing, 2007).

This perspective has been driven by finding out what engages children (and adults) in science learning (or teaching this subject) or how effective is the socioscientific perspective for framing learning and teaching in order to *change children's* *thinking*. Here the focus is still on *conceptual change* as the ultimate marker of program success. However, this perspective is still located within a constructivst view, one this is conceptually coherent with *Children's Science.* It is not a change in theory or practice, but rather it is an artifact of the original work done in 1970s and 1980s. We take up the variety of examples in the third section of the book where we discuss these ideas in more detail.

Research into socioscientific models of teaching at all education levels (except early childhood) highlights the affective dimensions of morality in scientific reasoning (Sadler 2004a, 2004b; Sadler & Zeidler, 2005) and the cognitive conflicts that arise, as well as both raising the importance of context (Korpan, Bisanz, Bisanz, & Henderson, 1997; Sadler & Zeidler, 2005) and student engagement in science (Bell & Linn, 2000; Sadler & Zeidler, 2004). In the extensive research of Sadler and Zeidler (2005) into informal scientific reasoning they have noted the importance of a personal dimensions of decision making in socioscientific dilemmas of college students. In particular they found that personal experiences, emotive engagement and the social and moral issues associated with informal reasoning as drivers in scientific thinking and decision making. Knowledge of the social world rather than material world was central to student reasoning in science. Morality has been thought to lead this thinking, as noted by Bell and Lederman (2003). However, Sadler and Zeidler found that attempts at isolating "morality, and by extension personal or social factors, as a guiding factor in the determination of positions regarding socioscientific issues are misguided" (p. 129). They found that reasoning in science was subsumed by morality, personal experiences, emotive factors and social considerations. This finding is highly significant because it draws attention to the unity of emotions and cognition in scientific learning, something that is foregrounded by Vygotsky in his earlier writings (Vygotsky, 1991) and the final works (Vygotsky, 1987). We discuss the unity of affect and intellect later in the book (see Chap. 3).

As might be expected, a socioscientific approach to teaching science has not directly influenced research in early childhood education. Presenting scientific dilemmas to children in the birth to five year period has really only emerged in relation to environmental sustainability (e.g., Davies, Engdahl, Otieno, Pramling-Samuelson, & Siraj-Blatchford, 2009) where research is focused mostly on what children think and how they might act, rather than investigating how through argumentation young children resolve issues or take a personal stand in relation to a socioscientific dilemma. Further to this research into socioscientific approaches to teaching science, are those studies which have examined everyday situations and contexts as either motivating learners, or influencing their concepts in science. However, most of these studies focus on secondary students and are outside of the scope of this book.

Collectively, these studies represent the other side of the coin – the teaching context. What these studies miss is the *dialectical relations* between context and concepts. That is, studies of children's thinking is only one source of knowledge and understanding of science education, and this does not go far enough in understanding how scientific knowledge is constructed by children. Research into teacher knowledge or program effectiveness also does not go far enough, as the focus of research attention is generally in one direction - from the program *to the child*. These programs focus on how their strategies or intentions shape children's scientific understandings. They generally do not examine how children shape the programs themselves because the focus is 'on the program'. This is the same for studies into teacher education, where the research either examines pre-service teachers scientific knowledge or competence (e.g., Garbett, 2003, 2007), or examines what effect a tertiary program has had on teacher knowledge or competence to teach science (Appleton, 1995; Gilbert, 2009). The studies do not examine how pre-service teachers shape the programs they experience or how teacher courses take account of the student as the learner of science. Simply studying the effect of a science program on children's learning is like only studying an embryo. The essence of development is there, but there is much to still know about how the embryo develops over the course of its lifespan. An investigation of the embryonic development of science programs is a limited approach to the study of science education. We believe that in the field of research into early childhood science education we are still at the embryonic level of development.

Cultural-historical research into science education seeks to examine the relations between the child/teacher and the concepts/contexts as a dialectical process, where the learner is shaped by, but also shapes the social and material conditions for science learning. We now turn to a discussion of the central theoretical concepts for understanding this dialectical relation.

1.4 The Dialectical Relations Between Everyday Concepts and Scientific Concepts

The experiences of Sophia and Uncle JJ in the park, led Sophia and her teacher Christine into preparing a slowmation animation together in order to explain the *forces* acting in the park. Hoban (2007) explains that *Slowmation* (www.slowmation.com) is a simplified way of making stop-motion animation. By taking a series of photographs of objects and loading them into Slowmation software, the images can be played slowly at 2 fps allowing Sophia and her teacher to narrate an explanation of a science concept of *force* over their 'set of slow moving images' of their recreation of the park scene using two soft toys (Fig. 1.4). Their narration follows:

Sophia:	*Yay, see-saw, I can go up and down. Why can't I go up?*
Christine:	*Hello Doggy, that's because gravity pulls you down. But I'm heavier than you. See, now I go down and you go up. Just give a little kick and we will go up and down, up and down.*
Sophia:	*Thank you, but now I want to play on the slide. I am climbing up. Wheee. See, I came down so fast. Ah-ha, that's because gravity pulls me down.*

Fig. 1.4 Slowmation animation co-constructed by Christine and Sophia

Christine:	*You are right, Doggy.*
Sophia:	*Watch me, OUCH…*
Christine:	*Oh dear, be careful, Doggy.*
Sophia:	*Okay. Shall we play on the merry-go-round, Piggy?*
Christine:	*Sure, why not? Do you wanna go fast or slow?*
Sophia:	*Fast, very very fast!*
Christine:	*Okay, then I will have to give you a very big push! Watch out!*
Sophia:	*Oh! I am spinning so fast! I can't stop! HELP!*
Christine:	*Okay, let me give you a little push in the opposite direction then.*
Sophia:	*Oh man, I am so giddy.*
Christine:	*Ha-ha, I'm sure. Hey look, there's a football, shall we play? I'll kick it to you. Kick it back to me.*
Sophia:	*Ha (kicking action).*
Christine:	*Doggy, you kicked it too lightly. Try again.*
Sophia:	*Okay.*
Christine:	*Oh-oh, you have to kick even harder than this.*
Sophia:	*Ha (kicking action).*
Christine:	*Yay, that's good. Now back to you! Now I am going further away. See if you can make the ball travel far and fast.*
Sophia:	*No problem, I will kick it really hard. There you go. Piggy, you went the wrong way.*
Christine:	*He-he, oopsy, let me try again.*
Sophia & Christine:	*Aren't we having so much fun?*
Sophia:	*Gravity pulls you down.*
Christine:	*Gravity pulls you down.*
Sophia:	*A hard push will make something spin fast.*

Christine:	*A light push will make something spin slow.*
Sophia:	*A light kick will make the ball move a little.*
Christine:	*A strong kick will make the ball travel far.*
Sophia & Christine:	*The End. Hope you enjoyed the show* (Adapted from Fleer & Hoban, 2013, p. 66).

We deliberately introduce this Slowmation example as an explicit investigation of the scientific concept of *force* by a young child and her teacher because we use it to introduce a different conceptualization of early childhood science education. At the beginning of this chapter we shared the tacit intuitive engagement with the concept of *force* that is experienced by Sophia in the park, where Uncle JJ begins by spinning Sophia. Uncle JJ says, "You should know how to spin it yourself…" Sophia responds by saying, "Hold on tight" as Uncle JJ beings to spin her whilst she says, *"Yes hold on tight".* Sophia holds tightly onto the pole.

Rather than conceptualizing this reading of Sophia's experiences as part of building an intuitive understanding of *force* as explained by the concept of *Children's Science,* or potentially building an *alternative view of force,* we prefer to conceptualise this as Sophia's *everyday concept* of *force*. Here we use Vygotsky (1987) concept of everyday concepts and scientific concepts for our analysis. Vygotsky argued that "*The existence of a concept does not coincide with consciousness of that concept either in the moment of its appearance or in its mode of functioning.* The former may appear earlier than the latter and act independently of it. Analysis of reality on the basis of the concept emerges much earlier than analysis of the concept itself" (p. 161; Original emphasis). Much of the alternative conceptions literature suggested that children's ideas in science get in the way of learning scientific concepts, and once formed they are difficult to 'remove' (see critique by Fleer & Robbins, 2003b) as discussed previously. However, a cultural-historical reading would suggest that it is important for children to develop everyday concepts of their experiences, as these may arise earlier than scientific concepts, or later than scientific concepts, or even at the same time. But regardless of when an everyday concept is formed, everyday concepts **are central**, *not alternative*, for developing a scientific concept. For instance, a cultural-historical analysis seeks to capture both the everyday concept of *force*, alongside of how the child gains a conscious awareness of the concept. We begin to see this consciousness emerging in the everyday situation of Sophia spinning, and Christine using everyday language to draw her attention to the experience *"Is your head spinning too?"* Sophia does not respond to this, but rather references the concrete situation by saying, *"No, but the wheel is…".* Vygotsky has argued that "We know from research on concept formation that the concept is not simply a collection of associative connections learned with the aid of memory. We know that the concept is not an automatic mental habit, but a *complex and true act of thinking* that cannot be mastered through simple memorization. The child's thought must be raised to a higher level for the concept to arise in consciousness.

Table 1.1 Everyday concepts and scientific concepts

<table>
<tr><th>Everyday concepts</th><th>Scientific concepts</th></tr>
<tr><td>Sophia knows that Uncle JJ can make her spin faster; she uses the term ‘faster’</td><td rowspan="3">Force is required to get a still object to start moving. The greater the force, the greater the speed. However, the friction between the object and the surface slows down the speed. Force exerted in opposite direction of the moving object will cause it to slow down or stop.</td></tr>
<tr><td>Sophia is aware that when it spins too fast, there is a danger of falling off</td></tr>
<tr><td>Sophia knows that she can stop Uncle JJ from moving by using her arms and body strength</td></tr>
</table>

Adapted from Fleer and Hoban (2012, p. 65)

At any stage of this development, the concept is *an act of generalization*” (p. 169; Original emphasis). In this reading of children’s thinking, everyday concepts build in breadth, depth and complexity as the child experiences more. In Table 1.1 we see the generalization of the everyday concept of force that is being lived as Sophia plays in the park with her Uncle JJ. But we also know that there is a scientific explanation of force as detailed on the right, as part of Christine’s teaching program of intentional teaching of the concept of force to Sophia (as planned by using Slowmation). Vygotsky argued that “The process of defining the concept when it is torn from the concrete situation in which it was developed, when it no longer depends on concrete impressions and begins to develop in an entirely abstract plane, is significantly more difficult” (p. 161). Scientific concepts do not by their very nature have built into them some internal form of logic that can be reproduced by the child (ie as though somehow moving from Buridan to Newtonian explanations of force), but rather they are cultural inventions that are inherited by children from the society in which they grow up. We capture scientific concepts through truncated and specialized terms, formulae and explanations. They are built in practice, named and then abstractly used away from their original site of conceptualisation. Therefore the limitation of everyday concepts must lie in ‘its *incapacity for abstraction’* because without naming the practice and giving it an explanation, it cannot be transported to another context. Conversely, when the scientific term is introduced to a child away from its site of use or development, then the weakness of the scientific concept lies in its “*verbalism*, in its insufficient saturation with the concrete” (p. 169).

Vygotsky suggested that everyday concepts lay the foundations for scientific thinking. However, he also said that scientific concepts lay the foundations for everyday conceptual thinking. The question is how are these two concepts interrelated so that they become foundations for each other? Vygotsky used the concept of a shadow to eloquently present this challenge to us: “What is the relationship between instruction, learning, and the processes involved in the internal development of scientific concepts in the child’s consciousness? Are these simply two aspects of what is essentially one and the same process? Does the process involved in the internal development of concepts follow instruction like a shadow follows the object which casts it, not coinciding with it but reproducing and repeating its movement, or do both processes exist in a more complex and subtle relationship which requires special investigation?" (p. 169).

Vygotsky (1987) has argued that the *direct* teaching of a concept is 'pedagogically fruitless'. When teaching of science occurs through verbal instruction or by giving scientific explanations of particular concepts, such as *force*, away from the everyday context, then this "achieves nothing but mindless learning of words" and under "these conditions the child learns not the concept but the word and this word is taken over by the child through memory rather than thought" (p. 170). Conversely, the experiences of the concept in everyday life, whilst providing a valuable intuitive and sensory based experience, does not on its own lead to conceptual development or the understanding of a concept such as *force*. Rather, it is the relations between everyday concepts and scientific concepts that leads to conceptual development. According to Vygotsky:

> These two types of concepts are not encapsulated or isolated in the child's consciousness. They are not separated from one another by an impenetrable wall nor do they flow in two isolated channels. They interact continually. This will inevitably lead to a situation where generalizations with a comparatively complex structure – such as scientific concepts – elicit changes in the structure of spontaneous concepts. Whether we refer to the development of spontaneous concepts or scientific ones, we are dealing with the development of a unified process of concept formation. By its very nature, however, it remains a unified process. It is not a function of struggle, conflict, or antagonism between two mutually exclusive forms of thinking. (p. 177).

In contrast, conflict between concepts underpins not only the work of Piaget (i.e. cognitive conflict), but has been used for many socioscientific teaching programs which seek to foster argumentation and create debate around general societal issues. This is the case mostly for programs designed for students outside of the early childhood period. In this theoretical reading "it is only the *child's spontaneous concepts and representations* which can serve as the source of direct knowledge of the unique qualities of the child's thought" (Vygotsky, 1987, p. 174; Our emphasis), and these are generally considered in relation to the views of the adults which surround the child. In separating out everyday concepts from scientific concepts, this implies that they have no relationship to each other (as the boundary in Fig. 1.2 shows). Here too, the practical value of the everyday concepts held by the child is not considered, other than as something in need of conceptual change.

A cultural-historical reading of the relations between everyday concepts and scientific concepts places great value on the everyday concepts, because it is through the act of capturing the everyday experiences, naming these through word labels in practice, that the child begins to develop a conscious realization and potential generalization for these everyday concepts. "When the child first learns a new word the development of its meaning is not completed but has only begun". (Vygotsky, 1987, p. 170). Vygotsky has shown that "the word acts as a means of forming the concept" (p. 165), and this is only part of the process of conceptual development.

According to Vygotsky scientific concepts can arise only "on the foundation provided by the lower and more elementary forms of generalization which previously exists. They cannot be simply introduced into the child's consciousness from the outside" (p. 177). Here we see the significance of the relations between everyday concepts to scientific concepts. However, what is the relations between the scientific concepts to everyday concepts? What does this means for science education? This relation can best be captured through an analogy, first cited by Vygotsky in relation to learning a new language. A child speaks her/his mother tongue, but has no conscious awareness of the grammatical structures and forms of speech that are used. It is only through the study of a second language, that the child's attention is drawn to the forms of speech and the grammatical structures inherent in the new language. It is through explicitly examining the second language that it is possible to recognize the verbs, nouns, adjectives, and grammatical structures of the mother tongue. But it is precisely because the mother tongue is already well developed that it becomes possible to recognise its basic structure and a greater level of awareness or consciousness arises for the child, previously not possible. Although the pathways to learning are different, their relations are tightly fused. One gives meaning to the other. The relations between everyday concepts and scientific concepts operate in exactly the same way. Introducing scientific concepts support the awareness raising of concepts that are enacted in everyday practice. New meaning is created in everyday practice as scientific concepts are introduced and conceptual development occurs. However, without the everyday concepts in practice, no meaning can be given to the words of the scientific concepts. Scientific concepts are given meaning through these everyday experiences. Conscious awareness of scientific concepts is clearly a special process, but what does this really mean in science based practice?

If we examine the slowmation example at the beginning of this section we can see that Christine sought to explicitly bring together Sophia's everyday concepts with scientific concepts. She did this by reproducing the play experience as a slowmation animation. What is important here, is that Christina and Sophia had to think about the everyday experiences of playing in the park and to create a representation of these in some way. The soft toys and the plasticine provided the resources for animating the experiences. This level of abstraction is still located within the everyday experiences of the child, as connected to the concrete lived event. However, the creation of a script for narration, not only provided the means for making aspects of the experience more conscious, it provided the mechanism for introducing a scientific explanation of the everyday concepts. For example, in the scene of the see-saw, Sophia says in the narration, "Yay, see-saw, I can go up and down. Why can't I go up?", and Christine responds "Hello Doggy, that's because gravity pulls you down. But I'm heavier than you. See, now I go down and you go up. Just give a little kick and we will go up and down, up and down."

Labeling the different sources of *force* in a park as occurs in the narration, and through the actual signs that are used to punctuate the significance of the forces that are acting, this creates a dialogue that moves the child's thinking from the everyday concepts and to the scientific concept of *force*. Having all of the sources of *force* that are acting during a particular everyday experience, such as the see-saw, is as important, as undertaking an audit of the forces that are acting as a result of all of the equipment, particularly equipment that is not moving. The latter being the more difficult idea for young children to contemplate. The scientific concept is more than a word. The development of a scientific concept captures the complexity of the movement between the everyday concepts and the scientific concept, and together over time the young child begins to think and act using scientific concepts.

Here the relations between learning and development are important. In this book we draw upon Hedegaard and Fleer's (2013, p. 183) conceptualisation of learning as a change in the child's "relation to another person and activities in specific settings" as a result of learning science concepts. The child is able to think and act differently in their world. We define development as a process where "children's motive orientation and engagement in different activity settings change qualitatively" and as such their leading motive changes (Hedegaard and Fleer, 2013, p. 183). In early childhood this usually means a change from a play motive to a learning motive. But these constructs of learning and development are interrelated. We examine the relations between learning and development throughout this book through examples taken from our research and the research of others. In the final chapter we discuss this relation explicitly in the context of introducing a model for science teaching suitable for early childhood settings.

In the next chapter we turn our attention to the child as a learner within the preschool environment, in order to determine how the resources and the structures support learning in science.

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