Chapter 6
Knowledge Construction Is Culturally Situated: The Human Invention of Empirical, Narrative and Theoretical Knowledges

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Abstract In this chapter the different forms of knowledge construction that are typically illustrated in the literature are examined alongside of data that have been used to illustrate what they look like in practice. Three forms of knowledge are introduced: narrative, empirical and theoretical. Paradigmatic thinking and dialectical thinking are discussed in the context of generating scientific knowledge. Examples from both the science education literature and a study of preschool children learning about mixing materials are given. However, knowledge construction in these forms is not a common framework for reporting (or even discussing) reports in science education research. As such, studies which demonstrate different forms of knowledge construction in science learning are drawn upon and used alongside of empirical data generated by the preschool children studying the mixing of substances (empirical and narrative) and the form and structure of insects (theoretical) found in the outdoor area in the preschool. The latter highlights both commonplace practices found in preschools for teaching science, and discusses the challenge of introducing empirical knowledge in a play-based setting and puts forward evidence on how theoretical knowledge can be introduced to young children.

Keywords Knowledge construction • Empirical knowledge • Narrative knowledge • Theoretical knowledge

6.1 Introduction

> The word *science* was deliberately chosen to replace *natural philosophy* during the political birth of a new organization in 1831: the British Association for the Advancement of Science … As a result of the evolution of natural philosophy into professional science, present-day science is strongly based on Euro-American thinking. . . most scientists' professional culture is Eurocentre in character, and can be described as *Eurocentric science* or *Western science* (Aikenhead & Michell, 2011, pp. 21–22).

Aikenhead and Michell (2011) suggest that there are many forms of knowledge that are culturally specific, and that Western science is one form of knowledge. So what kinds of knowledges do we privilege in early childhood settings when we

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teach science? This chapter examines three forms of knowledge that children can and do develop through the study of science in the early childhood settings. We begin by specifically introducing case examples of how empirical and narrative knowledge are formed in early childhood centres. We then contrast this with the development of theoretical knowledge for children through presenting a case example of science teaching in one centre were the focus was on paradigmatic thinking. The point we wish to make in this chapter is that most early childhood teachers privilege narrative thinking and learning when they do not take an active role in science education, leaving it to the resources 'to do the teaching of science'.

What do we mean by empirical, narrative and theoretical knowledge? These forms of knowledge construction are introduced in the next section through case examples to illustrate these knowledge forms in relation to the pedagogy used for teaching science to young children.

6.2 Empirical Knowledge

Empirical knowledge and paradigmatic thinking has been discussed in relation to science education (as well as other subject matter areas), through the metaphor of building blocks. Blocks of knowledge are learned in school science or discovered in the scientific community, and these blocks of knowledge build one on top of the other. These blocks of knowledge are abstracted concepts. According to this knowledge tradition, they are formed as a result of close observation, descriptions of those observations are made, classification of what has been observed is undertaken, and some form of quantification to document what has been discovered results. The assumptions underpinning empirical knowledge is that knowledge can be observed, quantified, presented as an accurate representation of what was observed, and understood as abstracted concepts, and then used away from the site of the original observation. The building up of this knowledge over time, like the blocks in a tower, continues unless one of the blocks or information is proven wrong.

In science curricula these building blocks of knowledge are ones that students must learn if they are to acquire the necessary science knowledge deemed important within both the scientific and education community within a particular society. Blocks of knowledge are often categorised around specific content areas within science, such as biology, physics, and chemistry. How these content areas in science relate to each other may not always be the focus of attention, but rather knowing the science knowledge (building block) is what dominates in many schools, and this has been a source of criticism, blamed for turning students off learning in the sciences. Hedegaard and Chaiklin (2005) have suggested that "If instruction is based only on empirical knowledge it will orient pupils to acquiring concepts from different subject domains that are not related to each other or to their local life world" (p. 54).

The disassociation of knowledge from the site of its construction, as is how science content knowledge is commonly conceptualized, is also a problem for teachers. For example, early childhood teachers who learn concepts in isolation from their construction, as blocks of knowledge to acquire, also find it difficult to then

Table 6.1 Interview of teacher beliefs about constructing empirical knowledge

Teacher	….parent's will find out that their children are learning more than just numbers and that….outside they didn't call it potions and I actually heard them use the word stuff…..**I'd rather the children didn't say this is a potion….. they didn't have fixed word for it….**
Research Assistant	The potion play went on too……it all flowed from one thing to the next and the next… from cooking to poisoning to siphoning…
Teacher	…it all just evolved….
Research Assistant	**…..so the potion could be anything…it's a non specific word……generic…and assumes that transformations can happen.**
	The leaves today went ….to cooking, perfumes, and experimenting with water, smell….various sequences…..but scientific words I didn't hear much
Teacher	There are children coming out and in …when they want… I really liked the independence…I **did not set** up one thing ….the children did it all themselves…..and **I was really pleased** with **that because I just think people set things up too much for the children.**

Adapted from Fleer (2009a)

work out how these knowledges can be taught to young children. In the following interview about a science teaching program on materials, we see that the preschool teacher was keen to introduce science activities to her children, but she found it difficult herself to know what were the concepts and how the concepts could be reproduced in the activity, or how knowing the concept could solve a problem or address a personal need of the children. Rather, her focus was on just setting up the environment to see what might happen, what the children would do with the materials. In the example, we see that the teacher and the assistant teacher gave a different perspective on how to organise science learning for the children (Table 6.1).

Without adult suggestions about what to do with the materials, the teacher believed that the resources themselves would generate learning opportunities.

In the actual teaching program the teacher provided oil, water, vinegar, and shaving cream for the children to mix. The teacher also placed an array of pumps, buckets, different sized containers, water, and dyes for the children to explore, as shown in Fig. 6.1. This activity was named by the children as 'potions'. She wished the children to learn about mixing substances together, as an activity to support science learning. But the teacher did not frame the experience in any particular way. Rather she simply provided the materials, as a form of discovery learning.

This approach to teaching and learning in early childhood education is commonplace. Teachers generally do not set up controlled experiments for the generation of empirical knowledge. The teacher's interactions with children in these situations is about supporting the children's free exploration of the materials, perhaps drawing their attention to what is happening as they are mixing the materials. The experiences remain

Fig. 6.1 Children explore materials by mixing substances together

at the everyday level, because no system for focusing the children's attention on the materials occurs, no descriptions of those observations are made via photographs or drawings, the classification of what has been observed is not undertaken or discussed across the group, and no form of quantification to document what has been discovered results. Consequently, no empirical knowledge is formed for the children, but rather a deepening of everyday concepts of these everyday materials results.

In the example that follows, we observe how the teacher introduced above through the interview, explored materials in the sandpit with a group of children (see Fleer, 2009b). The teacher placed a range of items on the edge of the sandpit for the children to use in their free play. The children had oil, vinegar, shaving cream, water, and sand, plus a range of containers. In the first part of this transcript, the teacher labeled Lana's play as an experiment. Lana also used this language.

6.2.1 *Observation: Mixing Oil in Sandpit (26.8)*

Teacher: "*Um it's it's Lana's oil experiment*" (Lana pouring oil into a bowl, puts oil down, makes sure the lids on and then turns the oil container so that the label is facing her).

Lana: "*There*". (picks up oil container and looks at the label)

"*Baking, oil experiment*" (Puts oil container down and picks up container with mixture and walks to another area where Molly is playing. Lana puts sand into her container and swishes it around. Molly then gets up and goes to where Lana was. The child then brings the oil back and starts pouring it into another container).

"*Oh this is working babe*" (Lana looks up as she speaks, walking back to a pretend oven and puts ingredients into the space).

The teacher sat alongside of the two children – Molly and Lana – and interacted with them as they poured or sprinkled into the different containers the materials available to them. Molly took an oil bottle over to her teacher and asked her to close the lid.

Teacher: "*Ah that is hard to shut isn't it?"* (Molly tries to push lid down).
Molly: "*Hard to shut".*
Teacher: "*So what are you going to do with it?".*
Molly: "*Shake it".*

The teacher begins to direct the children's attention to the materials in the containers. The teacher's focus of attention was on 'mixing' substances and using their senses to notice any changes. However, as becomes evident in the interactions of the child with the teacher, Lana's focus of attention was on cooking meat. She had created an imaginary situation of cooking in the sandpit. The oil and vinegar containers and their actual contents, suggested 'cooking' to these children – cooking meat specifically.

Lana: (Child is mixing ingredients in a bowl). "*I'm going to mix this* (Teacher: *hm-hm*) *all the way to the bottom, to the end*."
Teacher: "*What does it smell like?".*
Lana: "*Um, cause I'm making meat".*
Teacher: "*You're making?*".
Lana: "*Meat*".
Teacher: "*Meat okay*" (Lana stops mixing and pours oil in). "*More oil?*".

The teacher tried to explicitly point out to Molly and Lana that the substances were not mixing together. Molly attributed this to the physical difficultly of mixing. Molly's focus of attention returned to cooking, and this time she suggested that she was 'making different kinds of oil'.

Teacher: "*What can you see Molly what can you see?"* (tilts container).
Molly: "*Oh water and oil".*
Teacher: "What's this at the top?" (Molly looking). "*Can you see how something's at the top and there's other stuff at the bottom and then?".*
Molly: "*There's oil* (points to top) *there's um water* (points in middle) (Research Assistant-yep) and there's sand (points to bottom)".
Teacher: "*Why do you think it does that?*".
Molly: "*Cause I put it in there I put them all in there*".

Teacher: "*Yeah but why do they all stay layered I thought you shook it?*" (Molly starts shaking).
Molly: "I couldn't shake it properly".
Teacher: "*You can't shake it properly well how about we shake it together* (shaking together) *here we go. We're doing really well together aren't we?*".
Lana: "*Yeah we make some more different oil*".
Teacher: "Okay let's have a look at it".
Lana: "I make some more different oil".
Teacher: "See we shook that didn't we Molly but it's still the same".
Lana: "I make some more" (comes over to Molly and teacher and observes).
Molly: "Yeah but it ?" (pushes on lid).
Lana: "I make some different oil".
Teacher: "Okay you made some different oil" (Lana pours oil into bowl and Molly looks on).

The teacher worked hard to re-direct the children's attention from making meat to looking at the mixing of the oil, water and sand. The children took note, but focused on 'making different oils'. The activity did not support scientific thinking, but rather provided the children with a playful event where they expanded their experiences of playing with cooking oil. Later the teacher asked the children to comment again on the materials in the mixture, but the response from the children indicated that they had reframed the experience in relation to cooking once more:

Lana: "Put a little bit, a little bit more sand (grabs a handful of sand and puts it into bowl) little bit, mix it all around".(Picks up handful of sand with other hand and puts it into the bowl) "Lots of sand" (Mixes then picks up oil and pours it into bowl).
Teacher: A different type of oil.
Lana: (Puts oil down and grabs something else and puts it down next to the oil. Opens up oil and stands up).
Teacher: "How come there's all these spots in it?" (Pointing in bowl, Lana leans forward and looks into bowl).
Lana: "Oh cause that's my meat" (Stands up and walks away with oil).

The children used their everyday concepts of these substances provided, having seen them used in cooking, in order to contextualise their experimentation. Their investigations in these playful events focused on mixing but not in relation to developing a scientific understanding about the nature of materials, but rather through pretending to be cooking meat. Because the children were in an imaginary situation, they were not thinking about the resources in relation to the concept of materials and their properties they were using to support their cooking. The teaching program was not organized to build empirical knowledge through a systematic approach to knowledge construction using a form of scientific method suitable for preschool children. Rather the children were left to make sense of the materials on their own, and when the teacher joined the children it was not possible for them to leave their imaginary situation and to focus on the real attributes of the materials.

This example highlights both commonplace practices and the challenge of introducing empirical knowledge in a play-based setting. It also shows why it is important for a teacher to be clear about what empirical knowledge s/he wishes to introduce. That is, if the focus is on exploring the materials (and not setting them up in a particular scientific way) then it is important that the experiences will allow for a particular kind of scientific concept to be discovered. In the example given, the teacher introduced a range of materials, but the combination of these materials through the children's mixing of them, did not necessarily lend themselves to generating empirical knowledge through discovery learning.

Whilst empirical knowledge is highly valued in society, as demonstrated by the fact that most countries have a science education curriculum of some kind, there are limitations to this form of knowledge construction, as evidenced by the way this knowledge is taught in preschools and schools (Carter, 2007). We now turn to another form of knowledge construction that is common in preschools – narrative knowledge.

6.3 Narrative Knowledge

Jerome Bruner in his book *Actual minds, possible worlds*, conceptualised an epistemology for a proposed set of characteristics of narrative knowledge and thinking. He argued that "We know the world in different ways, from different stances, and each of the ways in which we know it produces different structures or representations, or, indeed, "realities." (p. 109). Bruner argued back in 1983 that "Narrative deals with the vicissitudes of human intentions" and stories contain well-formed realizations (p. 16) of these vicissitudes. With narratives, arguments that are pro and cons are deemed more interesting than conclusive. Knowledge construction in this form is about constructing a convincing story. As Bruner (1986) states that:

> In the *telling* there must be "triggers" that release responses in the reader's mind, that transform a banal fibula into a masterpiece of literary narrative... Whatever the medium-whether words, cinema, abstract animation, theater-one can always distinguish between the fibula or basic story stuff, the events to be related in the narrative, and the "plot" or just, the story as told by linking the events together (p. 19).

What we see emerging in narratives is a dual landscape, where both reality and fantasy occur concurrently as human plight is contemplated in the narrative:

> the reader is helped to enter the life and mind of the protagonists: their consciousness are the magnets for empathy. The matching of "inner" vision and "outer" reality is, moreover, a classic human plight (pp. 20–21).

Narratives have their own internal structure and logic for building characters. For instance:

> . . . in the folktale, character is a *function* of a highly constrained plot, the chief role of character being to lay out a plot role as hero, false hero, helper, villain, and so on. For while

> it may be the case that in the time-smoothed folktale story-stuff determines character (and therefore character cannot be central), it is equally true that in the "modern" novel plot is derived form the working out of character in a particular setting (on of the earliest theorists of modernism, therefore, being Aristotle on tragedy!)" (p. 20).

Structures such as plight is also significant:

> the fibula of story-its timeless underlying theme-seem to be a unity that incorporates at least three constituents. It contains a *plight* into which *characters* have fallen as a result to intentions that have gone awry either because of circumstances, of the "character of character," or most likely of the interaction between the two. And it requires an uneven distribution of underlying consciousness among the characters with respect to plight. What gives the story its unit is the manner in which plight, characters, and consciousness interact to yield a structure that has a start, a development, and a "sense of an ending". Whether it is sufficient to characterize this unified structure as *stead state, breach, crisis, redress* is difficult to know. It is certainly not *necessary* to do so, for what one seeks in story structure is precisely how plight, character, and consciousness are integrated (p. 21).

Narrative dialogical thinking helps children to conceptualise experience and construct personal meaning that can be transcended from situated experience to general human and societal life. To do this, Bruner (1986) worked with three categories for formulating a narrative method. For instance, *presupposition* captures the idea of creating implicit meaning. Implicitness dominates, rather than explicit meaning. *Subjectification* is foregrounded in the narrative method, where reality is constructed through personal subjective narratives rather than objective processes. Multiple perspectives are also valued. Instead of a single universal truth, narratives feature different perspectives expressing segments or parts of a constructed reality. Bruner argued that "we become increasingly adept at seeing the same set of events from *multiple* perspectives or stances" (p. 109). These 'folk theories' of everyday events are built and expressed through a range of media, and this represents knowledge construction and models of thinking of daily life that is common among most young children. What children gain is an internal form of logic that is principled.

Bruner (1986) in contrasting narrative knowledge with empirical knowledge construction, states that with the formulation of the latter through experiments, the knowledge generated tells "us nothing about the discourse that converts an unworded narrative into powerful and haunting stories" (p. 19). Most experiences of the world go beyond documenting events and actions into rational or scientific knowledge, where accounts must be "replicable, interpersonally amenable to calibration and easy correction" (p. 110). An example of this form of principled knowledge construction in the same preschool described above is discussed further below (Fleer, 2009a, 2009b). In the example that follows, the children did not make meaning of the objects as intended by the teacher. Rather than producing empirical knowledge in science about an array of scientific concepts, the children made meaning of the situation by drawing upon a known narrative of a nursery rhyme of humpty dumpty as a form of narrative knowledge, extending it further to include an activity of medicating humpty dumpty as a way of 'repairing humpty after falling off the wall'.

6.3.1 *Transcript: Medicine for Humpty Dumpty (23.8)*

Three girls at a table outside, they have two plastic bottles one has a spoon in it the other has a pump action dispenser. There is a Humpty Dumpty soft toy nearby.

Jayde:	He fell off the wall again and this is a girl Humpty
Lana:	Humpty fell off the wall again
Grey Girl:	Wait I'll spray it I have to spray it. (takes spoon out and puts it under the dispenser and fills spoon)
Jayde:	Oh hi ah Humpty Dumpty
Lana:	Hello
Grey Girl:	Here you go (passes spoon to Jayde)
Jayde:	Hello how are you today (Another child wearing cream jacket joins)
Cream Girl:	Ah let me see. (Comes over to table, is holding a mobile phone in one hand and touches Humpty Dumpty's arm) touch it here.
Green Girl:	Yes he's dead, he's dead I knew he he's dead. (climbs onto table, little girl with black jumper leaves).

The children had to draw upon known narratives in order to make personal meaning of the materials provided by the teacher, because the materials, made no sense to the children, and the teacher did not introduce a conceptual framework to the children for generating empirical knowledge. Rather what happened was that the group of children used the narrative of Humpty Dumpty to bring their everyday understandings of medicine together with their understandings of healing Humpty Dumpty who has fallen off the wall. Potions for these children was not about materials and their properties to be gleaned through mixing, but rather it was about medicine and caring for people in the community. The conceptual focus for the children was personal, and their way of working with the materials and knowledge construction was narrative.

As often happens in preschool settings, the science activities provided by the teacher were used by the children in ways unintended by the teacher, as the children explored common personal experiences in their play of being given foul tasting medicine. Many teachers acknowledge that this will happen, often stating "Let's see what they will do with this" or "Let's find out where these materials will lead the children". Narrative knowledge construction and thinking is common in early childhood settings, and fits with the pedagogy of a play-based curriculum, where a great deal of role-play occurs. The example above not only illustrates how children create narrative knowledge in early childhood settings, but it demonstrates how personal knowledge construction in early childhood science education occurs when adults are not involved, or minimally involved in the process.

In the next section we examine another form of knowledge construction that includes empirical and narrative knowledge construction, but draws upon a different form of logic for realizing science learning for young children. The case example examines theoretical knowledge and paradigmatic thinking.

6.4 Theoretical Knowledge

We begin this section by introducing Davydov's (2008) theorisation of the term 'concept' followed by a discussion of how he used this term in theoretical knowledge construction with children. According to Davydov a concept can both *represent* a material object *and* be used to *reflect* on that material object. The concept allows for a particular mental action to occur. To do this, a child must first be aware of the material object, in order to form a conscious mental representation of that object. For example, the air that surrounds children will be experienced intuitively as part of transpiration and as a force when they are running or riding their bikes or playing with prams and toy cars. However, children will not necessarily consciously consider the air that surrounds them, let alone factor it into their play as one force that is acting upon their toys. We know from research that young children do not consciously consider air, or even contemplate air as a material (see Sere, 1985).

It is only when children consciously consider an object, that they can give it a new meaning. In preschool settings children are already well practiced in giving new meaning to objects in their play, such as when a stick becomes a hobby-horse or when a box becomes a car (Fleer, 2011). In science education, teachers also want children to give new meanings to objects in their environment, but they wish for children to develop a scientific meaning of that environment. In play-based programs what is needed is teacher mediation to frame or draw attention to the natural environment as affording scientific meaning (see Chap. 2). As we noted above, teacher mediation is critical for helping children to develop a scientific meaning of their environment.

Davydov (2008) argues that concept formation that successfully builds theoretical knowledge and dialectical thinking is about a system of concepts that are relationally linked and relationally understood. For example, young children regularly interact with their natural environment when playing in the outdoor preschool area, but are unlikely to consciously realize that they are a part of a natural ecosystem. Children find things in their environment, both at preschool and at home. They will look under leaf litter, sheets of tin, stones and logs and discover all kinds of insects. They may observe these insects, re-discovering these kinds of insects in other contexts. To build theoretical knowledge requires a particular kind of mediation by the teacher, so that children look with scientific eyes, as they build an understanding of their finds in relation to the ecosystem. Research by Fleer (2011) has shown that to achieve this, the teacher needs to:

1. determine what might be the core scientific concepts to be learned;
2. engage children in considering both the particular (e.g., ant), and the general (species classification)
3. support children to re-create their learning as models (often rudimentary)
4. *rise to the concrete* by having the opportunity to consider how the abstract knowledge (e.g., species classification) was formed in the first place (observing form, function, food source, and habitat of a particular insect)

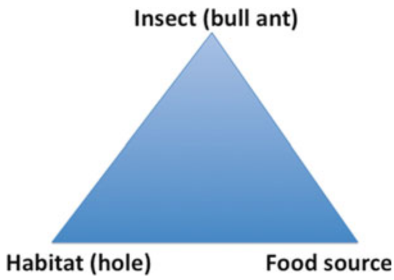

Fig. 6.2 Determining core concepts – beginning with the child's personal interest of a "bull-ant in the wrong place"

Core Concepts Davydov (2008) argues that for theoretical knowledge construction to occur, that the essence of the concept must be determined. What really matters for concept formation when a child finds an ant in the 'wrong place'? What concept or theoretical knowledge could the teacher develop in this situation? Unlike the example of the teacher who provided materials for mixing substances, where the children used and developed narrative knowledge, the following example (Fleer, 2010, 2011) illustrates theoretical knowledge construction. The teacher did not just provide materials to the children to see what would happen, rather in the following example the teacher specifically considered the essence of the scientific concept she was seeking to develop. The teacher considered the child's comment about the bull-ant being in the wrong place, and used this as an opportunity to build theoretical knowledge about an ecosystem, where relational understandings is central.

The teacher considers the child's find (i.e., the ant) and determines what might be the core concepts for building theoretical knowledge and dialectical thinking. That is, she considers an ecosystem where habitat, structure of the insect, and food are all related (Fig. 6.2). The teacher determines the core concepts within a system of concepts that s/he believes are necessary for the child to build relational knowledge. For instance, looking at the relations between what the child finds, the habitat in which it was found, and the food sources available. This rudimentary ecosystem is a theoretical model that helps children move beyond single and disconnected forays when exploring their environment to a more systematic conceptual investigation of their natural environment.

With theoretical knowledge of an ecosystem, children explore their environment in a particular way. Davydov (1990) in drawing upon Davydova has argued that theoretical knowledge 'always pertains to a *system of interaction,* the realm of successively connected phenomena that, in their totality, make up an organized whole' (p. 254).

In the field notes that follow (see Fleer, 2011 for details of the study), we describe a context where a child has found an insect in 'the wrong place'. The teacher used the opportunity to introduce investigative tools, such as magnifying glasses, insect boxes, and binoculars, to frame how children engaged with their environment. The teacher conceptualised the experiences that follow, by supporting the idea of a map, and the task of mapping the finds.

6.4.1 Map and Treasure Hunt

Christian adapts a treasure hunt activity from the day before and takes the map he's made and marked with an X inviting Teacher J to follow him outside to hunt for bugs.

Teacher J: *Should we go and find the path?*
Christian: *Yes…*

Christian has spent time each day looking carefully around the yard with binoculars and magnifiers but today he is the trying to use the abstracted view of the yard that his map represents to locate bug treasure at point X. This is a new experience and challenge and he seeks support from his teacher to embark on this venture.

Christian: *…(can we find it) …without the map*
Gale: *I gave something to Christian.* (Gail hands Christian something to encourage his treasure hunt search in the environment)

All four children follow Christian and the teacher (14.2).

Davydov (2008) explains that children's investigations begin as 'flashing impressions', where elements of significance are singled out or are conceptualized as the 'essence of the thing' being observed. That is, children may notice that a specific insect can be found in specific locations within the preschool, such as a slater under rotting wooden logs, or ants coming out of ant holes. Knowing about the *relational link* between insect and habitat as a rudimentary model for an ecosystem, valued by Western science, is an important concept for children to learn.

In building theoretical knowledge, what is to be developed is not just an understanding about a particular insect, but rather a concept of an insect, within a system of relational concepts (insect form and structure, habitat, food source) which together make up the universal concept of 'an ecosystem' and 'classification system of living things', as is detailed in many science curriculum documents.

Dialectical Relations Between the Particular and the General Children need to consider both the particular ant, and the general conceptualization of insects in an ecosystem. Building theoretical knowledge is also about the particular and the general. Davydov (2008) stated that children need practice at concurrently thinking about the particular (individual organism – e.g., ant), and thinking about the general system of concepts (e.g., insect as a classification system). Investigating an outdoor area of a preschool, creating a map, allows children to move from the general to the particular, and from the particular to the general – as a dialectical process. Here children also concurrently deal with the imaginary situation of the map and the real situation of the outdoor area. In the case example introduced above, the teacher also used books and photocopied sheets of insect classifications to support Christian's investigation of insects in the preschool environment. The field notes show how the teacher moved Christian from the particular ant to a more general conception of insects.

6.5 Naming Bugs (27.2)

Teacher J has charts and insect identity sheets as resources for children in the centre who want to name the bugs they find. Christian has found a 'bug' and believes it to be a centipede. He brings it indoors for clarification of identification. Christian looks closely at the chart and points to and names, the Centipede, Mosquito, Praying Mantis and Lacewing.

Christian:	I think that's a centipede
Teacher J:	I think that's a centipede. Yep. I'll read the word centipede yep that one's a centipede. That one's a millipede. They're the ones we find around the kinder all the time.
Colleen:	We found one. Sticks on. I think it will go through those holes.
Christian:	Mosquito.
Teacher J:	That one's called a scorpion fly.
Christian:	Praying mantis.
Teacher J:	Special names.
Colleen:	Praying mantis.
Teacher J:	Yep.
Christian:	Lacewing.

The naming of small creatures represents a bringing together of aspects of children's scientific knowledge (as Christian shares his understandings) and observational knowledge of the insects the children have actively sought, uncovered, cared for and played with, in their environment. Davydov (2008) argued that the essence of the learning must also be crystallised into a model. That is, examining resources without actively constructing a model of the essence of what is being investigated would not go far enough in the quest for developing theoretical knowledge.

Modeling Representing thinking as a model is possible within play-based programs because resources and time are readily available for engaging in drawing, painting, collage and box construction. In the example of the bull-ant in the wrong place, the teacher invited the children to represent their understandings as action drawings, paintings and collage. In reproducing the form and function of the ant in relation to it's habitat, Christian created a 'pac-man munching machine' and a 'bull-ant going to the dentist'. Although not fully functioning models, these examples illustrate how children make meaning and document their growing understandings of relational concepts as a rudimentary model. The field notes and transcripts of modeling making are shown in Table 6.2.

Rising to the Concrete Modeling helps children to *rise to the concrete*. Rising to the concrete encompasses the pedagogical principle of initially examining a holistic system and mentally ascending to this system in order to determine its specific nature. Through establishing the individual relations it is possible to observe its universal character. Through this kind of contemplation, children discover a general law. For example, a bull-ant can be found in relation to its habitat. In this relational

Table 6.2 Modeling with mediums of painting and collage

Observations	Transcript	Field notes
27.2 Bug machine *Christian is at a table with food dye and brushes when he spontaneously paints and explains about a machine he has represented on paper that can suck up bull-ants. The machine he painted represented a functional solution to managing stray bull ants that might bite and offered thought as to what might happen should they get sick*	*Christian: It goes up there and it gets the ants and this is when they go to the dentist.* Teacher J: *Go to the dentist?* *Christian: Yeah that's when they get sick and then they go here*	*The day before he had found a large bull ant near the sand pit and called for his teacher to come and get it. She had carefully removed it (using a glass and cardboard) to the adjacent bush land whilst he watched and told her about how bull ants have jaws and teeth to bite.*
21.2 Pacman person chomping *Christian continues to re-present his earlier idea about digestion and has chosen the collage table to create an imaginary bug like pac-man from a round piece of paper. He wants the character to function with a mouth that opens so it can 'burp, eat, bite and chomp'. With encouragement from assistant Teacher P, he cuts a design that allows the character to do this. Teacher P role plays with Christian's creation and he jumps with excitement when it is animated in front of his peer Colleen. Christian often converses with the creatures he finds and is delighted when Teacher P brings this imaginary creature 'to life' with comic voices.*	Teacher P: *Oh wow…. what fun….* (she plays with the pacman person opening its mouth.) *Colleen: Excuse me….* Teacher P: *He got a circle right and he got two dots for eyes and he cut, cut, cut for the mouth…. Look.*	Later in the day when *Christian's* peer Colleen stamps on a beetle, he cries out loud in anguish. Christian has strongly expressed concerns about preservation of life. Teacher J empathises and begins a new search with a group of children to find a new insect in the yard.

model the child sees a specific individual form of a bull-and and an ant hole, in its universal form it is an organism and habitat. The relations between habitat and insect represent knowledge generation that was created historically, as a form of classifying and organizing the world, as a scientific knowledge tradition. Consequently, a concept must reflect the process of its historical and scientific development. That is, the child must also have the opportunity to investigate its environment and notice the bull-ant and ant hole are always linked (specific) with the experience of generating a scientific model of organism and habitat (general). This historical and scientific development can be reflected through the knowledge base of the teacher, as the teacher directs the children's attention to specific features of the ecosystem, or through the strategic use of books and charts which in themselves contain the history of knowledge of Western science.

Although children are not working independently to re-discover bodies of established knowledge, they do engage in an investigative process guided by their teacher, which allows them to build theoretical knowledge and use dialectical thinking for establishing the relational knowledge (in the form of a model) that underpins the historical and scientific journey undertaken initially in revealing the discovery and building of the particular knowledge system – in this case science.

The case example discussed above highlights how the teacher helps Christian to think scientifically about his world. Rather than simply looking for insects in his environment, Christian is supported to think paradigmatically about his everyday world using theoretical knowledge of the ecosystem. Christian has not been left to discover the world on his own. But the valued forms of knowledge that have been constructed by human society to explain why the ant was in the wrong place, were introduced to Christian through the thoughtful interactions of his teacher. This example contrasts with the example of studying potions, where the teacher's belief system about her role and how children learn (individualistic paradigm) created very different conditions for learning for Molly and Lara. The children brought their own personal knowledge of 'cooking' or 'nursery rhymes' and tried to make meaning of the materials through these lenses. Narrative knowledge was supported. But the narratives they formed did not help them to scientifically understand the materials they were playing with. What is important here is recognizing how beliefs about knowledge construction (narrative, empirical and theoretical) and children's development (individualistic, social interactionist or cultural-historical) determine what action a teacher takes. As we see in the examples given above, the consequential outcomes for early childhood science education are very different.

6.6 Knowledge Construction in Early Childhood Science Education

In this chapter we have examined three types of knowledge construction, narrative, empirical and theoretical. Our discussion focused on preschool aged children, and through this it was noted that some early years teachers have difficulties with considering science education from an empirical knowledge construction perspective because most preschool practices within European and European heritage communities, tend to privilege narrative knowledge construction. It was argued that theoretical knowledge construction and dialectical thinking allowed children to engage in historically developed empirical knowledge and turn this empirical knowledge into personal knowledge when:

- children had the opportunity to study the particular bull ant whilst considering at the same time the general concept of an insect as an established body of scientific knowledge;
- insects were studied in relation to the concept of habitat, and food sources, allowing for the development of a relational understanding or concept of a rudimentary ecosystem
- children created a model that represented the essence of what they were studying, so that core elements of the concept could be consciously considered.

Whilst theoretical knowledge allows children to turn scientific concepts into personal concepts, this should not discount the usefulness of narrative knowledge and empirical knowledge construction. These other forms of knowledge construction are drawn upon extensively in preschools, but on their own they have been shown to be less effective forms of knowledge construction for early years learning in the sciences when the teacher is not clear about the core concepts s/he is investigating with children. It is important to be aware of what knowledge construction dominates in a particular institution, such as a family, preschool or school. Knowing what dominates, or that which is found most comfortable for teachers and particular groups of children, means that a more explicit approach to introducing other forms of knowledge construction are necessary. We now turn to the final chapter in this section, where we examine how children are positioned in research and how this influences knowledge construction in science for early years education.

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