Chapter 3
Imagination and Its Contributions to Learning in Science

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Abstract This chapter examined the young learner's imaginary play world and explored how this lays an important foundation for scientific thinking. Vygotsky (J Rus East Eur Psychol 42(1):7–97, 2004) argued that 'imagination is not just an idle mental amusement, not merely an activity without consequences in reality, but rather a function essential to life' (p. 13). Imagination becomes the means for broadening a person's experience. Vygotsky (J Rus East Eur Psychol 42(1):7–97, 2004) suggests that humans imagine what they cannot see, conceptualise what they hear from others, and think about what they have not yet experienced. That is, a person 'is not limited to the narrow circle and narrow boundaries of his [sic] own experience but can venture far beyond these boundaries, assimilating, with the help of his imagination someone else's historical or social experience' (Vygotsky, J Rus East Eur Psychol 42(1):7–97, 2004: 17). In this chapter we examined the young child's learning in science through an examination of imagination and creativity in science. Because young learners continually move between reality and imaginary situations in play, it was shown in this chapter that this builds the foundations for thinking with concepts in science. We show through empirical research of science with fairytales how the young learner explores science concepts through their play. The concepts of collective investigations, emotional filtering, duality of emotions and thinking, flickering, and affective imagination are discussed. These are brought together under the concept of perezhevanie.

Keywords Imagination • Creativity • Emotions • Fairytales • Affective imagination • Collective investigations • Emotional filtering • Duality of emotions and thinking • Flickering • Perezhevanie

3.1 Introduction

Matthew (4 years) and his teacher have just been observing a rainbow that had formed on the wall of their preschool. Matthew looks intently at his teacher and says:

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Matthew:  I saw a rainbow.
Teacher:  When did you see a rainbow Matthew?
Matthew:  In a dream.
Teacher:  In a dream, what a lovely thing.
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Matthew: And I, and it hasn't got any bad things, bad dreams. You were in there, and kids.
Teacher: So I was there, kids and a rainbow in your dream.
Matthew: And I had another dream about coming here. Last time it was. But it wasn't that one (pointing to the rainbow on the ceiling).
Teacher: Which one was it? Is it the one that shines through our prism in the afternoon.
Matthew: Yeah.
Teacher: You know the one that shines on the floor and the wall?
Matthew: No, outside (points out of the window).
Teacher: Outside. An outside rainbow.
Matthew: It was it.
Teacher: Was it in the sky or our wind (moves fingers gesturing windmill action)?
Matthew: The wind was blowing the rainbow away (gesturing with hands).
Teacher: Was it?
Matthew: And I had to go on it (gesturing with hands)
Teacher: What a beautiful dream (Fleer, 2013).

So how is it that rainbows featured so strongly in Matthew's dreams? Dreaming about rainbows is representative of Matthew's imagination. Mentioning that his dream "hasn't got any bad things" suggests an emotional tone to not just Matthew's imagination, but also his learning in science in this particular preschool.

An emotional tone is also evidence in science generally within our community. Despite the myth of the scientific method, we find prominent scientists use intuition, imagination and emotions in their work. Fox Keller (1983) stated that "Good science cannot proceed without a deep emotional investment…" (p. 197). In her review of the work of Nobel-Laureate Barbara McClintock, she states that McClintock had an ""exceedingly strong feeling" for the oneness of things" (p. 201), where she projected herself inside the microscope joining the chromosomes. She notes that "If you want to really understand about a tumor, you've got to *be* a tumor" (p. 202). McClintock approach was not to position herself outside looking in, but rather she was on the inside being a part of the structures she was seeking to better understand. Through this technique she gained a "feeling for the organism" (p. 201). This approach "both promotes and is promoted by her access to the profound connectivity of all biological forms – of the cell, of the organism, of the ecosystem." (p. 201):

> Her answer is simple. Over and over again, she tell us one must have the time to look, the patience to "hear what the material has to say to you," the openness to "Let it come to you." Above all, one must have "a feeling for the organism." (p. 197).

In learning about how genes can be transposed, where the DNA is influenced by the outside conditions, Barbara McClintock put forward evidence that was in contradiction to the dominant view at the time about genetics. This was gained through a radical way of viewing herself and the material she studied, where emotional connectivity and imagination were clearly evident as a "feeling for the organism"

(Fox Keller, p. 199). This approach has also been named as creativity (see Connery, John-Steniner, & Marjanovic-Shane, 2010).

In this chapter we build upon the previous chapter where we introduced the idea of *wonder as an emotional quality through which children build a particular scientific relationship to their environment*. In that chapter we examine the concepts of *emotional experience* and *environment* for affording science learning in preschools. We draw upon Vygotsky's (2004) dialectical concept of *imagination and creativity* to argue the case that science is a highly imaginative and emotional act, which young children learn within families, communities and preschools. We begin by discussing these terms, followed by examples from an empirical study of children learning science through fairytales (Fleer, 2013). Here we elaborate the concept of *affective imagination for science learning* – where the "feeling for the organism" or the 'feeling for the science concept' is established.

3.2 Imagination and Creativity in Science

How is it that science finds its way into children's imagination? To answer this question, we must first examine what is *imagination and creativity?* Vygotsky (2004) argued that:

> Imagination, as the basis of all creative activity, is an important component of absolutely all aspects of cultural life, enabling artistic, scientific, and technical creation alike. In this sense, absolutely everything around us that was created by the hand of man [sic], the entire world of human culture, as distinct from the world of nature, all of this is the product of human imagination and of creation based on this imagination (pp. 9–10).

In everyday language and conversations, imagination is usually considered as a form of fiction, something that is not real. It is spoken about as though the content were formed solely from within the mind. Creativity also is perceived to have this internal quality, as something that a person invents purely through mental processes, often expressed through the body in some way (e.g., hands, voice, body movement). That is, imagination and creativity are not usually associated with coming from the concrete world, but rather are viewed as fictitious. In using this logic, imagination would appear to be the antithesis of science.

However, Vygotsky (2004) suggests that creative activity is "based on the ability of our brain to combine elements" as an imaginative act (p. 9). It is not always immediately obvious that our cultural world (as distinct from our natural world) has been created through humans as a *result of combining in new ways element taken from our experiences*, or through inheriting the experiences of others. It is argued by Vygotsky that imagination occurs *because* of our experiences. He suggests that the richer our experiences are, the more we have to draw upon, and the more we have at our disposal to combine in new ways. So rather than considering imagination and creativity as something that is unique to the person, as a personal attribute that is genetically transmitted, Vygotsky argued that imagination is acquired through cultural and social interactions within the concrete and social world. This is consistent with contemporary research into creativity, such as that of Ferholt (2010), John-Steiner, Connery, and Marjanovic-Shane (2010) and Lobman (2010) who have also drawn upon Vygotsky's dialectical conception of imagination and creativity.

In line with this theorization, imagination and creativity is deemed to be a product of collectives, rather than individuals, despite the fact that a single person may put forward the new idea, artefact, system, or expression. Patent and copyright laws tend to confirm this individualistic belief (see Wertsch, 1998 for a critique). In science we regularly attribute particular discoveries to individuals (e.g., Boyles Law; Nobel prize), but in the history of science it is clear that individuals stand on the shoulders of past scientists. That is, scientific ideas form because we use past conceptions, drawing from those elements, that we combine in new ways, elements observed through everyday life or through experimentation, or through reading scientific journals or attending conferences and listening to presentations.

Vygotsky (2004) argued that historically, many scientific and technological inventions were formed anonymously and through collective activity over time. For example, "just as electricity is equally present in a storm with deafening thunder and blinding lightening and in the operation of a pocket flashlights, in the same way, creativity is present, in actuality, not only when great historical works are born but also whenever a person imagines, combines, alters, and creates something new, no matter how small a drop in the bucket this new thing appears compared to the works of geniuses" (pp. 10–11). He termed this *collective creativity*.

> When we consider the phenomenon of collective creativity, which combines all these drops of phenomenon of collective creativity that frequently and insignificantly in themselves, we readily understand what an enormous percentage of what has been created by humanity is a product of the anonymous collective creative work of unknown inventors (Vygotsky, 2004, p. 11).

If we apply this logic to young children learning science we can begin to identify imagination and creativity through their play. Vygotsky (2004) argued that "children at play represent examples of the most authentic, truest creativity" (p. 11).

> Everyone knows what an enormous role imitation plays in children's play. A child's play very often is just an echo of what he saw and heard adults do; nevertheless, these elements of this previous experience are never merely reproduced in play in exactly the way they occurred in reality. A child's play is not simply a reproduction of what he [sic] has experienced, but a creative reworking of the impressions he has acquired (p. 11).

In this reading of play and imagination, what the child does in play, is combine prior experiences to create a new concrete situation, one that is focused on the child's own needs and motives.

However, as has been noted by Marjanovic-Shane, Connery, and John-Steiner (2010), traditional thinking and everyday perspectives on concrete situations and fantasy draw a sharp distinction between these terms. For instance, if we consider fairytales, this is an area within early childhood education that is always positioned as pure fantasy. However, Vygotsky (2004) conception of the dialectical relation between fantasy and concrete situation gives a very different reading of fairytales, and this is important for understanding how science can be conceptualised as an imaginative act.

Fig. 3.1 Waiting for hot porridge to cool

In the classic fairytale of Goldilocks and the 3 bears we find bears that live in houses, bears who cook porridge, and bears who sit on chairs and sleep in beds. If we examine this fairytale closely we see that bears, houses, porridge, chairs and beds all exist in reality. However, it is the combination of these things that is unique, imaginary and purely fiction. That is, bears do not live in houses, performing domestic activities, and exhibiting essentially human qualities. Here we see that for young children, imagination builds from concrete situation – from known experiences of living in a house, being part of a family, and waiting for 'hot food to cool' (Fig. 3.1).

Vygotsky (2004) postulated three laws for governing imagination. In the example given, we see that "creative activity of imagination depends directly on the richness and variety of a person's previous experience because this experience provide the material from which the products of fantasy are constructed" (pp. 14–15). That is, a child's experience of waiting for food to cool is a real need, and gives a reason for why Goldilocks could enter the three bears home – no one was there to stop her. Vygotsky suggests that the "richer a person's experience, the richer is the material his [sic] imagination has access to" (p. 15). That is, having experience of eating hot food or cooking gives the experience for children to identify with the bears going on a walk to wait for the porridge to cool, but also the possibility for learning about heating and cooling as scientific concepts. Every imaginative act begins with this accumulation of experience, and in the context of science education, it begins with valuing the experiences and their associated possible alternative everyday conceptions (see Chaps. 1 and 7) as an importance source of scientific concept formation (see Chap. 4). The implication for science education is that children need rich everyday experiences of their world. The richer the experiences, the richer are the possibilities for imaginative and creative thought and action.

The second law put forward by Vygotsky (2004) regarding fantasy and concrete situation centres on how children can appropriate the experiences of others to furnish their imagination. Children do not have to experience in concrete terms a range of different kinds of security systems and locks in order to make sense of how the bears might be able to keep Goldilocks out of their house. Through looking at books or hearing explanations from other children about how they keep their house secured, children can draw upon these vicarious experiences to work imaginatively when 'designing a security system for the three bears'. The linkages between fantasy and the concrete situation are possible through someone else, as a form of social experience. Vygotsky suggested that "In this sense imagination takes on a very important function in human behavior and human development. It becomes the means by which a person's experience is broadened, because he [sic] has to imagine what he has not seen, can conceptualize something from another persons' narration and description of what he himself has never directly experienced" (p. 17). In science, many concepts are not directly observable, and consequently children (and adults) need to imagine these concepts. Children are unlikely to directly see the molecular movement of atoms during the cooling process. Rather children have to imagine the science concepts which help explain how the 3 bears' porridge cools. *Without imagination, thinking with science concepts is difficult*.

The third law for understanding the relations between fantasy and reality put forward by Vygotsky (2004) is emotion. Vygotsky argued that there is a double and mutual dependence between imagination and emotional experience. The *doubleness* can be expressed through the conception that imagination is based on experience *and* experience is based on imagination. The idea is that every experience has an image associated with it; that is, a specific image has a corresponding feeling, an emotional quality. "Emotions thus possess a kind of capacity to select impressions, thoughts, and images that resonate with the mood that possesses us at a particular moment in time" (pp. 17–18). For instance, children who are cooking porridge in anticipation of eating it, waiting for it to cool, will have a different emotional experience to children who do not like porridge, but who nevertheless are expected to eat it. The former creates a positive emotional tone and image for exploring heating and cooing, whilst the latter potentially (if forced to eat the porridge) builds a negative tone and image of the science cooking experience. We see both an external physical expression (disgust at having the eat the porridge; or enthusiastic and joyful anticipation for eating the porridge) and "an internal expression associated with the choice of thoughts, images, and impressions" (p. 18), such as, remembering the eating of porridge at home or imagining the 3 bears walking whilst waiting for their porridge to cool. This duality between the external expression and internal feeling and image bearing state is what is meant by *dual expression of feelings*. Vygotsky suggested that:

> The image of imagination also provides an internal language of our emotion. The emotion selects separate elements from reality and combines them in an association that is determined from within by our mood, and not from without by the logic of the images themselves (p. 18).

In looking at the porridge cooling, the child whose duality of emotion and experience is positive potentially imagines the feeling state of the bears, wanting to cool their porridge, thinking about the cooling process (particularly when supported to consciously consider the concept of cooling by the teacher), and potentially *imagining* how this might occur. The emotional tone for the science cooking experience is positive, the anticipation of eating the porridge is foregrounded, making the cooling process more urgent, and the learning situation has an emotional quality that makes science a positive event. All forms of imagination include an affective tone or quality. This mutuality of emotions and imagination is captured in the concept of *affective imagination* and is centrally important in understanding how very young children experience science.

In returning to the example of Matthew's dream of the rainbow, we also see an emotional quality to his science learning as represented in his dream, as something positively experienced. Vygotsky (2004) in citing Ribot says:

> These types of associations are very often present in dreams or day-dreams, that is, in states of mind in which the imagination has free rein and works at random, any which way (not dated).

It can therefore be argued that the affective imagining of rainbows by Matthew characterizes how both imagination and the concrete situation give meaning to each other in science learning.

In order to fully appreciate the relations between imagination and concrete situation, we must also give thought to how combining new elements in the process of imagining something new, must be substantially new, if imagination is to turn into a concrete situation. It is through the process of realising images and thoughts into concrete situation or constructions, such as occurs in the development of machines, the cycle of imagination becomes complete, as a creative act. We see this when children anticipate the eating of porridge, wishing for the hot porridge to cool quickly, or more concretely in the story of Goldilocks and the 3 bears, discussing how they can help the bears cool down their porridge by inventing a 'cooling down machine'. What is imagined becomes concrete and tangible as a new creation, as a cooling down machine. Here it is possible to see how "the intellectual and the emotional – are equally necessary for an act of creation" (Vygotsky, 2004, p. 21). The invention of the cooling down machine as a concrete creation now has a role in the story and in the play of the children, influencing reality. Similarly, imagining heat transference as a cooling process (perhaps not at the molecular level for young children), also influences reality because children have concrete actions they can now take in everyday life, such as stirring the porridge or putting a metal spoon in the porridge to aid cooling. Actions are changed due to the new meaning given, and here we see scientific imagining being foregrounded.

To illustrate these concepts more concretely, we now turn to a case example of using fairytales for science learning where affective imagination is explicitly featured.

3.3 Case Example: Learning Science Through Goldilocks and the 3 Bears

It is well understood that imagination and creativity are featured in children's play (Connery et al., 2010; Ferholt & Lecusay, 2010; Holzman, 2009; Vygotsky, 2004). How teachers draw upon play to further science learning has not always been well articulated. Rather what dominates the literature is conceptual understandings in science – notably conceptual change. This well established body of literature suggests that young children can learn many scientific concepts at a very early age (Eshach, 2011; Fleer, 2009a, 2009b; Goulart & Roth, 2010), such as, astronomy (Hannust & Kikas, 2007; Robbins, 2003; Sharp, 1995), electricity (Fleer, 1990, 1991; Fleer & Beasley, 1991), food (Cumming, 2003), digestion (Martins Teixeira, 2000), natural science (Keleman, 1999a; Ravanis & Bagakis, 1998; Shepardson, 2002, Venville, 2004), force (Hadzigeorgiou, 2002), matter (Krnel, Watson, & Glazar, 2005), as well as engage in co-constructing science with teachers (Goulart & Roth, 2010), engaging in epistemological reasoning (Pramling & Pramling Sameulsson, 2001; Tytler & Peterson, 2003), and teleological thinking (Keleman, 1999b). As noted in Chap. 1, much of the empirical work has been conceptualized from a constructivist perspective, with exceptions emerging in recent years (such as, Goulart, Pramling, Robbins, Roth) where more of a cultural-historical orientation has framed the research. The case study that follows drew upon a cultural-historical view of learning science.

One of the defining features of preschools is the existence of play-based programs. A play-based program is distinct from how learning is generally organised in both primary and secondary schools. The preschool from which the case study is drawn, is structured so that group learning usually occurs through both play periods and two 30 min sessions of teacher organised group time, where stories, role play, singing games, and the like are featured. Mostly children make choices about what they will do from a range of activities and infrastructure during the free play periods. The group sessions are usually organised by the teacher and all children usually participate in these sessions. The framework for science learning was the fairytale of Goldilocks and the 3 bears. Five dimensions were featured, and they are discussed in turn.

3.3.1 Collective Investigations and Narratives

The organizational structure of the preschool featured the telling and re-telling of Goldilocks and the 3 bears, followed by using the available props for role-playing the story. In particular an *Imagination Table* with bowls, bears, beds, etc., for role-playing was set up for the children, where an iPad allowed the children to capture pictures of their play (see Fig. 3.2). Also available were experiences which gave a more scientific reading of what was being introduced to the children in group time – that is, the teacher set up over a period of 8 weeks many opportunities to cook and eat porridge and to design and make a cooling down machine, something that emerged from the children as a way of helping the 3 bears to quickly cool their porridge so that there was no need for the bears to leave their house. See Fig. 3.3.

Central to the collective imaginary situation that emerged was a series of collective investigations. Through the telling of the fairytale, where the children identified with the bears, where they sought to assist the bears with cooling their porridge (see Table 3.1). This was a highly pertinent narrative, because, as mentioned previously, children regularly wait for hot food to cool before they can eat it.

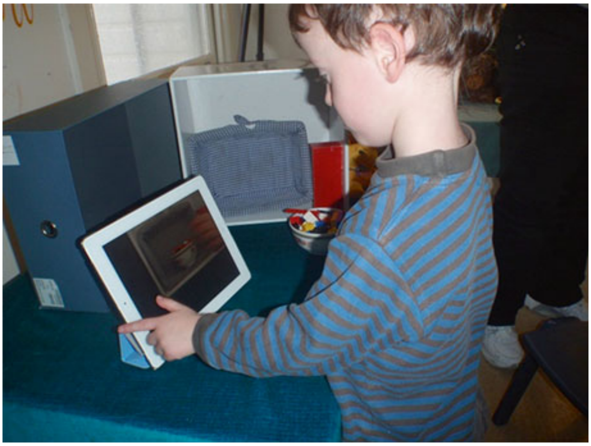

Fig. 3.2 Imagination table with iPad

Fig. 3.3 Cooking porridge – consciously considering heating and cooling

Through cooking porridge with the children, the teacher re-created an everyday situation common in all families, but also specific to what was central to the story of Goldilocks and the 3 bears. The teacher generated a scientific narrative as part of cooking porridge.

Table 3.1 Collective scientific investigations

Concept	Emotionality in fairytales	Emotionality in scientific and technological learning
Collective investigations and narratives	Children *want* to identify with the hero of the story, wishing to assist the hero, and through this, they *together re-enact the ideal moral response to the given situation, along with all of the associated risks, in reaching the final victory.*	*Collective scientific investigations* *Children collectively* develop a consciousness of scientific and technological *concepts and emotionality* by working together with other children to solve the problem.
	Children imagine the feeling state of the fairytale characters, and empathise and want to help the characters to solve the collective problem.	In a *scientific narrative*, children empathise and want to help the characters to solve the collective scientific and technological problem.

See Fleer (2013)

3.3.2 *Affective Imagination*

In the case example, the children not only had experiences of role-playing Goldilocks and the 3 bears with the teacher, but they also actively re-created the story during free play time where they used a scientific narrative, as occurred when the children took props relevant to the fairytale and role-played cooking and cooling porridge.

Jason (3 years) is at the 3 bears table. He has taken to the table a bowl of small cut straws and is pouring these into the 2 equal sized bowls that are at the table. One larger bowl also stands on the table. Jason pours the straw pieces back into the basket, and then turns to the research assistant Shukla and asks:

What can I get for you today? Shukla says she would like something.

Jason: Porridge?
Shukla: Yes. I'd like porridge.
Jason: Porridge.

Jason takes the small basket of sticks, shakes them around as he says:
Jason: But, I'm going to put it into the microwave, because it get's very hot.
Shukla: OK. Is it too hot?
Jason: Yes (shaking the basket of cut drinking straws). When I put it in this bowl (about to pour the cut straws into the bowl). Do you want it in this middle sized bowl or the big one, 'cause we don't do middle sized ones (shaking his head). Do you want a little one (correcting himself) or a big one, 'cause we don't do middle sized ones?

Table 3.2 Affective imagination in science

Concept	Emotionality in fairytales	Emotionality in scientific and technological learning
Affective imagination or emotional imagination	Through the re-enactment of fairytales, children gain a sense of the main character's actions in role-play, whilst clarifying their own feeling state because the story plot is mirrored in the acted out actions of the children.	Through role-play of scientific narratives and learning, the *children collectively* begin to anticipate the results of each others' actions in the play, begin to anticipate their own actions, including image-bearing dramatization, verbal descriptions, prop use and transformation, and importantly, the scientific solutions created through the support of the teacher.
Zaporozhets (2002) shows that through emotional and cognitive participation in fairytales that children reach "the ideal plane of *emotional imagination*" (p. 58).	Children are not *"enacting the story,* but *really living in it"* (El'koninova, 2002, p. 45).	

Through role-play children not only begin to use the language found in the fairytale (e.g., big, little and middle sized bowls of porridge) but also use rudimentary scientific language, such as, the use of 'hot' in an everyday context of pretending to serve porridge. Here children make conscious the concept of 'heating and cooling'. This play represents the beginnings of a scientific narrative (remembering these children are 3–4 years of age) where they are imagining 'hot food' in the same way as they will need to do later to imagine molecular movement in order to understand scientific explanations of heating and cooling (Table 3.2).

3.3.3 Being in and out of Imaginary Situations – Flickering

During play children move in and out of imaginary situations. That is, they are part of the role-playing reliving the story, but when the play does not progress as expected, then children slip out of the imaginary situation and direct the play from outside of the play. For example, we would see this when children are in role acting out being the bear cooking the porridge, but if one of the children deviates from the story line by saying "I can eat up all the porridge because it is just right", then the other children would coach them back in, by saying 'No, you have to say "the porridge is too hot"'. We also find children direct the play from within the imaginary situation, as is evident when a child might say in character and say: "But then Goldilocks comes along and she says 'the porridge is *too hot*'" (in an exaggerated tone). In this example the children are concurrently in the imaginary situation and the real world. Concurrently being in the imaginary situation and the real world helps children interrogate the concepts as they play, allowing for a more conscious response to a play or learning situation. Like with the approach taken by Barbara McClintock in her genetic work, the children are inside of the situation feeling the heating and cooling in their play. This is an important aspect of everyday and scientific concept formation, where a conscious exploration of a concept allows children to build deeper understandings in science. In role-playing heating or cooling, children have to exaggerate or explicitly show the concepts concretely or symbolically in their play, if other children are to understand and engage in the imaginary situation forming. In so doing, children make the concepts conscious, and thereby consciously explore the concept.

Flickering in and out of the imaginary situation supports children to build their imagination, as they actively enter into an imaginary world. Why this is important in science is that many aspects of science are not directly observable by children. Many of the scientific concepts, such as magnetism, gravity, molecular movement, the Earth's rotation around the sun, have to be imagined. Imagining scientific explanations for not directly observable phenomena is an important dimension of learning in science for preschool children. Yet this dimension of science is not always acknowledged. This flickering is represented in Fig. 3.4 (Adapted from Fleer, 2013) and also in Table 3.3.

Fig. 3.4 Flickering between the imaginary world and the concrete world

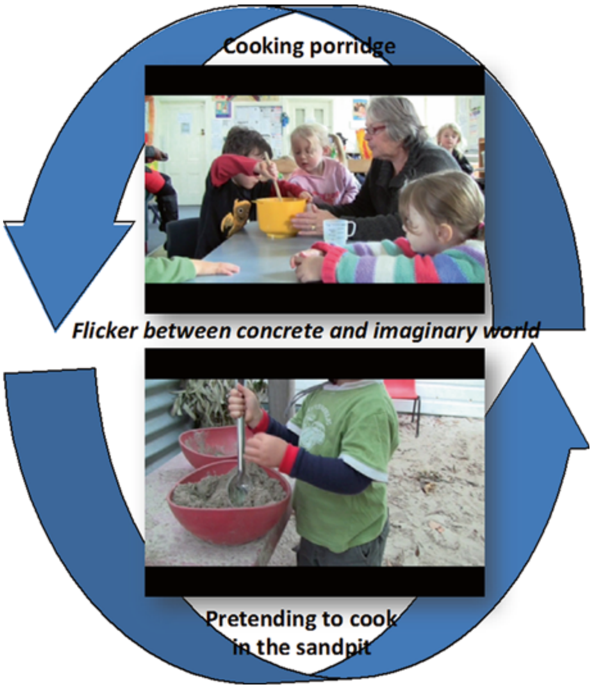

Table 3.3 Imagining non-observable concepts in science

Concept	Emotionality in fairytales	Emotionality in scientific and technological learning
Flickering Children flicker between the concrete and imaginary worlds.	In fairytales, children begin to separate out the imaginary world from the concrete world, and find themselves in the borderline between these worlds.	It is the border of the imaginary world and the concrete world that creates a dialectical relation and emotional tension that promotes scientific conceptual development, which helps children imagine scientific explanations not easily observable.

3.3.4 Duality of Emotions and Thinking

Fairytales are full of anticipation, where emotional responses usually feature – such as feeling frightened or excited – even thought the outcome of the storyline is well known to children. In identifying with the characters in the fairytale, either in the re-telling or in the role-play, children live through the emotions of the story. Identifying with the character, wishing to help them to solve the problem, are laden with emotions. Vygotsky (1966) argued that in play children can feel two things concurrently. They can feel the joy of playing, while also feeling the emotions of the characters – such as being frightened. This is relevant to science because children can also experience an emotional response to science learning. That is, they may feel happy exploring the science problem while feeling anxious about needing to solve the scientific challenge quickly for the role-play. The duality of emotions has also been noted in McClintock's work, when she discusses her delight for contradiction and surprise during the post-World War II period where the effects of radiation on flies (Drosophila) was being investigated:

> "It turned out that the flies that had been under constant radiation were more vigorous than those that were standard. Well, it was hilarious; it was absolutely against everything that had been thought about earlier. I thought it was terribly funny; I was utterly delighted" (p. 198).

In scientific investigations, children's feeling state becomes connected with the learning as they anticipate *finding a solution*. Through consciously considering feeling states in science, emotions become intellectualized, generalized, and anticipatory, while cognitive processes acquire an affective dimension, performing a special role in meaning discrimination and meaning formation (e.g., gut feeling this is going to work). The duality of external expression, and internal feelings and images, occurs simultaneously. Imagination is based on these dual experiences/images but both become emotionally charged in the process of being experienced, imaged and created (Table 3.4).

Table 3.4 Emotions and scientific thinking

Concept	Emotionality in fairytales	Emotionality in scientific and technological learning
Dual role of emotions in thinking	Children must be inside of the plot living the story, and outside of the plot as a real person. El'koninova (2002) argues that a child must "gropingly look for a "territory" where this is possible" (p. 41).	Children feeling happy enacting or exploring a science narrative with others, but also feeling excited or curious by learning new things and solving scientific and technological problems in order to scientifically help the characters in the narrative.
	Feeling happy in role-play, but also feeling frightened when pretending to be Goldilocks seeing the 3 bears.	

Barbara McClintock has also demonstrated these connections between emotions and thinking, when she became intrigued by the way Tibetan Buddhists could control their body temperature. McClintock's wonder and "feeling for the organism approach" led her to experiment with biofeedback, where "she began to feel a sense of what it took" (p. 200):

> "I was so startled by their method of training and by its results that I figured we were limiting ourselves by using what we call the scientific method"... "We are scientists, and we know nothing basically about controlling our body temperature. [But] the Tibetans learn to live nothing but a tiny cotton jacket. They're out there cold winters and not summers, and they have been through the learning process, they have to take certain tests. One of the tests is to take a wet blanket, put it over them, and dry that blanket in the coldest weather. And they dry it." (p. 200).

3.3.5 *Emotional Filtering*

In the case example of fairytales, the teacher used a lot of emotional filtering. That is, she regularly emotionally charged events and actions, which children responded to positively. For instance, in the example that follows the teacher emotionally charges the concept of cooling by foregrounding the word 'hot':

> Four children are sitting or standing around a table which has a large pile of Lego pieces in the centre. The teacher is seated at the table. She begins a discussion about porridge making so that she can discuss the idea of designing some sort of device for cooling down the porridge:

Teacher: Remember what the 3 bears cooked and ate for breakfast?
Child 1: Porridge.
Teacher: Yum. Do you remember how to make porridge?

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Child 2:  Yeah (other children nod in agreement).
Teacher:  How did we make it?
Child 1:  With some milk.
Teacher:  Milk. Yes. And?
Child 3:  Then you put it into the microwave.
Teacher:  And what did the microwave do to make porridge?
Child 2:  Warm it up.
Child 3:  Make porridge.
Teacher:  Warmed it up, or cooked it?
Child 2:  Cooked it.
Teacher:  What was it like when it came out of the microwave?
Child 3:  Hot.
Child 2:  Hot.
Teacher:  A little bit hot, or very, very, very, very, very,
          very, very, very, very, very, hot.
Child 3:  Very hot.
Child 2:  Very hot.
Teacher:  It was nearly boiling.
Child 3:  It was.
Teacher:  Why did it nearly have to be boiling?
Child 3:  Because it was in there for a long time.
Teacher:  So we have got boiling hot porridge. So can we eat
          it when it's boiling hot?
Child 3:  No (all children shake their heads). My grandmother
          only eats porridge when its cold.
Teacher:  Does she wait until its got cold before she eats it?
Child 3:  Yeah and puts yoghurt in it.
```

This is common practice in early childhood centres, where teachers regularly highlight something through an enthusiastic response or exaggeration. In this case, the teacher does this specifically in relation to a science concept. This draws the children's attention to the concept, and to the scientific challenge that presents itself. By making concepts conscious to children through emotional filtering, teachers are able to work informally in preschool settings, drawing out science in the everyday life of the program (Chap. 2), as well as create science through events that children find emotionally and intellectually interesting, such as the Goldilocks and the 3 bears. See Table 3.5.

Table 3.5 Emotional filtering in science

Concept	Emotionality in fairytales	Emotionality in scientific and technological learning
Emotional filtering	Teachers emotionally charge events, actions and objects which focus the children's attention, thinking and feeling state.	Teachers help children in knowing what is noteworthy to pay attention to in science learning. What should they notice or look for? The gesturing of teachers is usually accompanied by expressive sounds and surprised or interested facial expressions.
Emotional filtering is "where kindergarten teachers attribute emotional significance to events" (Iakovela, 2003, p. 93).		

3.3.6 Wholeness Approach to Science Learning in Preschools

Through an emotional connectivity, that the teacher foregrounds, children explore the wholeness of science. That is, they do not learn discrete parts of science (i.e., single concepts out of context), but rather are making meaning of science in everyday life, as we saw in chapter 3. However, the teacher's emotional filtering, can also be used effectively in creating imaginary situations, such as occurs in fairytales, where the teacher ensures that the imaginary situation affords scientific investigating.

What is important here is how the teacher emotionally filters science to the children. As Fox Keller (1983) states in her explanation of McClintock's approach to genetics, "without an awareness of oneness of things, science can give us at most only nature-in-pieces; more often it gives us only pieces of nature." (p. 201).

Affective imagination is foregrounded in the case example discussed. But as has been alluded to throughout this case example, Nobel-Laureate scientists too, work in ways that do not follow the mythical scientific method. As McClintock states "So you work with so-called scientific methods to put it into their frame after you know." (p. 200). But to get there, McClintock argues that you have to spend lots of time getting to know what you are seeking to study – in her case plants:

> One must understand "How it grows, understand its parts, understand when something is going wrong with it. [An organism] isn't just a piece of plastic, it's something that is constantly being affected by the environment, constantly showing attributes or disabilities in its grown. You have to be aware of all of that . . ." You need to know those plants well enough so that if anything changes, . . . you [can] look at the plant and right away you know what this damage you see is from – something that scraped across it or something that bit it or something that the wind did. *"You need to have a feeling for every individual plant"* (p. 197; our emphasis).

Fox Keller (1983) states that it is that emotional investment that provides the "motivating force for the endless hours of intense, often grueling, labor" (pp. 197–198). In the case example, the teacher worked with the 3 year old children for 8 weeks exploring heating and cooling. Whilst this was not grueling, it was an investment in time and emotional energy by the children and the teacher, as they role-played the 3 bears, experienced the cooking of porridge, invented a cooling down machine, and created their own slowmation of cooking porridge in the context of the fairy tale of Goldilocks and the 3 bears. As McClintock states "I don't feel I really know the story if I don't watch the plant all the way along. So I know every plant in the field. I know them intimately, and I find it a great pleasure to know them." (p. 197).

A wholeness approach to science teaching in preschools foregrounds, the following characteristics for imagination, creativity and emotions:

1. *Collective investigations and narratives*
2. *Affective imagination*
3. *Being in and out of imaginary situations – flickering*
4. *Duality of emotions and thinking*
5. *Emotional filtering*

3.4 *Perezhevanie* as an Explanation of Quality Early Childhood Science Learning

In concluding this chapter, we theorise further the relations between imagination, concept formation and emotions, by drawing upon Vygotsky's concept of *perezhivanie*. According to Veresov (2012) this word does not translate well into English. We have chosen to use the Russian term in our discussion of emotions and imagination in early childhood science education, because we believe this term captures and helps us to better understand how preschool children experience and learn science as they interact with their social and material world. Central to this concept is the idea that emotions, imagination and concept formation must be conceptualized in unity. That is, they cannot be separated out, as is often the case in early childhood science education where only the learning dimensions are discussed. All children, but especially young children, relate to their social and material world emotionally. Young children are still learning to regulate their emotions, and this means they are not always in a position to consciously think about their feeling state – this is after all something they develop throughout the early childhood period. To conceptualise science education, as an affective and imaginary experience, means that the central concepts discussed in this chapter need to be brought together. Perezhivanie captures this unity. As Vygotsky (1994) states:

> *An emotional experience [perezhivanie] is a unit where, on the one hand, in an indivisible state, the environment is represented, i.e.,* that which is being experienced – an emotional experience *[perezhivanie]* is always related to something which is found outside the person *– and on the other hand what is represented is how I, myself, am experiencing this*, i.e.,, all the personal characteristics and all the environmental characteristics are represented in an emotional experience *[perezhivanie];* (Vygotsky, 1994, p. 341; Original emphasis).

Consequently, we conceptualise science education as an indivisible unity of what the child brings to the activity setting in the preschool, the situational characteristics that are created by the teacher, as well as how these events are emotionally and conceptually experienced by the child. Together these represent the emotional experience or perezhivanie of the child's social situation of development. Veresov (2012) in line with Vygotsky (1994) has argued that perezhivanie is the prism through which both the individual and the socio-cultural environment is experienced, and together they represent the unit of human consciousness as a central force for human development. Consequently, perezhivanie is a cultural form of experiencing the scientific environment, and because play is the leading activity within the preschool period (Vygotsky, 1966), imagination and creativity are featured as part of perezhivanie, and together emotions, cognition and imagination become central dimensions for science teaching and learning.

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