Transformation through Language Use: Children's Spontaneous Metaphors in Elementary School Science

BRITT JAKOBSON and PER-OLOF WICKMAN

*Department of Curriculum Studies and Communication, Stockholm Institute of Education,
Stockholm, Sweden (E-mail: britt.jakobson@lhs.se)*

Abstract. This article examines the role elementary school children's spontaneous metaphors play in learning science. The data consists of tape recordings of about 25 h from five different schools. The material is analysed using a practical epistemology analysis and by using Dewey's ideas on the continuity and transformation of experience. The results show the rich and varied meanings that children put into their spontaneous metaphors. Their metaphors deal with facts as well as norms and aesthetics in relation to the science content taught and they influence learning both through what is made salient, as well as through their relations to the children's possibilities of proceeding with their undertakings. Often one and the same metaphor encompassed all these cognitive, aesthetic and normative aspects at the same time. It is discussed how this rich meaning can be cultured in a productive way, and how the children's spontaneous metaphors, with all their relations, can be used to enhance conceptual learning and also learning about the nature of metaphor use in science. Through their connection with various experiences of the children, it is also shown how children's spontaneous metaphors have the potential to enliven and humanise the subject.

Key words: Dewey, elementary school, learning, metaphor, primary school, science

1. Introduction

In this article we examine elementary school children's spontaneous metaphors and their significance for learning science. By spontaneous metaphors we intend those metaphors that children use spontaneously in the classroom when talking science. Our purpose is to look at the role of such metaphors in learning concepts and facts as well as in learning the norms and the aesthetics needed to participate in elementary science class.

We use the word metaphor in its broadest sense as

a figure of speech in which a word or phrase literally denoting one kind of object or idea is used in place of another to suggest a likeness or analogy between them (as in *drowning in money*); *broadly* figurative language (Merriam-Webster 2004, emphasis in original)

Several authors have discussed how metaphors are used in making sense of new experiences by relating them to previous ones (e.g. Flannery 1991; Sutton 1995; Cameron 2002; Lakoff & Johnson 2003; Zembylas 2004). According to Zembylas (2004) the use of a metaphor is a matter of transference from one situation to another. Such transference is discussed at length by Lakoff & Johnson (2003), who view metaphors as connected to situations and actions and not as just words labelling things. According to them metaphors are creating similarities, i.e. they are 'based on cross-domain correlations in our experience, which give rise to the perceived similarities between the two domains within the metaphor' (p. 245). Furthermore they maintain 'that the only similarities relevant to metaphor are *similarities as experienced by people*' (p. 154). Like we do here, also Lakoff & Johnson (2003) draw on John Dewey in emphasising the significance of experience and situated interaction for understanding the role of metaphor for conceptual learning and meaning-making generally. Metaphor use entails that certain similarities between experiences are made salient, whereas other aspects are backgrounded as differences. In this way relations (similarities and differences) construed through metaphor are building on earlier experiences and what follows from metaphor use is a new way of seeing the world, i.e. our prior experiences are reconstructed and transformed in the specific situation to make sense of the new experiences. When metaphors are seen in this way as transforming experiences through the relations made salient, it should be possible to see in talk and action how the metaphors used contribute to the meaning made and learning in science class.

The scientific language itself can be seen to be full of metaphors. Sutton (1995) gives examples of metaphors used in the sciences like 'magnetic field' (p. 17) and 'computer virus' (p. 19). Muscari (1988) gives other examples as 'white dwarf' and 'red giant' (p. 426). He contends that the use of metaphors in science, which are personal and emotional, often is of practical importance as metaphors help the scientists to understand earlier perceptions and create new knowledge, which also is pointed out by Ogborn et al. (1996). Analogies and metaphors play an important role 'in constructing new meanings within scientific work itself' (p. 72). But as pointed out by Lakoff & Johnson (2003) these analogies are not merely neutral or a matter of personal choice, since they through communication tend to make certain things prominent, whereas other things are made peripheral. Keller (1998) for example argues that many of the metaphors used in biology in connection to fertilization, tend to bias researchers in certain directions in regard to gender issues. Although such a bias initially might be apparent to researchers, by time metaphors tend to become reified and transmitted to students without discussing their metaphoric

nature, for example in biology textbooks. The metaphors produced by scientists in this way do not merely gain a cognitive function, but they also have aesthetic, normative and moral consequences as a result of how they actually are experienced by people. Such transformations should also be expected to be the case with children's spontaneous metaphors.

There has been an extensive debate concerning metaphors and science education and it has first and foremost been a matter of conceptual understanding. Asoko (2002) points out, that practical activities alone will not support learning. When teaching for conceptual change, abstract phenomena must be represented in some way, e.g. by words and analogies, to develop elementary school children's understanding of scientific concepts. Brown & Clement (1989) in line with many others argue that science teachers can use analogies in order to overcome students' misconceptions. By building on students' conceptions and use analogies as bridges between their understanding and the subject matter at hand, there is a possibility for the students to make meaning and learn the science content. Thomas and McRobbie (1999) investigated students' own metaphors concerning themselves as learners and how the metaphors can encourage metacognition. Wong (1993) studied in which way secondary school teacher candidates made use of their own self-generated analogies in advancing their conceptual understanding of scientific phenomena. He found that self-generated analogies function as 'means – as opposed to ends – in the process of understanding' (p. 1271) and that they can incite to new conclusions and insights.

Cameron (2002) maintains that children's understanding of science teachers' metaphors, when used as explanations, are dependent on children's knowledge of the specific domain being taught. She stresses that the metaphor used must be familiar to the children and make a relational connection to the topic in order to develop learning. According to Cameron (2002) textbook writers often miss this point when explaining different scientific phenomena. She also points out that children's own metaphors are spontaneous and 'a key starting point for moving conceptual understanding forwards' (p. 683). Sutton (1995) stresses the use and the abuse of metaphors when teaching and learning science because metaphors sometimes can confuse children, which also is stressed by Muscari (1988) and Cameron (2002). On the other hand, according to Sutton (1995), the teacher has to attend to the words used by the children, which can be metaphoric. He emphasises that you have to give life to the words, and in doing that, you need experience and imagination. However, Lubben et al. (1999) found that an everyday metaphoric use of hot and cold by Sotho speaking South African university students little influenced their scientific learning about heating.

But metaphors encompass more than the conceptual understanding of children. Heywood (2002) suggests that research concerning the role of analogies in science education instead of focusing on conceptual understanding should focus on how the teacher through using analogies can get students engaged in learning science. Lemke (1990) and later Dagher (1995) ask for more research concerning analogies and their function when students are talking science. Dagher (1995, p. 308) called for studies examining students' use of metaphoric language in inventive and creative ways.

However, except for Cameron (2002) there are relatively few empirical studies dealing with children's spontaneous metaphors. Notable is Bloom (1992a, b), who studied the role of children's own metaphors in the process of meaning-making. Bloom (1992a) emphasises the role of metaphors acting as comparative means. He further shows that they are often embedded within learning and enrich conceptual understanding:

For each child who generates his or her own metaphor, a connection or understanding is established that is not only personally meaningful but also extends that understanding beyond the basic concept. For example, the tip (or 'nose') of the earthworm does not just sense the environment, but, for Emily, it functions like 'cat's whiskers'. All of her personal experiences and knowledge of how cat's [sic] use their whiskers are linked to her new observations of how the earthworm appears to be using its 'nose'. (Bloom 1992a, pp. 406–407)

Bloom (1992a) shows that metaphors create meaningful concepts and that they give a contextual background for conclusions drawn. He argues that we hinder children's development of thinking and understanding by not including 'contexts of meaning' as metaphors and emotions-values-aesthetics (Bloom 1992a, p. 400), i.e. learning is not influenced only by cognitive processes, but also by personal experiences in a wider sense. For this reason, we should be interested in following Bloom (1992a, b) and Cameron (2002) in studying children's spontaneous metaphors, as they have the potential of bridging conceptual understanding as well as those aspects that are concerned with children's engagement and participation in science class activities. These latter aspects we will treat by expanding our analysis also to 'norms' (dealing with what should be done in science class) and 'aesthetics' (dealing with what is beautiful and pleasing in science class), which also have moral ramifications. Hence, in what follows we will build on these prior findings and show that children's spontaneous metaphors not only take part in the transformation of their conceptual understanding, but also in their learning of the norms and the aesthetics of science class. As discussed by Wickman (2006) all of these three aspects should be of significance in understanding the possibilities for children to understand and engage in science.

2. Theoretical Background

Particularly apt for the purpose of this study is Dewey's (1934/1980) holistic view of an experience. According to his view practical, emotional and intellectual aspects are interrelated in an experience. Furthermore an experience has to be aesthetic in order to be fulfilled and 'no experience of whatever sort is a unity unless it has esthetic quality' (p. 40). Moreover, in line with Dewey experience also involves action, of taking part in an activity (e.g. Dewey 1925/1958, pp. 18–19). An experience therefore also encompasses discerning what acts should be included and excluded, that is norms in the sense here used. In line with these premises we examine how children's spontaneous metaphors are continuous with experience in this general sense, and how they are involved in cognitive, normative and aesthetic transformation. This approach of empirically examining continuity and transformation in this Deweyan sense has been used in two earlier studies dealing with the significance of aesthetic experience for learning science (Wickman 2006; Jakobson & Wickman manuscript). There it was demonstrated how aesthetic experience is continuous with learning science, both regarding conceptual as well as normative transformation, and how the continuity and transformation of all these three aspects are necessary for engagement and participation in science class. However, in these studies metaphor use was not specifically examined.

The study of the cognitive aspects of learning is concerned with conceptual understanding and how empirical facts and logical consistency can support such an understanding. In line with this definition we will examine how children use metaphors as situational factual descriptors as well as more general concepts to make sense in science class. However, when learning science in class the children do not only learn facts and concepts, but simultaneously they learn norms, i.e. what observations to include and exclude, what belong and does not belong and which acts are appropriate and inappropriate when doing science. As a consequence it is of interest to examine how metaphors are related to learning facts and concepts as well as to learning norms. Finally we also study how metaphors are related to *aesthetic* experiences, expressed in aesthetic judgements, i.e. judgements about what children like or dislike, and whether they find actions, events and objects beautiful and pleasing or not.

In this study we examine how children's spontaneous metaphors are involved in learning science using a practical epistemology analysis. A practical epistemology analysis involves empirically describing what people are doing and saying in a specific situation, for example in the science classroom, and what this tells us about what they learn in the specific situation (Wickman & Östman 2002a; Wickman 2004, 2006). A practical

epistemology analysis is inspired by the work of the later Ludwig Wittgenstein, John Dewey and sociocultural approaches.

Epistemology traditionally concerns what knowledge is and how we get it (Grayling 1996). Piaget (1970) uses the term 'genetic epistemology' for his theory of learning. A practical epistemology as opposed to a genetic epistemology is a methodology of observing learning through action as part of an activity. This builds on a pragmatist idea of knowledge. Rorty (1991, p. 1) in line with such a view suggests that we should not 'view knowledge as a matter of getting reality right, but as a matter of acquiring habits of action for coping with reality'. In this Rorty draws upon Dewey. In a Deweyan and pragmatist sense a practical epistemology analysis can be seen as a way of reflecting upon or an inquiry into the epistemological habits of students or of teaching. The important aim of practical epistemology analysis is then to study the actual interactions that occur in speech and action and how these influence what people themselves decide to be valid knowledge in action. According to Wittgenstein (1967) words do not gain meaning until they show up in a *language game*, i.e. in a specific situation as part of an activity. As argued by Lakoff & Johnson (2003) this is true also of metaphors, whose meaning should be dependent on the circumstances when they are used. To study practical epistemologies and see how language games change involves examining the interactions that take place as part of an activity to find out *how* certain interactions are taking part in *what* is learnt. In this particular study these interactions are those that specifically involve metaphors.

This pragmatist view of knowledge is closely related to some sociocultural schools of thought. For instance Lave (1996) sees learning as something that occurs all the time when people interact with the world. Learning as such is thus unproblematic to people. Instead the problem is what direction their learning takes and what they actually learn. Rogoff (1990, p. 12) maintains that 'Rather than having to explain the fact that development occurs, it is necessary to determine the circumstances in which development takes one course rather than another.' This view is very close to one of Dewey's (1938/1997), who saw learning as part of a natural rhythm or habit where prior experiences are transformed and made continuous with new ones. This is Dewey's principle of continuity. The question then is to see how prior experience is used to make sense of new ones and what this means for the direction learning takes. A practical epistemology analysis therefore is closely related to other discourse analytic methodologies (e.g. Lynch 1993; Gee & Green 1998; Hutchby & Wooffitt 1998; Mortimer & Scott 2003), although it is particularly developed to analyse meaning-making from the perspective of a teacher: What do the interactions that occur mean for what content is learnt? The content learnt

might involve not merely conceptual learning but also ways to act, values and about yourself in relation to an activity. In line with this a practical epistemology has been used earlier to analyse such diverse learning situations as the significance of the laboratory artefacts for learning (Wickman & Östman 2002a), the impact of different kinds of teacher comments for the meaning students make (Lidar et al. 2006), the influence of the teaching sequence for the meaning students make (Wickman 2004) and how students generalize during laboratory work (Wickman & Östman 2002b).

3. Methodological Approach

Making a practical epistemology analysis to describe the route learning takes entails using four concepts, namely *stand fast*, *relation*, *encounter* and *gap* (Wickman & Östman 2002a). What *stands fast* is defined as those words that are used by the interlocutors without hesitation or questioning, that is those words that are intelligible in the situation studied. One illustrative example is the interchange between the girl Gunilla and her teacher about the appearance of a bud:

Gunilla: It looks like this one has a little hair here.

Teacher: Mm.

It can be seen that all the words used by Gunilla in this situation made sense to the teacher. The teacher did not ask what the words meant, but acted immediately upon them, concurring with Gunilla. Such words are said to stand fast in the particular situation. This does not mean that the same words could not be questioned in another situation. Standing fast is hence a highly situational description of the meanings words make in action.

Words that stand fast in a certain situation are used in a particular constellation that establishes *relations* between them. Such relations are used to create new meaning that is needed by the interlocutors to proceed with their activity in the specific situation. In the interchange just described the relations between 'It', i.e. the bud, and 'has a little hair' and 'here' apparently were necessary for the teacher and Gunilla to proceed with this activity in science class. This was not surprising, as this activity concerned making precise descriptions of buds. When people successfully establish a relation, they can be seen to learn something. Gunilla here learnt about the appearance of her bud by using words that stood fast. When a relation is construed to words that stand fast, a *gap* is said to be filled. Sometimes gaps are noticed that cannot be filled immediately. Such gaps are said to be lingering until they are filled. When relations are successfully construed to words that stand fast, continuity as well as transformation occurs.

These words are transferred from other experiences to make sense of this new experience, which has never occurred before. Using Dewey's vocabulary this means that the prior experiences of which these words are a part were made continuous with this particular new experience, merging them into an experience that brings the interlocutors forward in their undertakings. At the same time the experience as a whole is transformed through the new relation that is construed. Learning occurs all the time and here takes this particular direction. Words from before are used to make sense of what is new.

The terms stand fast, relation and gap deal with the meaning made in lingual terms. The concept *encounter* on the other hand deals with what can be seen to meet in making the meaning. In the situation above there was an encounter between the teacher and Gunilla. There was also an encounter between the teacher, Gunilla and the hairy bud. They all met in the situation taking place. The encounters that were seen to occur can be used to analyse what significance different kinds of encounters have for what is learnt in class. In the interchange above, the encounter with the bud was significant for the relation established by Gunilla and hence for what she learnt. The teacher on the other hand did not directly influence what Gunilla learnt about the bud.

We will here study the role children's spontaneous metaphors play for the relations construed in the encounters that occur in science class. When children used spontaneous metaphors they at the same time construed relations to other words. Some of these relations were of a cognitive and conceptual nature, whereas others related to normative distinctions or aesthetic judgments. By studying these different relations construed by the children in the various encounters of science class, it becomes possible to see how their use of metaphors influences their learning and engagement in science.

We here operationally define metaphor use (as opposed to conceptual use) as when children are using already familiar words in the meaning 'as if' in encountering something during the science activity. Conceptual use of a word, on the other hand, means that the children are not using an 'as if' mode in talking about what they encounter. For example when saying 'It's like crystals' (turn 11) the use of 'crystal' is seen as a metaphor, whereas in saying 'It's crystals' (turn 21) is seen as a conceptual use. These definitions should be seen as flexible, as children can be seen sometimes to negotiate the metaphoric status of terms, although, of course, they never use the term 'metaphor' as such in their negotiations.

4. The Study Settings

We present results from sound recordings made in five different Swedish schools. These schools represent a wide variety of settings including a big city

school, three different medium sized town schools and one in a rural area. One of the medium sized town school areas were dominated by first generation immigrants from the Middle East and north eastern Africa. Seven different classrooms were visited by BJ during one semester. Four classrooms were visited once, two were visited twice and one classroom was visited three times, resulting in about 25 h of recordings. Children of all classes except two were 6–8 years old (Swedish grade 1 and 2). The exceptions were one class of age 9 (grade 3) and one class of 10-year-old children (grade 4).

During the visits the children were involved in hands-on inquiry units in biology, chemistry, physics, and earth science working in pairs or small groups during lessons from 40 to 50 min long. This means that in each class recordings were made of 2–4 group conversations during each visit. The units were *Changes* (the transformation of matter), *Solids and Liquids*, *Electric Circuits*, *Mixing and Separating*, *Buds*, *Shadows* and *Soil*. All of the discussions in pairs or small groups were audio-recorded with a microphone at their desk, most of which were transcribe. Sometimes it was very hard to hear what the children said as they were talking in a low voice. In addition the voices of the children sometimes were very similar, and occasionally they might have been confused in the transcripts. All occasions on which the children used metaphors were analysed in light of the theoretical considerations mentioned earlier. Transcriptions given in the text have been translated from Swedish to English trying to preserve the original flavour and connotations of words used. To facilitate correct interpretation of audio transcripts BJ was present in the classrooms during recordings, observing children's actions at large and taking notes of what occurred.

5. Results

The children in this study frequently used metaphors in order to make sense of what they saw and of what happened in class. As the children were very young they did not yet own a scientific language, but typically communicated in an every-day language. Under this heading we first deal with children's spontaneous metaphors related to cognitive transformation and then with those concerned with aesthetic experiences and normative aspects, respectively. Finally we demonstrate how the metaphors used by the children take part in situations where cognitive, normative and aesthetic aspects are transformed simultaneously in whole educative experiences.

5.1. METAPHORS AND COGNITIVE TRANSFORMATION

The children's use of metaphors often involved a transformation of factual knowledge. On such occasions it could be seen how the use of a metaphor

helped the children to see certain things. One example was during the *Buds* unit, when the children observed buds of hazel using a magnifying glass. The aim was that the children should learn about how buds are constructed. A bud of hazel is round as an egg and has glandular hairs on the twig. The female flower is hidden in the bud, but the pistil stigmas can be seen as red straws sticking out from the bud. When the teacher asked Gunilla and Eva what the bud looked like, they responded by using a number of metaphors (metaphors are marked with bold type):

1. Gunilla: It looks like this one has a little **hair** here.
2. Teacher: Mm. A bud that has a little **hair**. You can write that down.
They look like...
3. Gunilla: **Caterpillars**.
4. Teacher: Skip one line and write on the next. They look like...
5. Gunilla: They look like little **w-o-r-m-s** [sounds out the word]. They look like teeny tiny **worms**.
6. Eva: **Caterpillars**.
7. Gunilla: **Worms**.
8. Eva: I'm done! Teacher!
9. Gunilla: They look like **caterpillars**.
10. Eva: They look like **caterpillars**.

Gunilla first used the metaphor 'hair' to describe the stigmas of the bud. In this she established the relation 'a little hair' to the bud. Obviously the metaphor hair was used as a *factual descriptor* of the traits of the bud, saying something of their general appearance. Seeing the stigmas as hair also helped her say something about the number of 'hairs' sticking out, which she did in using 'little'. She then suggested also the metaphors 'caterpillars' and 'worms', factual descriptors that also aptly described relations to the form and general appearance of the stigmas. The use of the worm metaphor apparently also tacitly related to the red colour of the stigmas. In using the worms metaphor Gunilla came to notice also the size of the stigmas as can be seen from her construing the relation to them of being 'little' and 'teeny tiny'. Apparently all these factual descriptors worked equally well also with Eva and the teacher as they stood fast and were not questioned by them. This is a clear example how metaphors helped the children in describing what they saw and also in making further observations in terms of the number and size of stigmas. In construing all these relations to their spontaneous metaphors, they effectively used their prior experiences of hair, caterpillars and worms in learning new things about buds in the science classroom. Besides, one metaphor did not exclude another, but jointly they aided the children in noticing different things about the buds.

The children used metaphors as meaningful factual descriptors in a lot of situations. Another example was the metaphor 'lava', which was used in order to describe what happened when mixing bicarbonate with water or vinegar. Another example was the metaphor 'mush' used as a factual descriptor when investigating soil. In the communication between the children their own metaphors with few exceptions worked, they stood fast and made meaning to the children in aiding them in construing new relations. Hence, the children's earlier experiences were reconstructed and transformed in the new encounter and their use of metaphors was thus continuous with learning science. But at the same time each metaphor only made certain things salient, and the metaphors that children spontaneously come up with in that way also restrict what they might see.

Metaphors typically were used as situational factual descriptors, and such uses were momentary. They worked as stepping stones, helping children to notice certain things about what they were observing. However, it could happen that metaphors developed into concepts. On such occasions the metaphors became more permanent terms for talking about specific phenomena. For instance in the unit *Mixing and Separating* the children were first told to observe and describe the salt and the gravel they later were supposed to mix and separate. When Lena and Jonas observed the salt, Lena immediately construed a relation to the metaphor 'crystals', which from that moment stood fast to them in relation to this specific phenomenon throughout the science activity:

11. Lena: Wait Jonas. I want to look too. Wow! [with wonder] It's white.
It's like **crystals**!
12. Jonas: Mm.
13. Lena: It's like **crystals**!
14. Jonas: Mmm. It looks like that.
15. Lena: It's like **crystals**!
16. Jonas: Yeah.
17. Lena: Little round things!
18. Jonas: Little, no, there are small big ones too.
19. Lena: I know! They are ve[ry], and so this is **crystal**. It looks like **bubbles**!
20. Jonas: Yeah.
21. Lena: It's **crystals**! Strange!
22. Jonas: Does it look like it's **crystals**?
23. Lena: Yes, here from below. Don't you see that they look a little like **crystals**?
24. Jonas: Move over a little. Look at those there, big ones.
25. Lena: They also look like **crystals**. They're big. They also look like **crystals**!

26. Jonas: [inaudible]
27. Lena: We'll take a little more salt!
28. Jonas: Yes! Can I have some?
29. Lena: We'll spread it out a little so we can see the different ones a little bit.
30. Jonas: Oh! [excited] So big! How big that one is!
31. Lena: That one was big!
32. Jonas: Yeah, whaddy call 'em, these are little **crystals**.
33. Lena: Mmm.
34. Jonas: This here is all wet like...
35. Lena: Mmm.
36. Jonas: Bad¹ **crystals**!
37. Lena: Yeah!

In this encounter the children construed a relation to salt by the metaphor 'crystals'. Their earlier experiences of crystals were transformed and they construed new meaning by establishing a relation to what was standing fast. The metaphor became a concept 'this *is* crystal' and 'these *are* little crystals'. That pieces of salt actually are termed *crystals* were not known to the children at the time. They kept on filling gaps with relations like 'little round things', 'That one was big!' and 'This here is all wet like...'. They also construed yet another metaphor in relation to 'crystals', namely 'bubbles', which meant that they observed that salt crystals among other things were round as shown in turn 17. Hence the metaphor was essential in their meaning-making. They made meaning, not from the observation itself, but by linking earlier experiences to this new one in trying to understand what they saw. The metaphor 'crystals' became a part of the observation and meaning-making and therefore deepened the observation.

In exceptional cases metaphors could also be a hinder to children's communication and undertakings. In the unit *Mixing and Separating* Jonas and Lena, after observing salt, went on observing gravel:

38. Jonas: That's a real **shark tooth**.
39. Lena: Hey, get real!
40. Jonas: All the same *that* one looks like a **tooth**! Look!
41. Lena: No way.

Jonas construed the metaphor 'shark tooth' in relation to the gravel and used it as a factual descriptor: '*That's* a real shark tooth'. In this encounter though there was a lingering gap as Lena obviously could not agree and use the metaphor when describing the gravel (turn 41). As a consequence the children had trouble talking to each other about what they observed as they did not come to an agreement:

42. Jonas: That's got to be a **tooth**.
43. Lena: No, it doesn't.

Jonas could not let go of the metaphor though and Lena was annoyed at him and thought he was playing around (turn 39). The children did not succeed going on in the desired direction, i.e. observing gravel, as their entire attention was directed to the ‘tooth-metaphor’ and they talked about if ‘tooth’ was a relevant descriptor or not of the gravel. Accordingly there was a gap regarding how to describe the gravel that lingered. The tooth metaphor did not help the children to continue their scientific activity.

5.2. METAPHORS AND AESTHETIC TRANSFORMATION

Metaphors obviously meant that children noticed certain things, while ignoring other aspects of the observed phenomena. Although these aspects were of a factual nature, at the same time they also had emotional consequences. Children’s use of metaphors thus often was related to aesthetics, i.e. judgements related to experiences of pleasure/displeasure and the beautiful/ugly. These distinctions dealt with the children’s emotions and feelings about objects, events and actions in science class, i.e. about what they liked or disliked. In the *Soil* unit, where the children investigated a sample of soil in order to find out what it consisted of, the children talked about their aesthetic experiences. In this conversation a metaphor played a role in this. Roger used the metaphor ‘spinach’, which summed up the experience of wetting the mixture (aesthetic judgements in italics):

44. Christine: So what are you doing?

45. Arthur: We’re spreading this out.

46. Roger: Oh, [observing] that feels like **spinach**.

47. Arthur: *Blooch!*

48. Christine: [giggling]

49. Arthur: That’s *not good*. **Spinach**. That looks like **spinach**.

50. Emma: *Eeee-oo...* That’s *yucky*.

The metaphor ‘spinach’ was construed in relation to ‘that’, i.e. the wet soil. The children went on and construed relations to ‘spinach’ in terms of negative aesthetics as ‘blooch’, ‘not good’, ‘eeee-oo’ and ‘yucky’. They clearly agreed on that wet soil was disgusting, like ‘spinach’, which was not questioned and hence stood fast in this encounter. But despite the negative aesthetic impression the soil made on the children, the experience yet meant that the children through the negative aesthetic metaphor noticed certain things about the soil.

The children’s metaphors were also used in relation to positive aesthetic judgements and dealt with what they liked. One example came from the unit *Liquids and Solids*. Albin and Sara observed salt with a magnifying glass and the task was to classify different substances as liquids or solids. In this encounter the children also related to earlier experiences by a metaphor:

51. Albin: *Whoa! Whoa! Whoa!* [shouts] It looks like little **diamonds!**...*Wow*, [in awe] how *cool!*...It looks like...little **diamonds!**

52. Sara: Yeah, *far out! God!* I'd like to have this!

The metaphor, 'diamonds' was related to positive aesthetic judgements, i.e. 'Wow', 'cool', 'far out' and 'God'. In this encounter it stood fast that salt looked like 'diamonds' which were 'far out' and 'cool', that is words used to express what the children found beautiful.

Hence, in using metaphors the children learnt that certain things in science class were either unpleasant or nice. At the same time they learnt that there were aspects of soil which looked like spinach and those of salt crystals, which reminded of diamonds. In this way learning aesthetically through metaphor was intimately connected also to cognitive transformation, irrespective of the aesthetic experience being positive or negative.

5.3. METAPHORS, AESTHETICS AND NORMATIVE TRANSFORMATION

It should be noted that what children liked and did not like also had normative consequences, and in this way metaphors also came to communicate which actions, objects and events that according to the children should be included or excluded in science class and what was the right and wrong way to proceed. When communicating norms the children frequently used aesthetic judgements emphasising their standpoint about what they should be doing. In this way the continuity of metaphors aesthetically and normatively came to deal with the students' possibilities of participation in class activities and learning about their own possibilities of taking part in science class.

Positive metaphors were used not simply about the things that the children liked or found pleasure in, but also in evaluating the norms for proceeding in class concerning what children were obliged to do. One example where a metaphor was used positively as a judgement of consent of class norm came from the unit *Soil*. The children investigated a soil sample in order to find out whether it consisted of sand, humus or clay, or of a mixture of them (aesthetic judgements in italics):

53. Peter: The dry sand feels *n-i-i-ce*.

54. Julia: It feels *smooth*.

55. Peter: *Marvellous*.

56. Julia: No, like **cotton**.

57. Peter: Mm.

Peter and Julia first construed positive aesthetic relations as 'nice', 'smooth' and 'marvellous' to the sand. Julia's metaphor 'cotton' summed up the whole positive aesthetic experience of observing the soil sample they had got. These relations between the metaphor cotton and the positive aesthetic judgements also was one of consent to class activities, where

students found no difficulties in dealing with the things they were supposed to handle in class. Hence, the children in this specific situation learnt that their doings with the sand and themselves could be successfully included in elementary school science. They related to 'cotton' in positive aesthetics and these distinctions meant that they could carry on in the right direction and succeeded in classifying the soil sample they had got, which was the purpose of the lesson.

In order to communicate children also used metaphors that communicated problems in dealing with norms of action in science class. This was obvious from the relations children construed between these metaphors and negative aesthetic judgements. One example was the earlier example from the *Soil* unit, where the children used expressions like 'not good' and 'yucky' (turns 44–50). All the same, in this particular case, the children were able to participate in the activity and carried it forward in the desired direction. However, this was not always the case when negative aesthetic judgements were construed in relation to the metaphors. Sometimes a conflict arose between the normative demands of science class regarding ways to proceed, on the one hand and what the children could handle, on the other hand. Oskar and Jakob, again in *Soil* class, investigated a mixture of soil. Jakob could deal with it and go on with the activity, i.e. touching the wet soil, although he found it disgusting. To Oskar it was impossible and he declared that he was not prepared to touch the wet soil, which he commented by saying 'Oh shit. I hate that'. This became even more obvious when the teacher came by asking if the boys could role the soil into a little ball:

58. Teacher: What's the next thing to do now?

59. Jakob: We have already...*disgusting*.

60. Teacher: What happens if you roll this around? Can you roll it? Pretty well? Can it be made into a little ball?

61. Oskar: Do I have to do that too?

62. Teacher: No, it's okay if you just watch. Is it working? [the rolling]

At this occasion the teacher noticed Oskar's dilemma and told him that he did not need to touch the soil, but at least look at it (turn 62). In that way she helped him to find a way out, i.e. an appropriate way to carry on, and confirmed that she knew that he could not deal with it. Jakob then used a metaphor, 'mush', which summed up the whole experience, also confirmed by the teacher (turn 64):

63. Jakob: It's turning into **mush**.

64. Teacher: Write that down!

65. Jakob: What happens when it turns into **mush**?

66. Oskar: You get all *sticky*. *Yech*.

The metaphor 'mush' was related to negative aesthetic judgements, i.e. it was 'disgusting' and 'You get all sticky' from it. Jakob, who nonetheless

could deal with the soil, realised that Oskar really had a problem in going on with the activity and teased him a little:

67. Oskar: I don't want to touch that stuff!

68. Jakob: Just a little! [presses a little mud against Oskar's cheek]

69. Oskar: *Yech!* **Doody!**

Oskar summed up his feeling of disgust in relation to the wet soil, by a metaphor 'doody'. He could not deal with the wet soil sample, which he hence wanted to exclude, and it was impossible for him to participate in this particular science activity and do what was asked of him.

As in the cases above, normative uses of metaphors often summed up the children's experiences of proceeding in certain ways. Such metaphors also dealt with what children would do next and about how to proceed, and in that way, through their relationship to the direction of actions taken, they also had consequences for what the children could learn. Hence, when learning is seen as the consequence of actions taken, metaphor use (aesthetically positive as well as negative uses) influences cognitive outcomes not only by making certain features of phenomena more or less prominent, but also by making certain paths of proceeding and thus of learning more or less likely.

5.4. METAPHORS – CONCURRENT COGNITIVE, NORMATIVE AND AESTHETIC TRANSFORMATION

From what has been said, it should be apparent that the cognitive, aesthetic and normative aspects of metaphor use were tightly interwoven and that they cannot easily be separated. Children's spontaneous metaphors thus are saturated with meaning and in this way are means of communicating complex relationships. One example of these rich, merged meanings came from the unit *Mixing and Separating* where Lars and Henrik observed salt:

70. Lars: Like **pearls**. Round **pearls**.

71. Henrik: And so round.

72. Lars: *Pretty* **pearls**.

73. Teacher: Mm. You think they're *pretty*?

74. Lars and Henrik: Yes!

These two boys related the salt to 'pearls', which was a meaningful factual descriptor to them and helped them to communicate the appearance of the salt. Lars and Henrik also construed the relations 'round' and 'pretty', which was a positive aesthetic judgement, to the metaphor 'pearls'. This positive aesthetic experience involved a positive aesthetic metaphor, which meant that certain things were made prominent in the comparison through metaphor to the earlier experiences of children. At the same time the children gave their consent to what they were asked to do in class, and

so to class norms. Besides, the teacher's comment 'You think they're *pretty*?' was used in a normative way, confirming that a positive aesthetic experience and one of consent was the right thing in describing the salt the way the boys did. This also meant that the children continued studying the crystals and could learn new things about them. So encouraged, their new experience of salt extended to a very close observation:

75. Lars: We'll look through this little one. Use the little one.

76. Henrik: *Ooooh!* [excited] A **snowball**! Look how big it is!

77. Lars: Look! Do it like this! In that direction.

78. Henrik: And there, you see! Look! When you get close like this you see tons...I'll put the glass on it.

79. Lars: Then you won't see.

80. Henrik: Look!

81. Lars: I know.

82. Henrik: They're little squares.

83. Lars: I know. Square **pearls**.

Lars suggested that they should look through the little lens of the magnifier and this resulted in that Henrik construed also the factual relations 'big' to yet another metaphor 'snowball', and finally that the salt was conceived as 'square pearls'. Their previous experiences of pearls and squares were transformed, linked to their new experience of salt crystals and made continuous and changed through metaphor use, which made it possible for them to discuss the experience at hand and to proceed with the science activity. The children also learnt that doing science could be pleasant and what was relevant to discern, that is, what should be included in order to proceed with the activity. The metaphors had an important role in communicating all these things.

Similar continuity and merging of all three aspects of meaning is everywhere apparent in the children's use of metaphors. A survey of the earlier examples given, e.g. *crystals* and *diamond* illustrates this fact too. Even the cases where children used metaphors with negative aesthetic relationships had cognitive continuity. For example, when Jakob and Oskar in turns 63–66 compared their soil sample to *mush*, they at the same time noted that it was *sticky*. Children learn all the time, but the question is how different metaphors affect *what* is learnt. As can be seen the metaphors are not part only of learning science, but also when children learn about their own relation to science.

6. Discussion

So, what do all these observations of children's spontaneous metaphor use mean for teaching science? To start with it should be noted that children

use metaphors spontaneously recurrently and that they use an every-day language in recruiting these metaphors. Just like teachers have a limited language to describe teaching and learning (Tobin & Tippins 1996), elementary school children have a limited scientific language. Thus as made clear also by the studies of Bloom (1992a, b) and Cameron (2002) the teacher cannot decide whether or not children should use or learn through metaphors. The children's spontaneous metaphors are there whether we want it or not. The important question should instead be how the teacher can use children's spontaneous metaphors to support children's learning of science. We will here go over some of the most important considerations that follow from our results.

First, the most well known aspect of metaphors is that they help learners to see certain qualities through the similarities made salient through the specific metaphor chosen (Lakoff & Johnson 2003) and hence that the metaphor chosen limits what children could learn (Sutton 1995). What can be seen in the conversations of this study is that children in a tacit way seem to be aware of this limitation, in that they see no conflict in using several metaphors for the same phenomenon. Obvious examples were the different metaphors used for salt crystals ('pearls', 'snowball') or the various ones used for buds ('worm', 'caterpillar', 'hair') by the same children. This observation suggests that additional metaphors deepen children's observations. Multiple metaphor use per se does not necessarily create conceptual confusion, but instead make additional qualities salient.

Second, just like in Wong's (1993) study of teacher students, also children's metaphors typically are means rather than ends. As opposed to science proper, where metaphors can be seen to be frozen into concepts, the children typically used their descriptive metaphors as temporary stepping stones in making sense of scientific phenomena. That is, metaphors were typically used as children's routes to learning about already existing scientific concepts like gravel or buds. Only on one occasion were children seen to reify a metaphor into a concept. Interestingly, this metaphor – 'crystal' – was one that actually coincided with an already existing scientific concept. Nevertheless, the predominant use of metaphors as means rather than ends accentuates the importance of not mistaken children's spontaneous use of metaphors with the historical process in science of establishing new concepts through metaphors. As opposed to scientists, that are trying to make sense of phenomena that has never been described before, children through metaphors are conquering the scientific language as already in use. This emphasises that teachers should take notice of children's spontaneous metaphors not in terms of ends being right or wrong, but by considering how they work as means in directing their scientific learning. In this, metaphors need to connect also to children's experiences.

Third, the metaphors that children actually use tend to restrict what they can observe. When children use a metaphor to describe a phenomenon, scientifically relevant traits of that phenomenon might go unnoticed. This is especially so because children's spontaneous metaphors are not only directed by their wish to describe phenomena on cognitive grounds, but because they also use metaphors aesthetically and normatively. Of course teachers could help children by presenting additional metaphors. However, there is a risk that the temporary, descriptive metaphors of the teacher do not connect with the experiences of the children, or that the teacher metaphor makes other qualities salient with the children than those which the teacher intends. Therefore the teacher should also encourage additional spontaneous metaphor use by open questions like 'What do you see?' or 'What else do this remind you of?' The different metaphors should then be judged by how they supplement each other in making those differences and similarities salient that are important for developing the concepts that children are supposed to learn (see under the next item).

Fourth, children rarely, when using metaphors, mentioned the actual qualities that the metaphors were making salient. Typically such qualities or traits of phenomena remained tacit. Neither did the teachers help the children to make such elucidations of the actual features that were made important through the metaphors chosen. Obviously there is a risk that the teacher might misjudge what features children make salient, especially because the teacher does not always share the experiences of the children. It is also possible that the children need to explicate the tacit qualities that their metaphor actualizes, to help them learn the qualitative concepts that are used in science to communicate these features. Using such words also help the children to note not only those features that are immediately salient to the children, but also those specific qualities which are conceptually important to science, for example in distinguishing sand from gravel or in distinguishing the bud of hazel from that of ash. The teacher should thus not be content with the tacit qualities expressed through the spontaneous metaphors that students use, but discuss what qualities that they intend and ask questions like 'What do you mean by that?'. The teacher in the *Bud* unit could for instance have asked what the girls meant by liken the pistil stigmas to a caterpillar, something which is not obvious.

Fifth, by taking note of items 1–4, a teacher should be able to develop children's ability to talk science in inventive and creative ways as requested by Dagher (1995). It should be possible to develop a habit of children, where metaphors are encouraged, but also where children recurrently discuss what qualities they intend with their metaphors and their relevance for making scientific distinctions. Further, in discussing these aspects with the children a first awareness of the significance of metaphors for scientific

understanding can be developed, that in older children can be used to explain that conceptual metaphors should not be understood as similar to the phenomena they refer to in every aspect (e.g. the metaphor 'selfish gene') or that every-day language meanings of the words used as metaphors do not match the scientific meaning on a one-to-one basis (e.g. 'energy' or 'force').

Sixth, because children's spontaneous metaphor spring from their experience, this means that children are not able to share all metaphors with each other, since children do not share every aspect of experience. This was especially obvious with the tooth metaphor used to describe gravel. A teacher therefore needs to be aware that a metaphor used by one child can be without meaning to another child. This is another reason for inviting children to come up with additional metaphors and to describe the actual qualities that they intend with their metaphors.

Seventh, metaphors cannot be chosen only by how they make certain qualities salient or not. Since metaphors also entail aesthetic and normative meaning-making, they influence the further route taken by the children in their learning. As was shown, also metaphor use that involves negative aesthetic experiences means that the children see certain similarities. Although such similarities might mean that children are observing scientifically relevant qualities, they might at the same time have the consequence that the metaphor make the children see certain features of the phenomenon, which make them less prone to further deal with it. Although not demonstrated in this particular study, it seems reasonable that by using metaphors with more neutral or even positive aesthetic consequences should help children in proceeding and thus to learn additional things through metaphor use. The introduction of a playful metaphor, might be a way for the teacher to change negative aesthetics hindering children to proceed into a positive aesthetics that entice them to continued efforts. By setting up a make-believe game through a metaphor children can be made to imagine that what was first unpleasant also can be experienced as rewarding and worthwhile observing. Although such a metaphor might not make scientific qualities more salient first, it might be able to carrying the activity forward and thus create opportunities to see new and relevant qualities. Jakobson & Wickman (manuscript) in another study give an example that could be interpreted in this way. There it was reported how a girl in primary science class – who first found it disgusting and difficult to handle an earthworm – came up with the idea of pretending that the worm was injured and needed care. In that way her disgusting earthworm was turned into something she liked and which she could handle, resulting in new, relevant observations of the earthworm.

Eighth, it is well known that choice of science content have cultural implications and hence can deter students of some backgrounds from entering the science discourse (Cobern & Aikenhead 1998; Brickhouse et al. 2000). This is very much because science content in various ways connects with moral and aesthetic values (Östman 1994; Wickman 2006). In a similar way, this study suggests that metaphor use through its connection to personal experiences and backgrounds have aesthetic and moral consequences, which need to be considered by the teacher. Using metaphors that hinder students from proceeding with their science tasks should be demoralizing in the long run. The shark tooth metaphor suggests that some metaphors might exclude certain students from class work. The girl's aversion of the shark tooth might have resulted because of the boy's and the girl's different interests and hence could relate to questions of gender and identity. A metaphor like the shark tooth might be very attractive to some boys, but perhaps less so to some girls. Boys at this age often are fascinated by sharks and dinosaurs, while girls' interests are of another kind. If the teacher does not note such a bias in metaphor use in for example group work, this might result that some girls find science mainly a male project. The same might happen to children that belong to certain ethnic groups, if metaphors that do not connect with their experiences are frequently used. Here, the teacher can play an important role of encouraging a wide cultural variety of metaphors.

Finally, it should also be noted that the spontaneous metaphors are communicating how the children are experiencing their own participation. If children are using mainly aesthetically negative metaphors, this should be seen as a warning sign that the teaching situation needs to be reconstituted.

To conclude, children's spontaneous metaphors are very rich in meaning. They deal with facts as well as norms and aesthetics in relation to the science content taught and they influence learning both through what is made salient, as well as through their relations to the children's possibilities of proceeding with their undertakings. When cultured in a productive way, children's spontaneous metaphors, with all their relations, have a potential to enhance conceptual learning and also learning about the nature of metaphor use in science. Through their connection with various experiences of the children, they also have the potential to enliven and humanise the subject.

Note

¹ The original Swedish word 'värsta' literally is a negative aesthetic judgement. But here it was used in a positive way like in Michael Jackson's tune 'Bad'.

References

- Asoko, H.: 2002, 'Developing Conceptual Understanding in Primary Science', *Cambridge Journal of Education* **32**(2), 153–164.
- Bloom, J.W.: 1992a, 'The Development of Scientific Knowledge in Elementary School Children: A Context of Meaning Perspective', *Science Education* **76**(4), 339–413.
- Bloom, J.W.: 1992b, 'Contexts of Meaning and Conceptual Integration: How Children Understand and Learn', in R.A. Duschl & R.J. Hamilton (eds.), *Philosophy of Science, Cognitive Psychology, and Educational Theory and Practice*, State University of New York Press, Albany, pp. 177–194.
- Brickhouse, N.W., Lowery, P. & Schultz, K.: 2000, 'What Kind of a Girl does Science? The Construction of School Science Identities', *Journal of Research in Science Teaching* **37**(5), 441–458.
- Brown, D. & Clement, J.: 1989, 'Overcoming Misconceptions via Analogical Reasoning: Abstract Transfer versus Explanatory Model Construction', *Instructional Science* **18**(4), 237–261.
- Cameron, L.: 2002, 'Metaphors in the Learning of Science: A Discourse Focus', *British Educational Research Journal* **28**(5), 673–688.
- Coburn, W.W. & Aikenhead, G.S.: 1998, 'Cultural Aspects of Learning Science', in B.J. Fraser & K. Tobin (eds.), *The International Handbook of Science Education*, Kluwer Academic Press, Dordrecht, Netherlands, pp. 39–52.
- Dagher, Z.R.: 1995, 'Review of Studies on the Effectiveness of Instructional Analogies in Science Education', *Science Education* **79**(3), 295–312.
- Dewey, J.: 1925/1958, *Experience and Nature*, Dover, New York.
- Dewey, J.: 1934/1980, *Art as Experience*, Perigree Books, New York.
- Dewey, J.: 1938/1997, *Experience and Education*, Touchstone, New York.
- Flannery, M.C.: 1991, 'Science and Aesthetics: A Partnership for Science Education', *Science Education* **75**(5), 577–593.
- Gee, J.P. & Green, J.L.: 1998, 'Discourse Analysis, Learning and Social Practice: A Methodological Study', *Review of Research in Education* **23**, 119–169.
- Grayling, A.C.: 1996, 'Epistemology', in N. Bunnin & E.P. Tsui-James (eds.), *The Blackwell Companion to Philosophy*, Blackwell, Oxford, U.K., pp. 38–63.
- Heywood, D.: 2002, 'The Place of Analogies in Science Education', *Cambridge Journal of Education* **32**(2), 233–247.
- Hutchby, I. & Wooffitt, R.: 1998, *Conversation Analysis: Principles, Practices and Applications*, Polity Press, Cambridge, U.K.
- Jakobson, B. & Wickman, P.-O.: manuscript, Aesthetic Distinction in Elementary School Science.
- Keller, E.F.: 1998, 'Gender and Science: Origin, History, and Politics', in D.L. Hull & M. Ruse (eds.), *The Philosophy of Biology*, Oxford University Press, Oxford, pp. 398–413.
- Lakoff, G. & Johnson, M.: 2003, *Metaphors We Live By*, The University of Chicago Press, Chicago.
- Lave, J.: 1996, 'The Practice of Learning', in S. Chaiklin & J. Lave (eds.), *Understanding Practice: Perspectives on Activity and Context*, Cambridge University Press, Cambridge, U.K., pp. 3–32.
- Lemke, J.L.: 1990, *Talking Science: Language, Learning, and Values*, Ablex Publishing Corporation, Norwood.
- Lidar, M., Lundqvist, E. & Östman, L.: 2006, 'Teaching and Learning in the Science Classroom: The Interplay Between Teachers' Epistemological Moves and Students' Practical Epistemology', *Science Education* **90**(1), 148–163.

- Lubben, F., Netshisaulu, T. & Campbell, B.: 1999, 'Student's Use of Cultural Metaphors and their Scientific Understandings Related to Heating', *Science Education* **83**(6), 761–774.
- Lynch, M.: 1993, *Scientific Practice and Ordinary Action*, Cambridge University Press, Cambridge.
- Merriam-Webster: 2004, Merriam Webster Online Dictionary, <http://www.m-w.com>.
- Mortimer, E.F. & Scott, P.H.: 2003, *Meaning Making in Secondary Science Classrooms*, Open University Press, Maidenhead, U.K.
- Muscari, P.G.: 1988, 'The Metaphor in Science and in the Science Classroom', *Science Education* **72**(4), 423–431.
- Ogborn, J., Kress, G., Martins, I. & McGillicuddy, K.: 1996, *Explaining Science in the Classroom*, Open University Press, Buckingham, U.K.
- Östman, L.: 1994, 'Rethinking Science Teaching as a Moral Act', *Journal of Nordic Educational Research* **14**(3), 141–150.
- Piaget, J.: 1970, *Genetic Epistemology*, Columbia University Press, New York.
- Rogoff, B.: 1990, *Apprenticeship in Thinking: Cognitive Development in Social Context*, Oxford University Press, New York.
- Rorty, R.: 1991, *Objectivity, Relativism, and Truth: Philosophical Papers* Vol. 1, Cambridge University Press, Cambridge, U.K.
- Sutton, C.: 1995, *Words, Science and Learning*, Open University Press, Buckingham.
- Thomas, G.P. & McRobbie, C.J.: 1999, 'Using Metaphor to Probe Students' Conceptions of Chemistry Learning', *International Journal of Science Education* **21**(6), 667–685.
- Tobin, K. & Tippins, D.J.: 1996, 'Metaphors as Seeds for Conceptual Change and the Improvement of Science Teaching', *Science Education* **80**(6), 711–731.
- Wickman, P.-O.: 2004, 'The Practical Epistemologies of the Classroom: A Study of Laboratory Work', *Science Education* **88**(3), 325–344.
- Wickman, P.-O.: 2006, *Aesthetic Experience in Science Education: Learning as Situated Talk and Action*, Lawrence Erlbaum Associates, Mahwah, New Jersey.
- Wickman, P.-O. & Östman, L.: 2002a, 'Learning as Discourse Change: A Sociocultural Mechanism', *Science Education* **86**(5), 1–23.
- Wickman, P.-O. & Östman, L.: 2002b, 'Induction as an Empirical Problem: How Students Generalize During Practical Work', *International Journal of Science Education* **24**(5), 465–486.
- Wittgenstein, L.: 1967, *Philosophical Investigations* 2nd edn, Blackwell, Oxford.
- Wong, E.D.: 1993, 'Understanding the Generative Capacity of Analogies as a Tool for Explanation', *Journal of Research in Science Teaching* **30**(10), 1259–1272.
- Zembylas, M.: 2004, 'Emotion Metaphors and Emotional Labor in Science Teaching', *Science Education* **88**(3), 301–324.