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What Difference Does Art Make in Science? A Comparative Study of Meaning-Making at Elementary School

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Abstract Here we examine the role art activities play in aesthetic experience and learning of science. We compare recordings of two sequential occurrences in an elementary school class. The purpose of the first sequence was scientific and involved the children in observing leaves with magnifiers. The second sequence had an artistic purpose, where the children made pictures of leaves by rubbing them with crayons. The material was analyzed by means of practical epistemology analysis, Dewey's philosophy of aesthetics and socio-cultural approaches using the concept of mediation. The results show that what was mediated in the two sequences differed; the mediating artefacts used thereby having an effect on learning. The children also learned how to take part in the activities aesthetically. What the results mean for the use of artistic activities in science education is discussed.

Keywords Art · Comparative study · Elementary school · Mediation · Pragmatism · Science

Introduction

We study how artistic activities contribute to engagement and learning of science. We compare two activities in an elementary school class. The purpose of the first was scientific and involved the children observing leaves with magnifiers. The second had an artistic purpose, where the children made pictures of leaves by rubbing them with crayons. The question we ask is how these two different activities afforded the children making certain observations and thereby learning specific things about qualities of leaves. We also examine the ways in which

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participation can be seen to develop through aesthetic experience. Finally, we discuss what the results mean for the use of artistic activities in science education.

The inquiry is of interest from a comparative didactics viewpoint as the different subjects in elementary school often are not delimited and typically taught by the same teacher. A strict subject didactics point of view might miss analysing important opportunities for learning. The paper is thus not taking for granted that didactic transpositions (Chevallard 2007) of science content, through classroom interactions, are happening in a linear fashion from the elementary science syllabus through teaching in science class, but also mediated through what is happening in other subjects, in this case art, when nature is in focus. Second, the paper is comparative in including the cognitive content as well as the socialization content in terms of the aesthetic companion meanings (Östman and Roberts 1994) afforded by the two subjects.

The problem of how art can contribute to science education might be perceived as having little significance, as art has traditionally been viewed as a subjective and emotional activity, while science depends on cognitive and objective interests (e.g., Gardner 1971; Strike and Posner 1992). Several scholars have pointed out that such a view tends to disregard the complex and contingent processes involved in science and science classrooms; processes that closely resemble those of art (e.g., Bloom 1992a, b; Cherryholmes 1999; Jakobson and Wickman 2008a; Wickman 2006). Many argue that both science and art are creative activities that are complementary, compatible and possible to combine (e.g., Fischer 1999; Root-Bernstein 1996; Watts 2001; Weisskopf 1979; Vickers 1988). Today the value of creativity and the arts-based learning is emphasized by the science, technology, engineering, art and mathematics movement in North America (e.g., Henriksen 2014).

Arguments for using art in science education can be divided into two camps (Adams and Fuchs 1985): those who argue that art can be used as a motivating power or as a means of injecting zest into the classroom and those who claim that art is a means for learning science. Simultaneously it has been argued that more empirical studies are necessary in order to determine whether such arguments can be supported (Wickman 2006; Watts 2005). Here we study both questions in terms of what children were afforded to learn cognitively and aesthetically about leaves.

Although several scholars have emphasized the importance of incorporating art in science classes on rational or ideological grounds, few empirical studies address the significance of artistic activities for learning science. Most studies are concerned with investigating the significance of depicting objects as precisely as possible. Symington et al. (1981) found that instead of drawing leaves from a close observation, children tended to draw them from memory. However, some results suggest that drawing in conjunction with learning science could contribute to the enhancement of children's observational skills (Hayes et al. 1994; Laverne Nelson et al. 1998). Moreover, Hayes et al. (1994) found that art activities used in science classes promoted children's enjoyment and satisfaction, that is, their aesthetic experience of science (sensu Dewey 1934/1980). Weigand (1985) carried out an empirical study in which high school students in an integrated art/science class used drawing when learning about ethology. Weigand claims that students in the integrated class had a more positive attitude to both science and art and a better

retention of both art and science-related knowledge, than those students who had not attended the integrated class. He argues that art should be used in order to enrich and enliven science education.

An empirical study of special interest is that of Kress et al. (2001), in which they describe Grade 7 students making models of plant cells as homework. The material used was carefully chosen by the students in order to explain the structure of the cell and its functions. Accordingly, the material was motivated and interwoven in the students' meaning-making processes as part of the purpose of the specific activity. Consequently, Kress et al. claim that spoken or written language is not enough when communicating science, but that different modes of communication have different consequences for the meanings made. Likewise, Jakobson and Wickman (2008b) have shown how various resources afforded primary school children to observe certain qualities and disregard others when involved in observing and simultaneously painting, sculpturing, talking or writing poems about a goldfish. Consequently, the realisation of meaning differs with different modes (Kress 2010). In socio-cultural parlance the different modes of communication could be viewed as different kinds of mediation embedded in various kinds of activities, and that such differences have consequences for what teachers and children talk about and hence for what children can learn (cf. Säljö 1996; Wertsch 1995). Kress et al. (2001) studied activities where different modes of communication were used but that had a straightforward scientific purpose. Here we take their results further and compare two activities—one with an artistic and one with a scientific purpose. Both activities focus on the same biological objects (leaves) although employ different mediating resources (crayons and magnifiers, respectively) in order to determine what the children learn. To our knowledge such a comparison of what scientific versus artistic activities afford students to learn has not been made before.

Theoretical Background

In this article we use the concept "mediation" in the sense of human actions mediated by artefacts used (Wertsch 1995). We include language use as action, since talking means acting towards other people (Wickman 2006; Searle 1996). This is in line with Wittgenstein (1953/1967), who maintains that language is part of an activity and if we want to understand the meaning of words we have to look at the activity in which they are used. According to Wittgenstein, words first acquire meaning when they occur in a language-game, that is, in a specific situation as part of an activity. This view of meaning-making as learning in action has also been used by several socio-cultural studies (e.g., Lave 1996; Rogoff 1990).

Here we are interested in how the artefacts used in art and science education, mediate the teachers' and the children's actions and, accordingly, what the children are afforded to learn. Mediating artefacts are culturally and historically constituted and participating in an activity means that the artefacts used carries the heritage of the specific practice. However, mediation does not occur automatically, but is shaped by interactions with more competent users and peers (Wertsch 1998; Wertsch et al. 1995; Vygotsky 1986). We do not view mediation as passive,

mechanical and determinate. Instead, mediation has to be examined empirically since it is not only dependent on the situated activity and its specific purposes, but also on the interlocutors' earlier experiences of similar situations. This can be said to constitute a pragmatist understanding of "mediation", where you study mediation as encounters and are interested in how these encounters influence the direction learning takes by the use of certain artefacts (Wickman and Östman 2002).

We have adopted the meaning of an experience in accordance with Dewey's (1938/1997) principle of continuity, meaning that our previous experiences are continually reconstructed and transformed when making sense of new situations. In accordance with this, observing, whether the aim is scientific or artistic, is not just a question of absorbing facts. Instead, prior experiences need to be carried into the new experience, so that it is expanded and deepened and can be made sense of (Dewey 1934/1980). The question is to determine how earlier experiences are used when children make sense of new ones and what this means for the direction learning takes. In addition, imagination is necessary when prior experiences are reconstructed and transformed and constitutes a link between what has gone before and what is new (Dewey 1934/1980). Moreover, Dewey's principle of continuity indicates that learning and meaning-making are continually taking place; also stressed by Lave (1996). However, the direction learning takes does not always embrace the expected and desired route of, for example, the teacher or with reference to accepted scientific knowledge (Rogoff 1990).

Dewey (1929/1958, 1899/1990) argues that observing is a common denominator in art and science. Moreover, he maintains that there is no other work in school than art

> that better develops the power of attention, the habit of observation and of consecutiveness, of seeing parts in relation to a whole. (Dewey 1899/1990, p. 174)

To Dewey (1934/1980), observing in both science and art always involves determining what to include and exclude when trying to compose an integral whole in order to carry the activity forward. What is observed and what can be learned is dependent on a particular activity. Accordingly, observing how the activity is mediated is of interest.

By using practical epistemology analysis (PEA) emanating from Dewey, the later Wittgenstein and socio-cultural approaches, it is possible to empirically describe the direction learning takes (Wickman 2004, 2006; Wickman and Östman 2002). Traditionally, epistemology deals with questions about how we acquire knowledge and what knowledge is (Grayling 1996). Rorty (1991) suggests that knowledge is "habits of action" (p. 1) that are necessary for managing our lives. PEA adopts a definition of knowledge that is close to Rorty's, that is, a study of *how* we learn such habits when participating in specific activities, for example, in the science classroom. Accordingly, the unit of analysis is the activities of individuals as participants in a social practice, which is in accordance with socio-cultural perspectives (Wertsch 1995). Hence, PEA empirically describes people's speech and actions in a specific activity and what this tells us about what they are afforded to learn.

PEA is a well established method and is developed to analyze meaning-making in order to determine whether what occurs in the classroom influences students' learning, and if so, how (Kelly et al. 2012).

In line with the theoretical considerations described we demonstrate how two sequential activities, observing and rubbing leaves for two different purposes in an elementary school class, mediate the teacher's and the children's actions. What significance do these two purposes and the mediating artefacts used (magnifiers and crayons, respectively) have for the direction the teacher's and the children's actions takes, what are children afforded to learn conceptually in science about leaves as a result, and how do they contribute to children's aesthetic experiences shown in the use of aesthetic judgements?

Analytic Approach

We use two operational concepts borrowed from PEA, *relation* and *encounter*, to describe the direction learning takes (Wickman and Östman 2002). In the context of this study, the *relations* the children construed about what they observed in the specific situation are particularly relevant. When relations are successfully construed in communication, the participants can proceed with the specific activity to learn new things. One example of this is when two girls observed leaves using magnifiers (19–20):

Julia: …and then it's dotted. It's got freckles.
Susan: Yes, it has [giggles].

In the transaction, Julia construed the relations "freckles" and "dotted" to the leaf in making meaning of and communicating what she observed. Such relations entail that continuity and transformation occurs, that is, learning and meaning-making are taking place. Borrowing Dewey's (1938/1997) vocabulary, words from previous experiences are made continuous with the new experience and carry the participants' undertakings forward. The relations construed by Julia were immediately intelligible to Susan, and the girls thereby were afforded to learn that the observed leaf was "dotted" or "freckled".

While the term relation deals with the meaning made through talk, *encounter* deals with what interact. In the example, there was not only an encounter between the girls but also between the girls, the leaf and the magnifier. Such situated encounters can be analyzed to see whether the relations found are influenced by the particular encounters that occur. Encounters that involve artefacts like magnifiers and crayons can be used to see how such artefacts mediate student conversations and other actions.

The relations in the quotation deal with the cognitive subject content, namely with describing the more objective qualities of leaves. The children also made aesthetic judgments about the leaves (e.g., a leaf was nice) and how they felt partaking in the activities (e.g., they liked mixing colours when rubbing leaves).

These companion meanings regarding how they enjoyed the science and art activities are also analysed (see Jakobson and Wickman 2008a; Wickman 2006).

Both settings included numerous encounters. During the observation sequence encounters took place between the children, between the children and the teacher and between the children, the magnifiers and the leaves. The rubbing exercise included similar encounters, although instead of using magnifiers the children used crayons and pieces of paper, meaning that the artefacts and their purposes were quite different.

In our analysis we iteratively read through the transcripts of the whole recorded material and noted all the relations that the children construed to the leaves cognitively as well as aesthetically. We then categorized them according to their possible consequences for what children were afforded to learn biologically about leaves and according to the kind of encounter, that is, whether it was with the artefacts, the teacher or the other children or combinations of them. We give numerous examples of transcripts to illustrate how our conclusions were drawn.

The Study Setting

In order to study the significance that observing leaves from a scientific and from an artistic purpose has for what elementary school children are afforded to learn about leaves, first author made recordings in a classroom in a medium-sized town school. The children were 6–7 years of age (Swedish Grade 1) and at the day of recordings 14 children were present in the classroom.

First author asked the teacher before the visit to plan a science lesson that included an art activity. The children had just started to learn reading and writing and the teacher chose an open-ended task, showing what a teacher and mediation can afford children to learn about leaves. The teacher chose to let the children start observing the leaves with magnifiers and thereafter rubbing the leaves with crayons. Before first author collected the data, she was present in the class 1 school-day. The children then were given an opportunity to become acquainted with cameras, recording equipment and the researcher.

The teacher started the unit entitled "Autumn" the day before the recordings, and allowed the children to pick different tree leaves from the ground outside, which she then put in press. During recordings the children were involved in observing and rubbing the leaves using two different kinds of mediating artefacts (magnifiers and crayons and pieces of paper, respectively).

The children worked in small groups during the 40 min lesson and audio-recordings were made of four group conversations by means of a microphone placed on the children's desks. These recordings were transcribed. At times it was difficult to determine what the children were saying because they spoke in low voices. In addition, the voices of the children sometimes sounded quite similar, meaning that they might have occasionally been confused in the transcripts. While the children were rubbing leaves we put two video cameras on a stand and focused them on two groups. In that way we could follow these two groups from start to finish rather than having mixed fragments of all groups. The video recordings were not transcribed in

full, but were used as a complementary backup in the analysis. First author was present during the lesson and took notes of what happened in the classroom as a whole.

Results

We first deal with the role that scientific observations using magnifiers played in what children noticed and were afforded to learn about qualities of leaves. Secondly, we demonstrate how artwork, produced by rubbing leaves with crayons, influenced the meaning-making process about leaf qualities. Under separate sub-headings we discuss what the children were afforded to learn cognitively and aesthetically about leaves as a consequence of the different mediating artefacts and the teacher's changing purposes. Finally, we compare the events that occurred within the two different sequences.

Learning About Leaves Using Magnifiers

At the beginning of the lesson the teacher distributed different leaves to each group telling the children that they should:

> Pick up a magnifier and select one or two of the leaves that I've given you and observe them very closely. Talk to each other while you're observing the leaves and tell each other what you see. It's really good if you talk about what you're observing, 'cause later on I'm going to ask you what you saw *on* the leaf. [our emphasis]

The purpose was scientific, which implied that the children were expected to make close observations of leaves using magnifiers. As part of the activity of "observing and describing", the magnifier mediates the instructions given by the teacher, as she emphasizes that the children should observe what is *on* the leaf. Thereafter each child picked a leaf and observed it closely. They continued to pick out other leaves, making observations and talking about their findings. During the observation sequence the teacher continuously posed questions to the whole class, thereby helping the children to participate in their classmates' observations of leaves despite being in separate groups.

Cognitive Learning

During this observation sequence the children made a number of observations relating to leaf qualities. The mediating artefact used afforded the children to observe certain qualities of leaves while others were excluded. They first and foremost distinguished microscopic details of the leaves. In doing that the children compared *individual* leaves and noticed differences and similarities between them. They also located their findings on *their* individual leaves. One example came from Eva, who discerned that a leaf had "hair":

1. Eva: I can see hair.
2. Teacher: It looks like hair. Is it on the underside or on the upper side of the leaf?
3. Eva: The underside.
4. Teacher: Can the rest of you see it as well?
5. Paula: Yeah!
6. Teacher: That there's hair on the underside?
7. Paula: Yeah!

The observation made by Eva was confirmed by Paula from another group in the class (5, 7). Paula's classmate, Mona, had previously told Paula that she could see "lots of hair" on the leaf she was observing. This observation resulted in Paula taking a closer look at Mona's leaf, although she did not comment on what she saw. However, when Eva brought up this quality of leaves in class discussion, Paula immediately agreed, which indicated that she had observed the hair on Mona's leaf. When asked by the teacher where you could see "hair" (2), Eva immediately responded that there was hair on the "underside" of the leaf, which Paula concurred with (7). The children did not therefore only observe microscopic qualities, noticing that there were similarities between the leaves, but were also able to locate their findings. It is also apparent that locating this quality did not mean distinguishing classes of leaves with or without hair. The important thing was to see that hair is a quality that can occur on leaves. All these construed relations might seem negligible, but regarding the children's age they can be said to be a first step in learning biologically about leaves and, subsequently, about trees.

Like Eva and Paula, the other children in class made comparisons between the leaves they were observing and distinguished that there were microscopic similarities, such as "holes", which the children related to bugs eating on the leaves, and "dots", which at times were referred to as bugs. However, the children did not only notice similarities but also differences, for instance, when observing the small veins on various kinds of leaves:

8. Douglas: I've got lines.
9. Ted: Not me.
10. Laura: I can see lines.

When trying to make meaning and communicate his findings, Douglas construed the relation "lines" to the small veins on the leaf being observed; a term apparently understood by the other children in this group. Laura stated that she could also see "lines" on her leaf, whereas Ted could not see any on his. Ted thereby noted that some leaves had "lines", that is, there were differences between the individual leaves being observed. Comparisons like this enhanced the children's learning about leaves and made them include qualities observed by their classmates. However, the actual words used limited the children's observations of the veins, in that they looked upon them as lines forming a two-dimensional pattern and did not distinguish that you could also feel them when touching the leaf. In that way the magnifier, together with the children's use of words, contributed to the salience of

some properties and to others being disregarded. It can therefore be concluded that observing with magnifiers primarily mediates qualities by means of vision.

The leaves' specific traits were not mediated directly to the children by the artefacts alone. The teacher was also active in this mediation via her instructions about the norms or procedure of the activity and so what the practice of using magnifiers in science class entails. Such norms relate to what to include/exclude and how to act when carrying the activity forward to a close. In line with this, the teacher improved the children's observations by regularly posing whole class questions. In that way she did not only encourage the children to make close observations, but also laid down the general outlines for what to include and, in addition, how to act, that is, using magnifiers, when proceeding with the activity. Accordingly, she influenced how the artefact mediated the children's actions in that she drew the children's attention to certain qualities of leaves, which mostly resulted in the children carrying the activity forward in accordance with the teacher's demands:

11. Teacher: Listen! Can anybody see them? If you're thinking about and looking at the leaf you can see, if you're looking really closely, that there're little tiny, tiny threads inside the leaf.
12. Laura: There're threads inside there!
13. Susan: Mm.
14. Paula: I don't have to look 'cause there aren't any here.
[ ]
15. Julia: How nice! Look! These have threads too.

The teacher drew attention to the smallest veins, stating that there were "tiny threads" inside the leaves. Laura, who earlier had agreed with Douglas' discernment that there were "lines" on the leaves they were observing (8–10), responded immediately to the teacher's comments. In other words a shift occurred in that instead of merely perceiving the veins as lines Laura could now observe the veins as threads inside the leaf. In that way the teacher's comments promoted Laura to make an even closer observation of the veins. The fact that there were threads inside the leaves was also quite intelligible to Susan and Julia (13, 15). Consequently, the teacher's comments and questions throughout the observation sequence enhanced what the children distinguished and thereby what they were afforded to learn about qualities of leaves. However, the teacher's attempts to improve the children's observations did not necessarily have the desired effect on all the children. Paula did not agree that there were threads inside the leaf she observed nor to that she had to take a closer look (14).

The teacher's guiding questions made the children aware of what to include in their observations with the magnifier. Hence, the children included microscopic qualities of the leaves throughout the magnifier sequence and discerned that such qualities formed patterns on the leaves. Susan, for instance, noticed that there was a "black dot" on her leaf and the teacher encouraged further observations:

16. Susan: Mm. Weird…like a black dot.
17. Teacher: Yes, looks like a black dot here…Julia!
18. Julia: There're a lot of dots on the leaf.
[…]
19. Julia: First it's brown and then it's dotted. It's got freckles.
20. Susan: Yes, it has [giggles].

Aesthetic Learning

Observing leaves using magnifiers meant that the children distinguished certain qualities of leaves. However, learning cognitively about leaves also had aesthetic consequences, which are closely related to emotions. The children occasionally expressed what they liked or disliked in aesthetic judgments, that is, words relating to what the children found beautiful/ugly and pleasing/unpleasant about the activity and the qualities of leaves. Julia, for example, liked the occurrence of threads inside the leaf which she expressed in the positive aesthetic judgment "nice" (15). Julia thereby assented both to the activity and that participating in science class could be nice. Likewise, Susan's use of the aesthetic judgment "weird" (16) here meant that she was willing to proceed with the activity distinguishing more qualities of leaves, although used in a different context the word may have had a more unpleasant ring to it. This demonstrates how the words used acquire their meaning in situated interactions through specific activities. At times the children expressed their excitement about what they were seeing by using positively toned interjections like "Oooh [devoutly]!" and "Oh [devoutly], it's shiny!"—expressions that indicated that they were willing to continue the activity. One example came from Paula and Mona who began to observe the leaves using magnifiers before the teacher actually had started the lesson:

21. Paula: (inaudible) white dots like sand.
22. Mona: Oooh! [devoutly]
23. Paula: Then there're pieces of fluff there.
[ ]
24. Paula: Two green dots on this one [the leaf].
25. Mona: Where? [looks at Paula's leaf]
26. Paula: There…there.
27. Mona: Here I can see lots of hair!
28. Paula: Where did you say? [looks at Mona's leaf]
29. Mona: Lots of hair!

Paula's comparison to sand had a positive aesthetic undertone, which was emphasized by Mona's interjection "Oooh!" When the girls observed that dots on leaves look like sand, they simultaneously proceeded with the activity, which resulted in them distinguishing more qualities of leaves: "pieces of fluff", "green dots" and "lots of hair".

The use of aesthetic judgments was rare during the magnifier sequence, although the children's imaginations tacitly showed that they were emotionally and

aesthetically involved in the activity. By using familiar words they were able to reconstruct and transform previous experiences in the new encounter when trying to make meaning of what they were observing. The children's imaginations constituted a bridge between prior experiences and the new one, which was shown through their choice of words, for example, "freckles" (19) and "sand" (21). Such distinctions frequently involved an anticipation of what would occur when continuing to observe. Accordingly, by interacting with leaves as mediated by magnifiers, the children did not only learn cognitively about qualities of leaves, but also about their own aesthetic relation to that particular activity. In the long run this may impact on children's possibilities to participate in science classes and their further engagement or disengagement in science activities.

Learning About Leaves Through an Art Activity

After a while the teacher interrupted the lesson by saying: "Let's see if we can make a picture of the leaves". She showed the children how to make a picture by rubbing leaves through a piece of paper using crayons. Accordingly, there was not only a shift in the mediating artefact used, but also with regard to the purpose of the activity. This shift, from observing with magnifiers to making pictures with crayons, had consequences for what the children were afforded to learn about leaves.

Cognitive Learning

During the rubbing sequence the teacher asked the children to choose different kinds of leaves and compare them with each other. She then encouraged the children to proceed by observing the leaves. The children compared the different kinds of leaves with each other and discerned macroscopic differences between the species. Those qualities that were of little interest for the resulting imprints were excluded throughout the exercise. An example of this came from Ted, Laura and Gisela, who were rubbing maple leaves while simultaneously distinguishing the shape:

30. Teacher: Oh [with admiration], how nice you've got it Laura! What a large leaf you've got under there.
31. Laura: No, that's the tree star.
32. Teacher: Is it that you call a tree star? Why do you call it a tree star?… Yesterday when we were out walking you said that it was a tree star.
33. Ted: They're stuck on sticks like that, up in the trees.
34. Teacher: Okay. So it looks like a star…up there? Is it only that leaf you're calling a tree star, or can you call this a tree star [shows another leaf] as well?
35. All in chorus: No!
36. Teacher: Who figured this out?
37. Gisela: 'Cause they're a little bit starry, like this… pointed.

The teacher confirmed Laura's picture by using the positive aesthetic judgment "nice", and noticing that Laura was rubbing a large leaf. Laura rejected this comment and instead construed the relation "tree star" to the leaf being rubbed. Her

wording was immediately intelligible to the other children in this group. It was quite clear that the maple leaf looked like a "tree star" because they are "stuck on sticks…up in the trees" (33) and are "a bit starry" and "pointed" (37). Besides, the word "tree star" could only be used when describing leaves of the maple tree (34–35). In this way the children were given the possibility to distinguish that leaves from different trees have different shapes and thereby were afforded to recognize different species even though they could not explicitly name the trees. Accordingly, the rubbing activity mediated talk about the shape of different kinds of leaves, meaning that the artistic activity enhanced what the children were able to learn about leaves.

During the rubbing sequence the children did not talk about the microscopic or macroscopic similarities between the different individual leaves. Instead they engaged in communicating the macroscopic qualities observed through distinguishing different kinds of leaves in accordance with the teacher's purpose. Like the children in turns 30–37, Mona noticed the shape and size of the maple leaf:

38. Mona: I'll pick the leaf star.
[ ]
39. Mona: I'll pick a large leaf.

Like the children above, Mona compared the leaf of the maple tree to a star, although used a slightly different wording. She observed that different kinds of leaves have different shapes, although she was not explicit about the shapes of other kinds of leaves. Mona later stated that she was going to pick a "large" leaf. Hence, she distinguished that the size of different kinds of leaves varies—that there are small and large leaves. Her classmates did not make any remarks about her observations, which was frequently the case during the rubbing sequence, although the children did observe a lot of differences between the different kinds of leaves. This became obvious when the teacher posed questions and commented on the children's artwork. The teacher's role was therefore of significance for what the children communicated about their findings.

Again the teacher staged the scene by posing questions relating to differences between the leaves, thereby encouraging the children to include different kinds of leaves in their rubbing, which meant that scientific learning was also included in this artistic part of the lesson:

40. Teacher: Is there a difference between the various leaves, do you think, or are they similar?
41. All in chorus: No, there's a difference.
42. Teacher: Yes, that's right! What's the difference do you think, Gisela?
43. Gisela: That they're different sizes.
44. Teacher: They're different sizes.
45. Douglas: And the line isn't in the same spot.
46. Teacher: No-o! And here you can see the line a bit more clearly, can't you?
47. Douglas: Ye-ah.

The children agreed that there were differences between the various kinds of leaves (41). Gisela distinguished that they varied in size, which was confirmed by the teacher (44). Although not explicitly described as biological species, Gisela could differentiate between different kinds of trees, which she had expressed earlier when talking about the "tree star" (31). However, in this activity neither the teacher nor the children took this discernment further to include the naming of trees. As in turn 8, Douglas maintained there were "lines" to be seen on the leaves, meaning that he still perceived the veins as lines forming a two-dimensional pattern. Nevertheless, his discernment increased during the rubbing sequence, as he now observed that the "lines" were shown to have various locations and were visible to varying extents on different kinds of leaves. Like Gisela, Douglas was able to sort out different types of trees, even though there was no discussion about species. Accordingly, the teacher's questions about differences between the leaves helped to mediate the children's art activity in terms of what was important to include in carrying the activity forward. By posing questions she encouraged the children to talk explicitly about the differences between the leaves that were of importance for the outcome of the rubbing. Hence, the mediating artefact and the experienced teacher were both of significance for what the children were afforded to learn about leaves in the rubbing activity.

The children occasionally taught each other how to proceed with the activity. One example was when Paula advised her classmates how to make the imprints: "You just put a leaf up-side down, then put a piece of paper over it and then you draw a bit so that you can see it, and then it's like a leaf". At the same time as she imparted this advise she distinguished that leaves have an upper and an under side. This discernment was of importance in the creation of the artwork and authenticity of the imprint, which meant that the veins were of significance for the outcome of the picture. When learning this, the veins became clearly visible to Ted, who during the previous scientific activity had been unable to distinguish any veins on the leaf he was observing (9):

48. Ted: Here it's real!
49. Teacher: Here it's real! Look! What makes it real?
50. Ted: The sticks!
51. Teacher: Yes, do you think they're like the sticks inside the leaf?
52. Ted: Yeah.
53. Teacher: Yes, like the sticks that you've been putting in all directions.
54. Ted: Here there're almost no sticks.
55. Teacher: There're almost none. Do any of the leaves have lots of sticks?
56. Ted: This one.

During the rubbing Ted construed the relation "sticks" to the veins. The meaning of this everyday word was quite intelligible to the teacher. His wording, "sticks", indicates that he could not just see the veins but could also feel them sticking up. However, the children seldom construed relations involving senses other than vision, for instance the sense of smell or touch. From being called "lines" (8–10) and regarded as a pattern of two-dimensional lines, the veins were now perceived as

a pattern of three-dimensional shapes that emerged as a result of rubbing, and which Ted discerned through the artistic activity. Moreover, the "sticks" were shown to be of significance for the authentic look of the imprints (48–50), which was also confirmed by the teacher (51). Ted also made comparisons between different kinds of leaves and noticed that all leaves do not have the same number of veins (54, 56); again something that was confirmed by the teacher (55). Ted was therefore able to sort out different kinds of leaves and, in extension, had acquired the potential to identify different species. The rubbing of leaves thus enhanced Ted's observational skills and promoted what he was able to learn about leaves. Although he did not only construe the relation "sticks" to the veins but also to the petiole of the leaves (33), he did not encounter any problems when communicating his findings. Nobody asked Ted what he meant by "sticks" in either situation, which indicates that his wording was fully intelligible to the others. This illustrates the immediacy of words and that their meaning is dependent on interactions taking place in a specific situation.

Aesthetic Learning

The art activity did not only involve cognitive learning. In addition the children construed positive aesthetic relations to the qualities of the leaves being observed as well as to the artwork taking shape. In that way they communicated that participating in observing and rubbing leaves was a pleasant activity. However, they did not only use aesthetic judgments when expressing their delight, but aesthetic meaning was also shown as an undertone, for example, when the children compared the leaves to previously known qualities or objects: "tree star" (31) and "leaf star" (38). Stars twinkling in the night sky are beautiful to look at, and imagining that leaves look like stars might result in them being worthwhile to observe. This was accentuated when Laura showed her rubbing to the researcher and stated that she had rubbed a "starry sky":

57. Laura: Starry sky.
58. Researcher: Why did you choose that leaf? [a maple leaf]
59. Laura: It was so nice.

Accordingly, the positive aesthetic undertones of the words used pointed out that observing and rubbing leaves was nice. Such distinctions dealt with children's emotions and aesthetics, both of which seemed to be of importance for their participation in science class.

Moreover, the children were shown to be aesthetically pleased with the imprints made from a naturalistic point of view; the children made a point of creating authentic imprints akin to a scientific purpose. To Ted the veins emphasized the authenticity of the picture (48–56). Likewise Susan pointed out that "you can see black much better than the other colours, I think". Hence, she noticed that the shape of the leaves as well as the veins became most visible when using a black crayon. Accordingly, the combination of choice of colour and observing the veins emerging on the paper when rubbing meant that the children were satisfied with the final

authentic imprint. Furthermore, when proceeding with the activity Susan stated that "I'll rub more leaves …on the back [of the paper]", which indicated that she enjoyed rubbing leaves. In similar manner Leif expressed his satisfaction by concluding that his picture was "a real painting", that he wanted to give to his daddy. Accordingly, the children throughout were quite satisfied with the authentic imprints made, meaning that they were aesthetically pleased with their finished artworks.

The children's experiences of art and science differed, thus meaning that the purpose of an activity has consequences for the direction learning takes. Taking part in an artistic activity during science class does not necessarily mean that the scientific assignment takes precedence over the artistic. Instead, some of the children enjoyed making nice pictures from an artistic point of view, which occasionally resulted in imaginative and figurative pictures. This was most accentuated in Mona's picture. While rubbing leaves she composed a picture showing, for example, trees and butterflies. She carefully chose which leaves to rub and either rubbed a small area of the leaves or tore them to pieces in order to fulfil her work of art. However, when observing leaves using a magnifier, she distinguished lots of details, like "lots of hair" and "white dots and holes". Accordingly, she discerned which properties of the leaves were important to include in the observation, although when making the picture she made choices about what to include from an artistic point of view. Mona was thus able to distinguish the two different activities, doing science and doing art, and discern what to include and exclude within the two domains. At first Paula, in the same group, rejected Mona's effort of making a figurative picture:

60. Paula: So. Like this. Is that the troll? It looks like a butterfly. It looks like a butterfly.
61. Mona: Yeah, yeah. It is.
62. Paula: You shouldn't make [inaudible, a figurative picture?]
63. Mona: Yes, I'm doing what I want.
64. Paula: Oh, which leaf looks like that then? [points at Mona's picture]
[…]
65. Paula: Can you make one like that for me [butterfly]? The same?
66. Mona: I can't make exactly the same.
67. Paula: The same colour.
68. Mona: Yeah. The same colour.

Paula pointed out that you were supposed to make an authentic imprint (62, 64). Accordingly, Paula's purpose was more naturalistic and hence more scientific, whereas Mona had a freer artistic picture in mind. But Paula then shifted from naturalism to free art and obviously liked the picture made by Mona—especially the butterfly (65). Hence, Paula learned from Mona what to include when making a piece of art, meaning that in this situation you could make a figurative picture instead of authentic imprints. In such instances the artistic purpose restricted what the children might learn biologically about leaves and instead enhanced their artistic skills.

However, the children involved in free art did not seem to be altogether unfamiliar with observing leaves from a scientific point of view. They occasionally became aware that their imprints looked authentic, meaning that in spite of the artistic focus they could shift from art to science when carrying the activity forward:

69. Laura: Teacher, look! Teacher! Look I'm mixing a little [colour]. I like that.
70. Teacher: Yeaah! It's very nice! You really can see what the leaf looks like. Can't you?
71. Laura: Mm.

Laura was eager to show her picture to the teacher, telling her that she liked what occurred. She was aesthetically pleased with the result of her rubbing and expressed anticipation about the fulfilment of the picture. At the beginning of the lesson Laura had observed that her leaf had "lines" (10), which she later perceived as "threads" (12). When rubbing the leaves, though, she was involved in making a picture by mixing colours that she liked. The teacher confirmed her artwork by using a positive aesthetic judgment, "very nice", and by saying: "You really can see what the leaf looks like", which Laura agreed to. Contrary to the children continuously being involved in making authentic imprints, Laura was engaged in pure art rather than art related to science. In spite of that she was able to shift perspective when the teacher confirmed that the imprint looked authentic.

Learning About Leaves Through Different Mediating Artefacts: A Comparison

Table 1 shows a comparison of the learning afforded in the two sequences. As has already been indicated, the children not only made certain observations depending on the mediating artefacts used, but also on the teacher's purposes and comments during the exercises. In both settings the children observed qualities of leaves and compared their findings, although in different ways. Moreover, using magnifiers and rubbing leaves was shown to embrace aesthetic experiences and the children's imagination.

Throughout the lesson the children were involved in noting qualities of leaves, which meant that there were continuous opportunities for cognitive learning. Moreover, what was mediated differed between the two sequences. Using magnifiers invited the children to observe microscopic qualities of leaves, including similarities and differences between the individual leaves being observed (1–7, 8–10). The observation naturally included vision, while other senses were disregarded. Rubbing with crayons resulted in observations of a more macroscopic kind and involved comparisons between different kinds of leaves. This meant that the children were sometimes able to sort out the different species even though they did not use the relevant biological terms (30–37). During the rubbing sequence the children did not use vision only, but also tactility as when Ted noticed that there were "sticks" on the leaves which he could feel (48–56).

During the two sequences the children also learned norms relating to what to include or exclude. To a great extent these norms were mediated by the teacher

Table 1 Summary of the relations the children included in the two sequences

	Magnifier sequence	Rubbing sequence
Cognitive qualities	Microscopic	Macroscopic
Cognitive comparisons	Between individual leaves	Between different kinds of leaves
Sensuous	Visual	Visual, tactile
Aesthetic qualities	About what is directly observable on leaves	About the representations (authenticity or artistic qualities)
Imagination	Metaphor	Metaphor
		Assemblage

(11–15, 40–47), which was shown to be of importance for directing the activities of the children and hence for what the children might subsequently learn about leaves. By posing questions and commenting on the qualities of the leaves the teacher frequently drew the children's attention to what was of interest to notice. During the magnifier sequence the teacher emphasized that the children should observe using the magnifier, which resulted in the children making comparisons relating to microscopic similarities and differences between the individual leaves. Likewise, the teacher communicated what was of importance to include during the rubbing sequence, that is, using various kinds of leaves. In that way the children proceeded to observe scientifically relevant qualities about leaves during the art activity.

Moreover, the children expressed their emotional and aesthetic involvement in the two sequences, although to a lesser extent when using magnifiers. When observing with magnifiers the children occasionally expressed their fascination by using positive aesthetic judgments (15, 16, 22) about qualities of the leaves observed, although during the rubbing sequence (48–56) the main focus was on the satisfaction of the authenticity of the imprints made. Occasionally, though, artistic license was central and learning aesthetically about leaves from a naturalistic point of view was put aside in favour of learning the aesthetics of free art (60–68).

The rubbing, as well as observations using magnifiers, gave rise to experiences of an imaginative kind, which were demonstrated in the children's metaphorical expressions (1–7, 19, 21). In addition, the rubbing sequence involved making imaginative assemblages of their imprints (60–68). In order to communicate their findings, the children made comparisons of objects or qualities they had previous experiences of, which involved using words they were already familiar with. This indicates how imagination is used in order to reconstruct and transform prior experiences when making meaning of new ones. In such situations familiar words had a positive aesthetic undertone (16–20, 30–37). Accordingly, it can be seen that the children enjoyed participating in the activities; something that is of importance for their further engagement in science classes. In their artistic assemblages well-known objects like butterflies were inspired from the forms produced by the leaf imprints. Moreover, the relations construed by the children throughout this exercise were immediate and fully intelligible to others, and the meaning-making process

often took the route outlined by the teacher. In that way, observing using magnifiers and rubbing using crayons were continuous, albeit along different routes, with learning about leaves in science class.

To sum up, the children continuously were afforded to learn more about qualities of leaves in both sequences. The teacher's direction and the mediating artefacts encouraged the children to make close observations in both the scientific and artistic sequence. In that way, the children frequently proceeded with the activity and made observations of a scientific kind throughout the lesson. In addition, they learned norms relating to how to proceed when observing and rubbing, which was frequently tantamount to the children's pleasure and satisfaction of having carried the activity to its fulfilment.

Discussion

So, what about art in the science classroom? Contrary to scholars who claim that art in science education can only be used as a motivating power or a means of adding zest, this study shows that artistic activities can be used in order to enhance at least these children's meaning-making of scientific content, and so giving support to Adams and Fuchs's (1985) suggestion that art can be a means for learning science. We have demonstrated how different modes of communication have different consequences for the meaning made, as pointed out by Kress et al. (2001), and hence for the route learning takes (Rogoff 1990). This should be of interest to teachers when staging science lessons as well as to science education researchers for further examination. It also supports that to understand the transposition of one school subject such as science, it may be necessary also to study what is happening in other school subjects.

What was mediated differed somewhat within the two activities, which was a consequence of how the artefacts mediated the children's and the teacher's speech and transactions as part of the activity. The interactions between the children and the teacher obviously influenced the details of this mediation. This illustrates the complexity of staging a lesson; something that teachers are tacitly aware of although seldom communicate as they have a limited vocabulary when it comes to teaching and learning (Tobin and Tippins 1996). Nevertheless, the children learned scientifically relevant things about leaves during both sequences, albeit distinguishing somewhat different qualities.

Mediation occurred through learning different norms relating to how to act and what to include and exclude. What was mediated was embedded in the specific activity the children were partaking in, as argued by Wertsch (1995) and Säljö (1996). The leaves observed and rubbed were not just objects, but "developed and became visible" during the two sequences. Observing and rubbing were therefore complementary activities, meaning that the combination of science and art enhanced what the children were afforded to learn about leaves; something that has been stated by many scholars (e.g., Watts 2001), but not demonstrated comparatively before. It also illustrates that the teaching of science can be enriched by using a number of mediating resources and activities in that these encourage the learning of

different subject matter content (Kress et al. 2001). The results also show the supplementary importance of the teacher in helping the children to appropriate the artefacts in fruitful ways for learning. Both sequences were aesthetically pleasing and inspiringly imaginative. Although the artistic activity proved inspirational to the children, as has also been shown in earlier studies (e.g., Hayes et al. 1994), there is nothing to suggest that it was better in this respect than the scientific activity. Again, this can be demonstrated through the comparative approach. It is of interest, though, that the kinds of aesthetic experiences mediated differed between the two types of activities. Examining how such different kinds of aesthetic experiences support science learning is therefore of educational importance.

Some of the different qualities of leaves were excluded in both sequences, for example, names of trees and colours of leaves. Again this is related to the purposes of the activities and the mediating artefacts used. In focusing on microscopic and macroscopic qualities such discernment falls outside the scope of the children's observations and emphasis of what was important to include. Although the children observed that different kinds of leaves have different shapes, their discernment did not lead to an identification of species, but to a comparison of already known objects. Likewise, the children did not talk about the autumn colours of the leaves, which might seem surprising as such colours are rich in tone. Even though the children may have tacitly noticed the colours, relations involving the brilliantly coloured autumn leaves were excluded from the children's discussions. This means that, in this situation, the children were afforded little opportunity to learn more systematically about the actual colours of leaves. During the rubbing sequence the children were mostly engaged in making as authentic an imprint as possible, meaning that the veins and shapes of the leaves were of interest to include in the pictures. Accordingly, the real colours of the leaves were secondary in the selection of which colours to use in order to create artistic pictures from the leaves emerging on the paper when being rubbed.

Furthermore, to a large extent the children overlooked those qualities of leaves that could be referred to senses other than sight, which was the main sense employed when using magnifiers and when rubbing. However, Ted's discernment about the veins emerging as three-dimensional forms when rubbing shows that the children noticed that it was possible to feel the veins being mediated by the artefact. The children did not construe relations of, for example, smell and sound or qualities relating to touch. In that way, and in both parts of the lesson, the mediating artefacts used served to bring certain qualities to the fore while other were excluded. Again this shows how different modes of communication have different consequences for what children discern and hence for what they are afforded to learn (Jakobson and Wickman 2008b; Kress et al. 2001). Therefore artistic and scientific activities need to be chosen by the science teacher with regard to the learning that they most likely will mediate.

To conclude, although the purpose of the lesson studied was partly scientific and partly artistic, and the mediating artefacts changed, this study has shown that different modes of communication—observing, rubbing, and talking—have various consequences for what children are afforded to learn. The magnifier sequence and the art activity were continuous with learning about leaves in elementary school

class, which indicates that science and art are compatible and possible to combine. It is important to note that the artistic aim sometimes took precedence over the scientific, which suggests that art as an addition of zest may not always promote the learning of the scientific topic taught. Further research is therefore needed to examine the difference that art can make in science classes.

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