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Why and how teachers make use of drawing activities in early childhood science education

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ABSTRACT

Researchers have provided many arguments for why drawing may contribute to science learning. However, little is known about how teachers in early childhood education (ECE) make use of drawing for science learning purposes. This article examines how teachers' views and framing of drawing activities influence the science learning opportunities afforded to children in the activities. We use activity theory to analyse teacher interviews and observation data from ten science classrooms (children aged 3–8 years) where drawing activities occurred. The interviews reveal that few of the teachers relate drawing to science learning specifically. Rather, they portray drawing as a component of variation in teaching and learning in general. Looking at what happens in the classrooms, we conclude that drawing has a relatively weak position as means of communicating and learning science. Instead, the teaching emphasis is on writing or on 'making a product'. However, there are examples where teachers explicitly use drawing for science learning purposes. These teachers are the same few who, in interviews, relate drawing to science learning specifically. Based on these findings, we encourage school teachers, teacher educators, and researchers to identify, and overcome,obstacles to realising the pedagogical potentials of drawing in ECE science classrooms.

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Activity theory; teacher views; visual representations

Introduction

Drawing is often put forward as an integral part of science practice. Throughout the history of science, drawing has been used to document concrete science content, spanning from small organisms to astronomical objects, as well as to visualise 'the invisible' (Hoffman & Wittman, 2013). In early childhood education (ECE), it is common that children draw as a part of their science lesson, partly because drawing serves as a substitute, or precursor, for writing. The fact that drawing is a common mode of expression in

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ECE is potentially positive given the many arguments provided by researchers for how drawing may contribute to science learning. *For one,* researchers point out that students' drawing may enhance their conceptual learning in science since drawing makes their understanding explicit and helps them to organise their knowledge effectively (Ainsworth et al., 2011). *Second,* students' drawings may function as evidence or indications of students' conceptual knowledge and progress in science (Chin & Teou, 2010). *Third,* students should learn to draw in order to visually communicate knowledge in science the same way scientists do (Danish & Phelps, 2011). *Fourth,* students should draw to develop a visual literacy in science (García Fernández & Ruiz-Gallardo, 2017), that is, an ability to critically interpret, use, and create visual media (Lopatovska et al., 2016), which is crucial in today's world, where children are bombarded with visual information (Friedman, 2018). Although science education research has outlined many pedagogical benefits related to drawing, little is known about whether these benefits are actually realised in ECE classrooms. Instead, most research of representational practices in science classrooms have focused on the representations as such or on the cognitive capabilities of the student making the representation (Danish & Saleh, 2014). Seeing that some researchers have suggested that teachers should, but rarely do, support children in their drawing processes in ECE science classrooms (e.g. Wilson & Bradbury, 2016), the current article addresses a need to examine how and why ECE teachers make use of drawing for science learning purposes in their classrooms.

A sociocultural approach to drawing in the science classroom

Building on sociocultural theories, we assume that drawing in science class is an act of participating in a specific community (Wertsch, 1991, 1998), typically consisting of the teachers and children in the classroom. When children draw, they engage in interaction with teachers, peers and material, as well as with the norms and languages that apply in their classroom. These interactions shape how they make (scientific) meaning while drawing. Herein, we use activity theory (AT) (Engeström, 1987) to describe and analyse drawing activities in ECE science classrooms. According to AT, classroom activities can be understood as collective activities where the participants in the classroom community head towards a shared object. The object describes the intention that the activity is meant to fulfil (Kaptelinin, 2005). For example, in a drawing activity in science class, the object can be 'to create representations that depict the life cycle of loggerhead sea turtles' (Danish & Saleh, 2014, p. 2318). In their actions and interactions, towards that object, students and teachers are influenced by culturally situated languages, perceptions, symbols, roles, and conventions (Engeström, 1987; Vygotsky, 1934/1999). Danish and Saleh (2014, 2015) have found that AT is a useful tool to identify how context matters to children's representational practices in ECE science classrooms. They conclude that the outcome of a drawing activity is dependent on back-and-forth interactions between the rules for what constitutes a good drawing in science (e.g. detailed and accurate), the material tools used (templates, books and websites), the division of labour (individual or collaboration), and teacher mediation (Danish & Saleh, 2014, 2015).

In our own studies of science teaching in ECE, AT helped us to identify how elements, such as, local rules, division of labour and material tools interact, and how they affect the science learning opportunities afforded to children (Sundberg et al., 2016, 2018). We found that the teachers' views on teaching and learning played a crucial role for how science was afforded to children. Accordingly, we presuppose that teachers' views on drawing in science affect children's possibilities to make use of drawing to communicate and learn science. ECE teachers' views on the role of drawing in science education are underexplored in research. Nevertheless, some studies of ECE classrooms indicate that children's drawing practices are influenced by how their teachers view drawing in science, for example, that drawings should be detailed and accurate (Danish & Saleh, 2015) and descriptive, without embellishments (Ero-Tolliver et al., 2013). The teachers' views were not explicitly investigated in these studies, but can be inferred from the way they organised the activities, and how they gave feedback on children's drawings. In the study conducted by Danish and Saleh (2015), researchers and teachers supported the 6–9-year old children to review each other's drawings. Consequently, the children gradually changed their idea of what constitutes a good representation in terms of detail, accuracy and correct sequence. In Ero-Tolliver et al.'s (2013) study, the 6–7 year old children recorded a decay process in their science notebooks. At first, it was common that the notebook entries were embellished with hearts and flowers. However, these embellishments became less and less common as the teacher gave positive response on the descriptive, rather than the decorative, qualities of the notebook entries.

Aim and research questions

We concur with previous research that drawing activities may provide many pedagogical benefits, such as supporting assessment, conceptual learning, communication, and visual literacy in science. Noting that little is known about whether the potential pedagogical benefits of drawing are actually realised in ECE science classrooms, we aim to contribute knowledge on how and why ECE teachers make use of drawing for science learning purposes in their classrooms. We seek to respond to the following research questions:

1. What are the teachers' views of the role of drawing in science teaching?
2. How do the teachers frame drawing activities in science teaching?
3. How do the teachers' views and framing of drawing activities influence the science learning opportunities afforded to children?

Our study has the potential to contribute unique perspectives on why and how pedagogical potentials of drawing are realised in ECE science teaching. This since the study examines and combines two previously underexplored issues: drawing activities as situated in a cultural context as well as ECE teachers' views on the role of drawing in science teaching.

Context and method

The Swedish context

We have conducted the study in Sweden, where ECE includes three school forms; preschool (for children aged 1–5 years), preschool class (6 years), and primary school (7–9 years). Preschool class and primary school are compulsory. Although preschool is voluntary, about half of the 1-year-old children, 89 percent of the 2-year-olds, and 94 percent of the 3–5-year-olds, are enrolled in preschool (Statistics Sweden, 2019). The three school forms have different cultural-historical grounds and are currently influenced by different pedagogical policies. Sandberg et al. (2017) conclude that Swedish preschool teaching is characterised by intertwining care, play and children's interests. The preschool curriculum allows for subject-integration and does not promote individual knowledge assessment, whereas, in Swedish primary school, teaching is influenced by distinct school subjects and individual assessments. Preschool-class, states Sandberg et al. (2017, p. 249), 'is both metaphorically and literally placed between preschool and primary school'.

We base the current study on data from the three school forms, assuming that such data will provide a wide range of different responses to our research questions. Still, we do not consider school form as the sole indicator of the cultural context. In line with results from our previous studies of preschool contexts (Sundberg et al., 2016, 2018), we assume that the local classroom culture shapes why and how teachers make use of drawing for science learning purposes in their classroom.

In Sweden, drawing activities are common in the early childhood education (ECE) science classrooms. When it comes to preschool, studies suggest that teachers often combine drawing and science in teaching practice (e.g. Sundberg et al. 2016). Regarding preschool teachers' views on children's drawing in general (not particularly in science), Änggård's (2005) study displayed that the teachers valued originality, preferring that children find out for themselves what and how to draw. In contrast, the children valued decorative features and templates, and wished to draw like their peers. Also in Swedish primary school science teaching, drawing seems to be a common feature. A report based on 98 observed science lessons in 30 primary schools reveal a teaching pattern where students copy the teachers writing on the board, or tell in their own words what they have experienced in the science lesson, often combined with making a drawing (Swedish Schools Inspectorate, 2012). However, the report does not focus on if and how the students are supported in drawing related to scientific content. To our knowledge, there are no studies of how teachers in Swedish preschool class or primary school teachers' views on, or work with, drawing in science classrooms.

Participants and data

This study is part of a larger project, which examines science teaching continuity across ECE. Our data was collected in three Swedish 'school units'. The sample depended on the condition that, in each unit, there were teachers willing to participate from at least one preschool, one preschool-class and one primary school class. Moreover, we wanted units that represented different local conditions, why we included one urban and two rural units (one in the north and one in the south part of Sweden) in the sample. Teachers in eleven classrooms participated in the project. We visited each classroom 2–5 times and observed 45 science lessons in total. It is important to mention that we had expressed that we wanted to observe their science teaching, but we had not indicated any interest in drawing. This study builds on observations from the ten classrooms where drawing activities occurred, and with interviews with the thirteen teachers who worked in these ten classrooms (Table 1). Twelve of the teachers were qualified ECE teachers and one was a trained child minder (Swedish: barnskötare).

Table 1. Overview of the observed activities.

Classroom	Teacher instructions to the drawing task
Preschool A	Choose a mushroom picture, paste it onto a paper, then draw who lives in the mushroom
Preschool B	Draw a spider
Preschool C	Create things that can fly
Preschool D	(a) Paint your own weather/cloud (b) Add colour to a line-drawing of a fish
Preschool-class A	Draw an animal and its track
Preschool-class B	Write 'friction' on the paper and draw what you did outdoors today
Preschool-class C	Draw what you have learnt about friction: High friction on one side of the paper and low friction on the other
Primary school A	Draw four important parts of the movie about the process from forest to paper
Primary school B	(a) Draw and write what you think will happen to the plant (b) Draw and write where you think the flower gets its water from
Primary school C	(a) Write and draw 'what will happen to the plant' (b) Document what your pea plant looks like today (c) Make a model of how the Sun, Earth and Moon move (d) Make an image of Big Bang

In order to respond to our first research question, we build on data from individual interviews with the thirteen teachers, conducted three-four months after we had made the last visit in their classrooms. Our interview guide included questions about their science teaching in general as well as the teachers' reasons to include drawing in science activities. We have not interviewed the teachers in relation to each lesson where drawing activities occurred and do not make claims about the teachers' specific aims for these lessons.

In order to respond to our second and third research question, we selected all the lessons where drawing activities occurred, hence, 15 of the 45 observed lessons (Table 1). At least two of the authors visited each classroom. In this study, we consider drawing as making visual representations on paper with pencils, crayons, or paint brushes. Most of the drawings in our sample were made in two dimensions. In one case, the children drew on paper and used it to create three-dimensional representations of 'things that can fly'.

An overview of the 15 lessons is provided in Table 1. In these lessons, the teacher commonly introduced a science topic in dialogue with the whole group of children, and then gave them a drawing task that related to the topic, such as to 'draw an animal and its track' or to 'draw what you have learnt about friction'. The observation data includes audio and video recordings, notes, and photos from observations including photos of the drawings produced by children and teachers.

Research ethics

The study has followed the ethical principles outlined by the Swedish Research Council (2017), regarding informed consent, right to withdraw from participation, confidentiality and use of data. All the teacher names mentioned in the article are pseudonyms.

Analytical process

As mentioned above, we draw on activity theory (AT) (Engeström, 1987) to describe and analyse activities in ECE science classrooms. In line with AT, we use Engeström's (1987) triangle model to identify six interacting elements; the *object, subject, tools, rules, community* and *division of labour*; that together form the activity, as well the *outcome* of the activity (Figure 1). We focus on outcomes in terms of the science learning opportunities afforded through the drawing activities. In all, we have constructed 15 triangle models, one for each science lesson that included drawing.

The analysis was conducted by all five authors, of whom four have previously conducted AT-based analyses of interviews and classroom observations (Sundberg et al., 2016, 2018). As researchers have noted before us, it may be challenging to assign different parts of the lesson to a certain element in the AT triangle. Danish and Saleh (2014) exemplifies that a list of criteria for science representations, provided by the teacher, may constitute a tool, a rule, or even both. In order to determine what belongs where, we jointly formed analytical questions for each AT element, to guide our interpretations of the data (Table 2).

Analysis of interview data

The answer to our first research question (what are the teachers' views on the role of drawing in science teaching), corresponds to the *community* element in the activity system. This analysis builds on interview data. As we are interested in teachers' views on drawing in science classrooms, we focus on teachers as the *subjects* who shape and interpret the activity (Engeström & Miettinen, 1999) and place the teachers' views on drawing in the *community* element. In our use, the *community* element captures the educational culture of the classroom, in terms of views on teaching and learning in that local setting. We have conducted a thematic analysis (Braun & Clarke, 2006) on the interview data to outline different teacher views on the role of drawing in science teaching. The first author coded extracts of the interview data that related to RQ1, hence to the role of drawing in science class. For example, one teacher's response to the interviewer's question 'Is there anything more that you have thought about drawing in science?' was:

> No, mostly that it as *a means to consolidate the knowledge*. But I am very interested in visual arts and have studied some at the university so I think it is an important mode of expression,

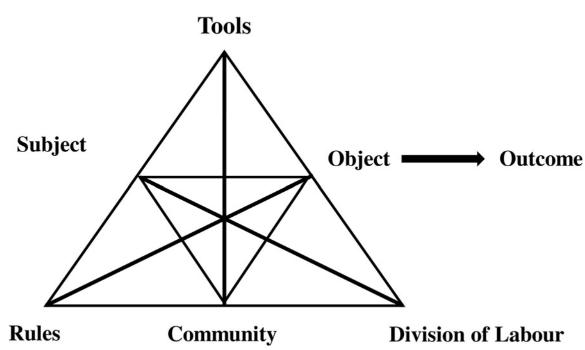

Figure 1. Triangle model displaying the interacting elements in an activity system (Engeström, 1987).

Table 2. The connection between research questions, elements of Activity Theory, analytical questions and data.

Research question	RQ1. Teachers' views	RQ2. Teachers' framing of drawing activities RQ3. How teachers' views and framing of drawing activities influence the science learning opportunities afforded to children				
AT element	*Community*	*Tools*	*Rules*	*Division of labour*	*Object*	*Outcome*
Analytical question	Why do teachers include drawing in their science teaching?	How do teachers introduce the drawing activities? What material does the teacher provide?	What appears as implicit/explicit norms regarding drawing in the science classroom?	What do children and teachers do during drawing activities?	What appears to be the science learning purpose of the drawing activity?	What science learning opportunities are afforded to children in the drawing activity?
Data	Interviews	Observations	Observations	Observations	Observations	Observations

> *visual arts is important in itself.* But to be able to mix (visual arts and science), that is great. (Our italics, to mark the grounds for the coding)

This extract was given two codes in response to RQ1, namely, 'to consolidate knowledge' and 'visual arts is important in itself'. These two codes were close to the original quotes, whereas in other cases, we made a condensed code, interpreting the essence of what the teacher said. This procedure can be illustrated by the following quote, where a teacher responded to why she integrated drawing and creative work into science lessons:

> It is about different *children finding different things easy and difficult*, so one has to hope that it gets in somewhere. If I find it difficult to write, then it may be easier to get it in when I dance or watch a movie, or talk about it or show something with my body. *Everyone should have the same chance of grasping it*, and we have different ways of grasping it.

In order to form a code that responds to RQ1, this quote was condensed to 'every child should have the chance to use the mode of expression that suits them the best', and coded accordingly.

When all interviews had been coded, the first author grouped the codes that provided similar responses to RQ1 into themes, each providing a view on the role of drawing in science teaching. These themes were refined in dialogue with the other authors, based on examples of coded interview transcripts. Finally, we sorted the themes under two main categories, that is, whether they were related to (1) teaching and learning in science specifically or (2) teaching and learning in general. The themes and categories are provided in Table 3, and further elaborated on in the findings section.

Analysis of observation data

The themes outlined as response to RQ1 feed into the *community* element for each activity system, that is, for each classroom. In order to identify the remaining AT elements for each activity system, all authors analysed observation data from six lessons individually. Next, we discussed our respective interpretations, to adjust the analytical questions (Table 2), and to agree on the AT triangles for these six lessons.

Table 3. Overview of themes identified in the interview data.

RQ1: What are the teachers' views of the role of drawing in science teaching? (community node)	
Teaching and learning in science	Teaching and learning in general
Drawing is a part of science practice To combine drawing and science supports scientific creativity	Drawing is a way for children to show what they know Drawing supports memory Drawing consolidates knowledge Drawing may support thinking and language development Drawing supports motivation and interest Drawing is important in itself Children learn in different ways, so some will benefit from the opportunity to draw To use many different modes of expression is good for learning

The first author constructed the remaining nine AT triangles, in dialogue with the authors that had visited that classroom.

The answer to our second research question (how teachers frame the drawing activities) corresponds to the *tools, rules* and *division of labour* in the AT triangle. In AT, the *tools* address both communicative and material tools that the *subject* uses to fulfil the object of the activity (Engeström, 1987). We focus on the instructions and materials that the teachers provide during drawing activities. The *rules* embrace the implicit and explicit standards for how to act within the classroom when drawing. Furthermore, the *division of labour* points at the roles that teachers and children take during drawing activities. For example, teachers and children may take on different roles when it comes to who draws (what), and who comments on the drawing of others, during the lesson.

Our third research question (how the teachers' views and the framing of drawing activities influence the science learning opportunities afforded to children) corresponds to the whole AT triangle. Here, we draw attention to the relation between the *outcome* of the lesson and what happens within the activity system during the lesson. Since the primary relation between the *outcome* and the activity system occurs through the *object* (Figure 1), we first examined whether the *object* and *outcome* were aligned. What constitutes the activity's *object* and *outcome* is based on our interpretations of observation data. We stated the drawing-related science learning *object* based on the teacher's introduction of, and instructions for, the drawing activity. The *outcome* is based on our interpretation of the science learning opportunities afforded to children during the lesson. Hence, we do not make claims about what the children actually learned during the lesson.

If the *outcome* and *object* were aligned, we looked at the relationships between the elements in the system to identify if and how the teachers' views *(community)* and the framing *(rules, tools, division of labour)* of drawing activities contributed to the science learning opportunities *(outcome)* afforded to children. For example, in one activity system, the *object* of a drawing activity was to learn about the process from forest to paper. In terms of material *tools*, a template with four pre-printed squares led the children to illustrate a process in four stages. In terms of communicative *tools,* the teacher commented on the science content and chronology of the children's four drawings, which in turn corresponded to this *community's* view that the point of drawing in science teaching 'is not that it should be aesthetically pretty, but that it should explain what it is'. In sum, we conclude that the teacher's framing, in terms of material and communicative *tools*, as well as the teacher's views of drawing in science teaching (*community*), supported children to make use of drawing to communicate and learn about the process from forest to paper.

As Engeström states, the relation between two elements in an activity system may be contradictory, in the sense that an individual within the system will receive 'two messages or commands which deny each other' (Engeström, 1987, p. 174). So if the *outcome* and *object* of an activity were not aligned, we sought for contradictions between elements in the activity system that could explain why the children were not afforded science learning opportunities (*outcome*) in line with a science learning *object*. For example, in one of the activity systems, we interpreted that the *object* was to observe and document fine details of a plant. Here, we noted a contradiction between the *tools* and the *object* because the *tools* provided by the teacher were blunt crayons, which did not support drawing of fine details. In other words, the children received messages that denied each other, namely to 'draw fine details' and 'use a blunt drawing tool'. Here, we could identify an aspect in the framing of the drawing activity that restricted children's science learning opportunities.

Findings

This section starts with three stories, in which we provide AT triangles to display how teachers' views (RQ1) and the framing of drawing activities (RQ2) influenced the science learning opportunities afforded to children (RQ3). We selected the stories to illustrate three different ways of making use of drawing for science learning purposes, which we identified through our analysis of all 15 drawing activities. After the stories, we present a summary in response to each research question.

Story 1: making a picture of the Big Bang

The first example is from a primary school classroom with a class of 8-year old children and their teacher Sanna. In this activity, the teacher read from a book about The Big Bang, and after she had finished reading, she discussed the phenomenon with the children, illustrating with her arms that 'the planets and sun still move, the Universe still becomes bigger and bigger'. Sanna explained that the children's drawing task was to make a picture of Big Bang. Using pastel crayons, Sanna demonstrated how to draw dots in the middle of a black paper and then used her finger to draw the colour outwards. Meanwhile, the children commented on her actions, discussing how and why to make the picture. For example, one child asked if they should fill the whole paper and another responded: 'No, then it won't be like an explosion'. The teacher filled in: 'It should look like it goes out from the middle. That is why I started in the middle and drew the colour outwards, but I did not go all the way to the end of the paper'. During this lesson, Sanna repeatedly pointed out, verbally, with gestures and by drawing, that the children should represent an *expansion* from the middle (Figure 2).

We posit that the *object* was that children should be acquainted with the theory about how the Universe was born, that it is called the Big Bang, and that the Universe expands (Figure 3). This *object* aligns with the observed *outcomes* of the activity. We have not

Figure 2. One child's picture of Big Bang.

identified any contradictions between the elements in this activity system. Here, the teacher's views on the role of drawing in science teaching (*community*) relates to science specifically. In the interview, Sanna says that the use of drawing 'depends on the [science] content area' and relates the role of drawing to different aspects of science practice, for example, to illustrate or hypothesise about a science phenomenon, to describe how one conducted an experiment, or to draw as a part of talking about a process, such as the water cycle. In the observed activity, the most prominent *rule* was that children should illustrate an expansion from the middle in their drawings. The teacher's choice of material *tools* was purposeful, as the marks from the pastel crayons were possible to 'draw out', which matched the object that children should learn about the Universe's expansion. In terms of *division of labour,* both teacher and children were involved in dialogue on how to make the drawing to illustrate the science content in a good way. Moreover, this activity system stands out from our dataset in terms of *division of labour* since the teacher, and not only the children, was drawing during the lesson.

Figure 3. Triangle model of the activity 'make a picture of Big Bang'.

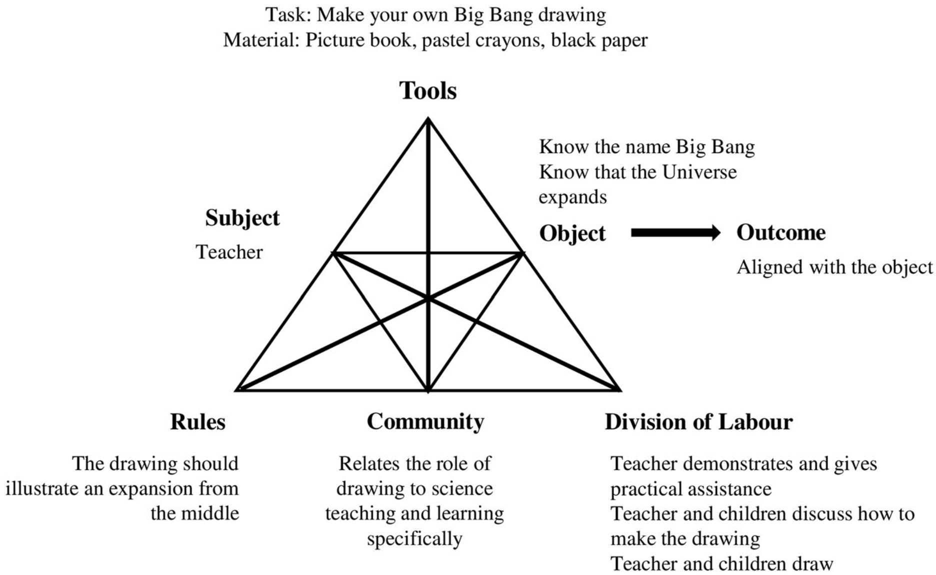

Figure 4. A view from the drawing table. The teacher writes the children's responses to 'who lives in the mushroom'.

Story 2: making drawings of 'who lives in the mushroom'

The second example is from a preschool for children aged 3–5 years. The analysed lesson was part of the preschool's Mushroom theme. On one occasion, the children had examined mushrooms, using knives and magnifying glasses, and found insects and larvae on the inside. When we visited the preschool a week later, one of the teachers, Mary, and four children were sitting at a table on which there were scissors, papers, colouring pencils, and photos of different mushrooms. Mary encouraged the children to choose a photo of a mushroom, paste it onto a piece of paper, and draw who lives in the mushroom. When the children signalled that they were done drawing, Mary asked 'Who lives in the mushroom?' and wrote the responses onto their drawings (Figure 4). The children could answer any animal, but she wanted them to say the correct name of the mushroom that was glued onto their paper. For instance, one child said that a duck lived on one of the mushrooms in her drawing. The teacher then asked for the name of that mushroom and wrote 'The duck lives on the Fly agaric' onto the child's paper.

In this activity, we interpret that there were two objects (Figure 5). One *object* was that children should connect the mushroom's appearance with the right name, which matched the *outcome* of the activity. This *object* aligns with the teacher's views of the role of drawing in science activities (*community*), because in the interview, Mary expressed that children's drawing can serve to consolidate knowledge. She also emphasised that children should learn the right names for different organisms and not only say 'a bird' or 'a flower'. The second *object* was to check if children remembered what organisms they had found inside the mushrooms in the previous lesson. This *object* was not in line with the *outcome*, because during the drawing activity, the children did not refer to any of the larvae or insects that they had seen inside the real mushroom in a previous lesson. Here, we identify an inconsistency between the *object* that children should

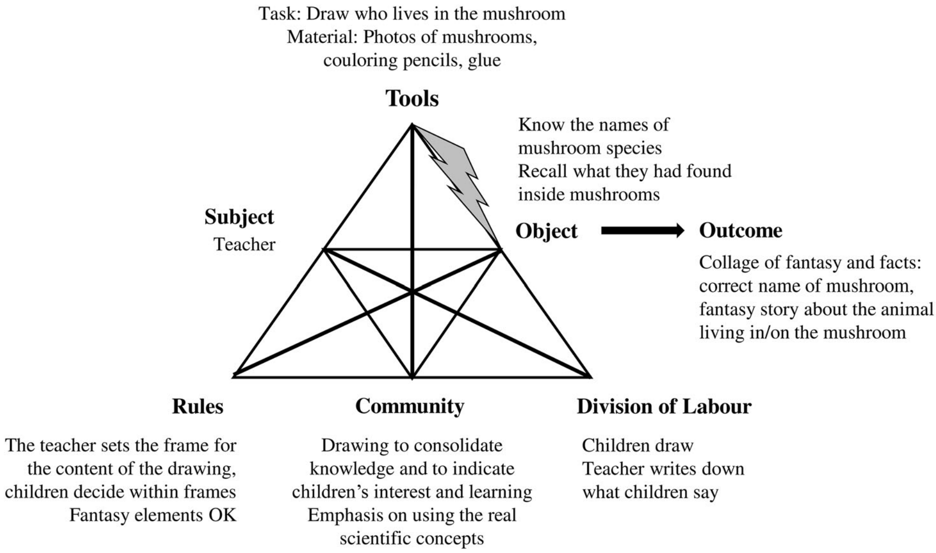

Figure 5. Triangle model of the activity 'draw a picture of who lives in the mushroom'. The flashes represent contradictions identified within the activity system.

draw who lives *inside* the mushroom, and the *material tools* in the form of pre-printed pictures showing the *outside* of the mushroom. Moreover, we identify an inconsistency between the *object,* and a *communicative tool*, namely the teacher's instruction to draw *who lives* in the mushroom, as opposed to asking them to draw *what they had found* when they examined mushrooms. The teacher's instruction seemed to inspire the children to create imaginative stories of ducks and lions living on or inside the mushrooms and the teacher followed the story-telling path the children had chosen. Interestingly, the teacher did not let go of the *object* that children should use the right name for the mushroom. In fact, this *object* seems to have been less negotiable even beforehand, since the children had access to pre-printed pictures of mushrooms but were encouraged to draw, in free hand, who lived in these mushrooms.

Consequently, the *outcomes*, in terms of children's drawing and communication, display a collage of fantasy and facts, for example: 'A lion lives in both my mushrooms, in the Inkcap and in the Birch bolete'. Here, the connection between the mushroom picture and the written name (Inkcap, Birch bolete) was correct, while there was room for fantasy regarding the animal living in the mushroom.

Story 3: making paintings of different types of weather

The third example is from a preschool for children aged 1–5 years. In the analysed activity, the teachers Wendy and Vera instructed a group of 4–5 year old children to print clouds using pieces of cauliflower and liquid paint. Wendy told the children to 'make any weather you like', giving the examples 'beautiful weather clouds' and 'thunderclouds'. At the table were photos of different types of clouds. When the children had finished they showed their paintings to the teachers who asked the children to tell what weather they had made. Depending on what the children said, the teacher chose a name from a list of cloud names and helped the children to paste it onto their paintings (Figure 6). After that, the children could leave the table to engage in free play.

We interpret that the science learning *object* was that children should learn that there are different types of clouds and that they have certain names (Figure 7). The *outcome* of the activity did not align with the *object* since the teacher–child communication centred on producing a painting and not on what different clouds looked like or were called. Here, we identify a contradiction in the *rules-object* relation because, in the teacher's communication with children, the science learning object was down-prioritised in favour of the prominent *rule* that children should finish the task. We also identify a contradiction in the *community-object* relation. Overall, we characterise this *community* as oriented towards 'doing', because, during our visits, the activities per se, and the material results of the activities, were in focus, rather than making meaning about the science content. When interviewed about drawing and other creative activities in science teaching, Wendy said that she 'thinks that children remember better if they get to do things in various ways'. Here, the *community* view that drawing activities mainly serve to be a part of teaching variation, did not support the *object* that children learn the names and appearances of different clouds. Instead, the *outcome* was the 'doing' as such, as children had engaged in an activity and produced a painting.

RQ1: teachers' views of drawing in science teaching

The overall pattern is that the teachers have relatively little to say when we ask them about drawing in the science classroom. When we look into what they do say, we conclude that their answers can be categorised in relation to whether they relate drawing to teaching and learning in general or to science teaching and learning specifically.

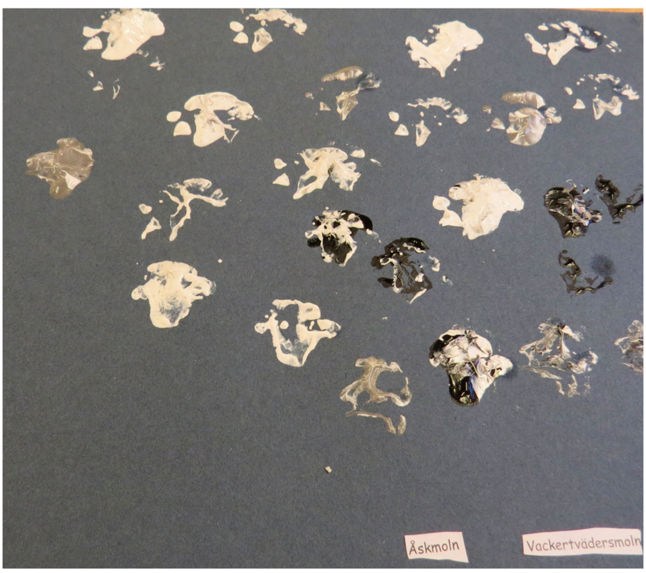

Figure 6. One child's paintings of weather. On the bottom to the right: the Swedish words for and 'Thundercloud' (Åskmoln) and 'Beautiful weather cloud' (Vackertvädermoln).

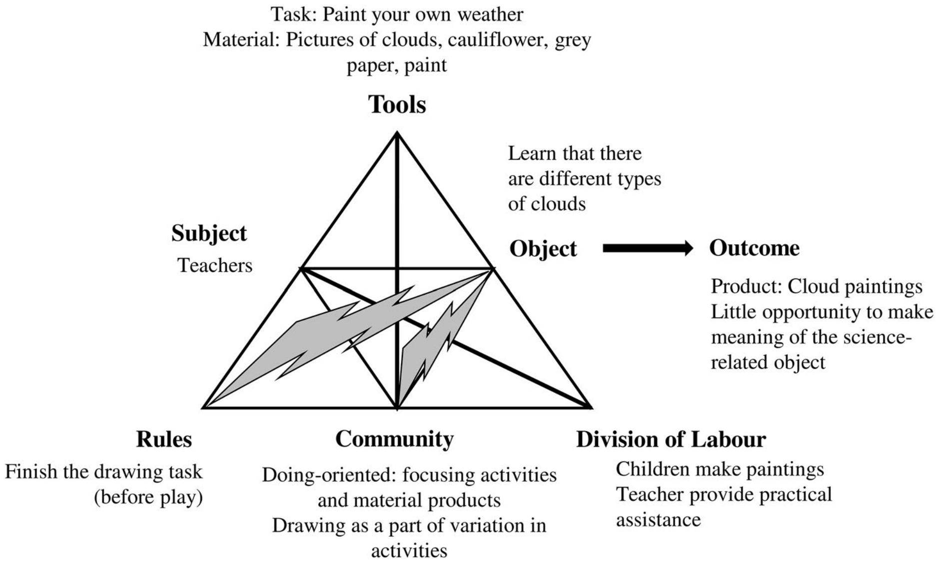

Figure 7. Triangle model of the activity 'making a weather painting'. The flashes represent contradictions identified within the activity system.

Drawing as a part of teaching and learning in general

Although asked about drawing in the science classroom, most of the teachers' responses relate to teaching and learning in general, not specifically in science. On one hand, teachers mention drawing in relation to children communicating and consolidating their knowledge. Some teachers express that they can use drawings to identify what children know before, and what they have understood from, an activity. Among the teachers who relate drawing to communicating knowledge in general, some highlight that children cannot (yet) write and therefore could use drawings as a mode of expression, because 'if you cannot write and show your knowledge, then you may draw and show your knowledge' (Preschool B).

On the other hand, teachers mention drawing in connection to variation, which they portray as positive for learning in general. For example, when asked why they include drawing in science teaching, teachers say that: 'I believe that children remember better if they get to do things in different ways' (Preschool D) and:

> I think that it [drawing and other modes of expression] is important for all children, but in different ways. Some children may learn more by building and talking, others by writing down what they have learnt (…) It is important to do both parts. (Primary school A)

In terms of drawing and variation, this view seems to be two-folded; one side of the coin is the idea that variation as such enhances learning, since the more modes or senses that are involved in teaching activities, the richer the learning. The other side of the coin is the idea that children learn in different ways and therefore teachers need to offer a variety of modes to make sure that all children get a chance to use the mode that suits them the best.

Drawing as a part of science teaching and learning specifically

Four of the thirteen teachers also express views of drawing that relate to science teaching and learning specifically. These teachers highlight that drawing serves different purposes depending on the science content:

> If we are to create something in science class that should look like an animal or a mushroom, then I try to give really clear instructions. If we have worked with chanterelles, I do not want a pink chanterelle. If we are to work freely, then I may give examples of what to do, and then they may create freely and choose colours. (Primary school B)

Moreover, these teachers portray drawing as a part of science practice as such, for example, that drawing may be a part of making hypotheses, observing, documenting, illustrating science processes, and making models. They also express that drawing can make way for children to develop their thinking and creativity in science. For example, when asked about the benefits of integrating drawing and science teaching, one teacher responds:

> As I see it, it is the creative … to use many parts of the brain. If you only write you only use a certain part of the brain … Creativity is important in science, it has made us explore. If we had not been creative we would not wonder why the apple has fallen from the tree. (Primary school A)

RQ2: teachers' framing of drawing activities in science teaching

Looking at *tools* in terms of the instructions given by teachers (Table 1), drawing seems to have many different functions in science lessons, such as to document organisms (e.g. a spider) and processes (from forest to paper), present hypotheses (what will happen to the plant) and make models (the solar system). Apart from the teachers' brief, initial instructions on how or what to draw, it is rare in our observation data that teachers explicitly guide children's drawing in relation to a science learning *object*. Instead, the teachers often appear to give implicit guidance through the material *tools* they provide. For example, one preschool-class teacher encourages children to search for pictures on the internet and in books, when she gives them the task to draw an animal and its track. The activities also seem to be influenced by *rules* regarding what it is to draw in the classroom. In some classrooms, the *rule* to 'finish the task' seems to overshadow the science learning object, since a large share of the teacher–child communication is about whether they have finished the drawing. In terms of *division of labour*, a striking result is that only two of the teachers drew anything themselves during the observed drawing activities.

However, in one of the preschools and two of the primary schools, teachers and children explicitly discussed how to make a visual representation of a phenomenon. One such example occurred in an activity where preschool children were encouraged to make things that can fly in the air. On that occasion, the teacher asked guiding questions such as: 'How does it work?' and 'How do you want to improve it?'. Another example occurred in an activity where primary school children were to make a model of how the Sun, the Earth and the Moon move in relation to each other. While the teacher demonstrated how to make the model, she and the children spoke about how to handle scale, measuring and perspective as well what colours and techniques to use to represent the Sun, the Earth and the Moon.

RQ3: how teachers' views and framing of drawing activities influence the science learning opportunities afforded to children

Looking across the ten activity systems (i.e. ten classrooms), we identify two main categories of activity systems as regards to how teachers make use of drawing activities. In the first category, the framing of the drawing activities aligns with a science learning *object*. This is not the case in the second category. In this category, the science learning *object* is either (a) accentuated in relation to what children write during the activities, but not in relation to their drawing, or (b) overshadowed by the focus on producing a drawing. In Table 4, we have displayed an overview of how these two categories correspond to the responses to our research questions. In the table, the responses represent what we interpret to be the dominating views and ways of framing drawing activities for each activity system.

As we compare the two categories, we identify the following pattern: In category 1, we find the teachers who, in interviews, relate drawing to science teaching and learning specifically. These teachers also tend to make use of drawing activities to fulfil some science learning *object* in the classroom. When drawing activities were part of science teaching in such classrooms, the *tools, rules* and *division of labour* regarding drawing activities seemed to be aligned with the science learning *object* of the activity. In category 2, we find the teachers who did *not* relate drawing to science teaching and learning specifically in interviews. They seldom made use of drawing to fulfil any science learning objects in the classroom. In their classrooms, we could identify contradictions between the science learning *object* of the drawing activity and the *tools, rules* or *division of labour*. In general, the drawing activity functioned as an add-on rather than being integral to science teaching, and the teaching emphasis was instead on science learning in written communication (category 2a) or on producing a drawing (category 2b).

Discussion

In this article, activity theory (Engeström, 1987) has helped us to unfold if, why and how the pedagogical potential of drawing was realised in ECE science classrooms. In many of the observed activities, we identified that the potential was counteracted by cultural factors such as local, often implicit, rules for drawing and the material tools chosen by the teacher. The most compelling finding of this article is that the teachers' views on the role of drawing in science teaching seem to be a key factor for children's opportunities to benefit from the pedagogical potential of drawing to learn science. In our study, there is a pattern that the few teachers who, in interviews, relate drawing to science teaching and learning specifically, are the same few who explicitly make use of drawing for science learning purposes in the classroom. This pattern needs to be further investigated, to better understand the relationship between ECE teachers' views of drawing in science and the ways they make use of drawing in the science classroom.

Another prominent finding is that the ECE teachers in our study have little to say about the role of drawing in science. In interviews, they mainly give general, and overall inarticulate, responses to why they integrate drawing with science teaching. It appears as if many of the pedagogical potentials of drawing, outlined in previous research, are not generally part of ECE teachers' views on the role of drawing in

Table 4. Categories of activity systems, as regards to how teachers make use of drawing activities in early childhood science education.

RQ1 (teachers' views on the role of drawing in science teaching)	RQ2 (teachers' framing of drawing activities)	RQ3 (how teachers' views and framing influence science learning opportunities)	Classroom
Category 1. Makes explicit use of drawing for science learning			
Drawing as a part of *science teaching and learning specifically* – to communicate science knowledge in adequate ways – to support creative thinking and experimentation in science	*Tools*: Support directed towards drawing in relation to science learning object *DoL:* Teachers and children discuss aspects of drawing – in relation to science learning object *Rules:* How to draw depends on the science learning topic	Science learning object aligns with the use of drawing	Preschool C Primary school A Primary school B *Primary school C (Big Bang)*
Category 2. Does *not* make explicit use of drawing for science learning			
2a. Teaching emphasis on written language			
Drawing as a part of *teaching and learning in general:* – to communicate interest and knowledge – to evaluate/consolidate children's learning	*Tools*: Support directed towards writing in relation to science learning object *DoL:* Children draw and write/speak, teacher writes *Rules:* Children should write if they can and all children should draw The written science words on the drawing should be correct	Science learning object focused in relation to written/oral language but not in relation to drawing	*Preschool A (Mushroom)* Preschool-class A Preschool-class B Preschool-class C
2b. Teaching emphasis on producing a drawing			
Drawing as a part of *variation in teaching and learning in general:* – the more modes that are involved, the richer the learning – children learn in different ways, drawing may fit some children	*Tools*: Support directed towards practical assistance *DoL:* Children draw *Rules:* Finish the task	Activity focus is to produce drawings Science learning objects not prioritised	*Preschool D (Clouds)* Preschool B

science teaching. None of the teachers in our study speak of drawing in terms of visual literacy, that is, as the ability to critically interpret, use and create visual information (cf. Lopatovska et al., 2016). Furthermore, only a few teachers mention any explicit connection to science learning opportunities in terms of drawing to learn (cf. Ainsworth et al., 2011) or learning to draw to communicate knowledge in science (cf. Danish & Phelps, 2011). There is a tendency, in our study, that primary school teachers relate drawing to science teaching and learning specifically, to a larger extent than preschool teachers and preschool-class teachers. This tendency could be explained by the different cultural-historical grounds and the different curricula of preschool and primary school, where the latter have more explicit focus on children's learning in science (e.g. Sandberg et al., 2017). It could also be a sign that the preschool and primary school teachers' different training – in arts education, science education or general education – matters to their professional views on drawing in science. Still, the sample is small and the pattern is not consistent, as we also find one preschool teacher among the four who, in interviews, relate drawing to science teaching and learning specifically.

Our findings indicate that drawing has a weak position as a means of communication in the science classroom, since only a few teachers support children's drawing or draw anything themselves. The scant teacher support in relation to children's drawing was accentuated by the fact that nearly all the teachers supported children's *writing* during the observed drawing activities. For example, they responded to children's questions about how to spell words and they wrote science words or sentences on the board for children to copy. If children could not write, teachers wrote down what children said onto the children's papers. Similar teacher support was very rare when it came to children's drawing. Wilson and Bradbury (2016) report similar results in a study of first grade science classrooms in the US, hence, that teachers support children's writing processes but not their drawing processes in activities that include both these modes of expression. We see that one possible explanation to why teachers do not support children's drawing is that their foremost goal is that children learn to write. That goal may align with the preschool or primary school traditions and curricula, but it may also be a sign of teachers trying to be accountable in relation to political demands that value written texts higher than drawings (Mackenzie, 2011). Anning (2002) has shown that ECE practitioners in England were preoccupied with 'getting the children to read and write' whereas they perceived drawing as a 'time-filler' (p. 208) and other international studies have reported that adults primarily consider drawing as a 'prewriting activity' to, for example, practice the motor skills needed when writing (see Delserieys et al., 2017). An additional possible reason why ECE teachers seldom support children's drawing practices is that they consider drawing as 'something which the children can do already, spontaneously, rather than as something they have to be taught' (Kress & Van Leeuwen, 2006, p. 16). Looking at our findings from another angle, the fact that teachers seldom support children's drawing practices may be understood in the light of the Froebelian heritage of promoting children's free creative activities in Swedish preschools and primary schools (Lindahl, 2002). Teachers may be reluctant to interfere with children's drawing, if they view drawing as a personal, creative form of expression.

The article raises questions about how to navigate between 'drawing to learn' and 'learning to draw' in science. We have portrayed teachers' explicit support of children's drawing as positive for children's science learning opportunities. For example, in story 1, the teacher demonstrates how to make the representation of Big Bang while discussing and motivating representational choices with the children. On one hand, one can argue that the teacher supports children to 'learn to draw' in line with specific conventions for the sciences (cf. Hoffman & Wittman, 2013). One could also argue that she supports them to 'draw to learn' since she provides children with a repertoire of representational tools, such as drawing techniques to illustrate expansion, that children can use to make meaning of the science topic at hand. On the other hand, one could argue that her guidance is too firm to allow for individual meaning making, if one, as Jewitt et al. (2001), view children's meaning making as a process of reshaping information communicated by the teacher. The framing of the Big Bang activity left little room for children to make their own representational choices or draw on their individual, previously acquired, representational repertories.

Further research

Our findings point at a need to investigate the outcome of the activities from children's perspectives. In this article, we have interpreted what science learning opportunities children were afforded, but we cannot say what children learned or what they experienced to be the focus of the drawing activity. For example, we cannot say if children in Story 1 perceived that the fact that the Big Bang expands was a main focus of the lesson. Perhaps, some of the children perceived that the focus of the lesson was to learn how to use pastel crayons or to produce a piece of art. We have shown that teachers may foreground drawing in relation to science learning (category 1), or the teachers may foreground children's writing in relation to science learning (category 2a), or their production of a drawing in itself (category 2b). Against that background, we find it important to investigate what children perceive to be foregrounded in the drawing activities.

Implications

To conclude, our findings suggest that there is a gap between the many pedagogical benefits of drawing in science class, outlined by researchers, and the ways ECE teachers make use of drawing in their classrooms. In order to close that gap, we suggest that teachers and school administrators identify obstacles and opportunities to realise the pedagogical potentials of drawing in ECE science classroom. Our study illustrates how contradictions between elements within an activity system may give rise to conflicting messages during a drawing activity. Building on our findings, we suggest that teachers and administrators draw on activity theory to plan, assess, and improve their use of drawing for science learning purposes in the classroom. Specifically, we propose that they outline each element of their activity systems, that is, their classrooms, by answering questions similar to those provided in Table 2:

Why do we include drawing in science teaching? (*community*)
What norms regarding drawing do we have in the science classroom? (*rules*)
What is the science learning purpose of the drawing activity? (*object*)
How do we introduce the drawing activities? What material do we provide? (*tools*)
What do children and teachers do during drawing activities? (*division of labour*)
What science learning opportunities are children afforded in the drawing activity? (*outcome*)

Next, we suggest that they analyse if there are contradictions between elements, since these contradictions may be obstacles to making use of drawing for science learning purposes. Moreover, our findings suggest that teachers and administrators should identify if the pedagogical potential of drawing is obscured by a strong teaching emphasis on writing or on producing a drawing.

Another way of supporting ECE teachers to make use of drawing in their classrooms could be realised through teacher training. There is currently a lack of studies that engage with the role of drawing in science in ECE teacher training. Based on our findings, we suggest that teacher education provide student teachers with practical experiences, and opportunities to conceptualise, what ‘drawing to learn’ and ‘learning to draw’ may mean in an ECE context. That way, they would be better equipped to make use of drawing in their future science classrooms.

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