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Children's understanding of representations of basic chemistry after participating in an early childhood drama pedagogical activity

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ABSTRACT: The purpose of this study is to generate insight into how young children in early childhood science education understand representation. Taking many forms: gestural, material and verbal (Gilbert, 2005), representations are critical to science education, already with young children. The empirical data for our analysis consist of interviews conducted with 6-year-old children after having participated in a playfully-formatted activity (van Oers, 2014) in basic chemistry held at a culture centre for children. The interviews are analyzed as social practice, clarifying how the children respond to the conceptual and communicative challenges they face. The results show that there are important differences in how the children show that they understand the forms of representations used in the activity. What these differences are and why they are critical to developing representational insight and basic scientific understanding, and therefore what educational implications our findings have, are discussed.

Keywords: chemistry, early childhood education, playfully-formatted activity, representation

Introduction

In this study, we analyze how a group of 6-year-old children understand representation of basic chemistry used in a playfully-formatted activity (van Oers, 2014) at a culture centre[1] for children. Following van Oers (2014), any activity can be formatted in a more playful or a more procedural way. Hence, rather than understanding play as a separate category, playfulness is understood as the way an activity is communicatively framed. In the present case, a chemistry activity is playfully-formatted into a dramatic enactment[2]. The centre offers, among other things, playfully-formatted learning activities for preschool groups. The chemistry activity that was the focus of this study, was planned and staged by the culture centre in collaboration with a chemistry teacher and drama pedagogues. The aim of the drama-activity was, in addition to creating an interest in science and specifically chemistry in young children, to introduce basic chemistry concepts to them. In the activity, a drama pedagogue, dressed up like a water molecule, invited the children to make sense of features of basic chemistry and to carry out experiments with water and coloring. The children participated in the activity through enacting and embodying chemical processes. Besides being able to interact with the drama pedagogues on stage, the children were invited to take part in experiments and to enact moving molecules. A scientific study was then conducted on the process of the educational activity and how the children had understood it.

Follow-up interviews were performed with a particular interest in finding out how the children understood the central concepts and processes enacted and in other ways represented in the activity, that is, (water and sugar) molecule(s) and the solution of water and sugar at different temperatures. Based on our findings, we will discuss the pedagogical implications of employing representations in early childhood science education. The following research question is posed: what repertoire of ways of understanding representations of basic chemistry are there in a group of 6-year-old children after participating in an early childhood drama pedagogical activity?

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[1] What is here referred to as a 'culture centre' denotes a house for cultural activity open to the public. In this particular case, the theme of the house is a famous Swedish fictional character, well known from children's books. At this centre, children can play, read/be read to, and engage in other kinds of activities such as theatre/drama. The culture centre of this study is located in the centre of a larger Swedish city.

[2] What is here referred to in terms of 'playfully-formatted activity' implies engaging in *as-if* actions (e.g., dramatizing, storytelling, imagining, playing). In a sense, all the chemistry activities the children experience at the culture centre has this character (even the experiment with the food coloring, serves as an *as-if* representation of dissolution on an entirely different level of description).

Representation in science and science

The objects of knowledge of scientific investigation are not simply there to perceive. Rather, for various reasons they have to be inferred. In order to be able to talk about and investigate these objects, different forms of representations are used (Gilbert, 2005). Representations take many forms; they may be speech-based metaphors and similes, where we speak about what we are trying to explain in terms of something more familiar and perhaps more tangible. Some examples of metaphors in the sciences are 'black hole', 'greenhouse effect', 'genetic code' (Semino, 2008), 'mind as a machine' (Draaisma, 2000), and 'gas' (Sutton, 1992).

The matter of representation also comes to the fore in science education. Visualization and being able to use and understand representation has a crucial role in chemistry education (Kozma & Russell, 2005). In this context, representations are employed to render scientific knowledge in more familiar form, making possible for learners to build upon their experience in making sense of the new forms of knowledge they encounter. Gilbert (2005) discusses different modes of representation that play a key role for understanding chemical processes: concrete or material modes of representation (i.e., three dimensional ones, like models of molecules), verbal modes that can be spoken or written (e.g., metaphors and analogies), symbolic and visual modes (e.g., chemical symbols, graphs), and gestural mode that makes use of the body or its parts. Gilbert (2005) argues that different modes are often combined and that to understand a phenomenon requires a fluent movement between the different levels of representation. However, an inherent problem with representations is that they may become more than what they are, that is, they may come to be taken literally. Furthermore, with time, what was introduced as tentative metaphors or similes may become the concepts of scientific work (see e.g., Pramling, 2009, on Darwinian evolutionary theory). Particularly for learners, who are new to the conceptual world of science, being able to distinguish between the representation and what it represents may pose a great challenge (see Fleer & Pramling, 2015; Pramling & Säljö, 2014). An example of the latter is students inferring from the common molecule model that molecules are solid balls connected with sticks, and being, for example, black or red in color (cf. Molander, Pedersen, & Norell, 2001; see also Hesse, 1966, for an elaborate account of the issue of what features of representations do and do not denote properties of the object of reference). Hence, learning to distinguish between representation and represented, or between what something *is like* and what it *is*, is integral to appropriating scientific knowledge (Kozma & Russell, 2005). How this tension between modes of representation or visualization and conceptualizations of learners plays out is of great interest to science education also with the youngest children where already such epistemological tools are introduced.

Research on drama pedagogy and children's understanding of representations

There is a body of work on children's understanding of representations and the development of what is sometimes referred to as representational insight. What we here refer to as 'representations', as a generic category, encompasses what in individual studies may be alternatively referred to in terms of symbolic development, representational awareness, or understanding models (DeLoache, 2004). How children understand representations has since long been an interest in developmental research, particularly from a cognitive psychology perspective (DeLoache, 1991, 2004; DeLoache, Uttal, & Pierroutsako, 1998; Troseth, Pickard, & Deloache, 2007). Primarily, this interest has been pursued in laboratory settings (e.g., Apperly, Williams, & Williams, 2004; Dockrell & Teubal, 2007). In these studies, different forms of representation, such as models and photographs have been employed to access children's thinking. One important finding is that children tend to attend only to the object as such (i.e., the model, photograph etc. serving as a representation), rather than to what it represents (DeLoache, 1991, 2004; Stevensson & Stiegler, 1992), and that this is contingent on the perceived attractiveness of the object: what children find to be more interesting objects to greater extent preclude them from taking these as standing for something else (i.e., work as representations). Hence, the root to the difficulty of understanding representations lies in the fact of their 'double face', to use Tolchinsky's (2007) phrase. That is, in the nature of a representation, something, which by necessity is something by itself (e.g., lines on a piece of paper) at the same time can be understood as standing for, in place of, something else (e.g., the terrain of an area, as in a map). Even though forms of representation differ in how closely they mimic what they represent, no representation is entirely transparent. Neither is it self-evident that children (or adults) will understand these as representations.

While there is substantial *experiential evidence* from classroom practice that the use of drama may provide incentive for learning in science, Ødegaard (2003) argues, there is less *empirical research and theorizing* on this issue. What existing research points out is that drama pedagogy activities such as role play can support higher order thinking skills and make learning experiences meaningful (Dorion, 2009). In fact, as Ødegaard (2003, 78) suggests, dramatizing content provides a way of connecting to children's own experience and life worlds, rather than merely presenting scientific concepts in the abstract. In her phrase, dramatizing allows, "scientific concepts [to] come to life". In a discussion of drama in relation to modelling in, and learning of science, Varelas et al. (2010) argue that dramatizing can be used to express models, integral to scientific knowledge.

Dramatizing may be categorized as *presentational* or *experiential* (Ødegaard, 2003). In presentational drama, children experience the act as an audience, while in experiential drama, they participate in living through some aspect of an experience, that is, the children themselves participate in the dramatization. Drama in the science classroom could be conceptualized as *role-play* taking place in an *imagined situation* and enacted within the *human dimension*, that is, in the context of what makes sense in terms of human actions and experience. When the child navigates between real and imaginary worlds, a state of double consciousness is created (Dorion, 2009; Varelas et al., 2010). Such double consciousness, or metaxis, means to be able to engage in and shift between an imaginary realm (*as if*) and reality (*as is*).

In a study of dramatic enactments with the aim of supporting primary-grade children to develop and communicate scientific understanding (Varelas et al., 2010), one of the cases concerned matter. The children acted as molecules in three states of matter: solid, liquid and gas, in a similar way as the younger children of the present investigation. In the study by Varelas et al. (2010), the children used the drama activity to elaborate on the movement, relative distance, and speed of molecules. The study sheds light on the complex ways in which children negotiate the ambiguity of meaning and development of, as well as communicating understanding. Varelas et al. (2010) draw the conclusion that dramatization as a certain form of modeling offers opportunities to expand science education beyond dualisms, such as thinking and feeling, and mind and body. Thus, it not only works to make more experiential sense to children, but it also allows for engaging with more complex modes of thinking than dichotomies.

In a recent theoretical discussion about imagination and role-play in learning basic science in preschool, Fleer and Kamaralli (2017) present a case study of using a giant inflatable plastic bubble to engage children in thinking about a microscopic world. In their discussion, and with their example, the researchers show how the creation of this "imaginary scientific situation" was instrumental in creating conditions for children to make the transition from everyday life to a microscopic world (Fleer & Kamaralli, 2017, 122). Imagining such a world, and generalizing over size, resulting in "real conceptual and emotional engagement" in children into natural phenomena. The example provided by Fleer and Kamaralli is similar to the activity that the children of the present study have participated in. In extension, interviewing them about this activity, as we will do, has the potential of generating additional insights into how they have perceived the activity and particularly its central representations.

Against this background of previous studies, the present study differs in several ways. Theoretically, a premise of our study is the need to study how children reason about representations, rather than merely studying the extent to which they can do so (at

different levels of development). Another difference is that previous studies on representation, almost exclusively, have made use of readymade representations for children to interpret (for rare exceptions, see Magnusson & Pramling, 2011, 2016). This difference between our present study and previous research is critical, in that our approach positions children as participants in representational practices; they are co-participants in representing chemical phenomena in the activity preceding the interviews we analyze here. Hence, rather than merely 'reading' representations presented to them, they are involved in representing what they are subsequently engaged in a dialogue about. An important general finding in developmental research is that children's abilities (e.g., understanding, reasoning) are contingent on the extent to which they can relate to what they are being asked about (Sommer, Pramling Samuelsson, & Hundeide, 2010). The approach taken in the present study therefore appears particularly fruitful to investigate how young children understand basic representations in the domain of science. In our study, we intersect the research fields of the development – or as we theoretically will conceptualize it, appropriation – of representational understanding and drama pedagogy.

Theorizing learning

In this study, we understand learning in terms of the tradition building on the founding work of Russian psychologist Lev Vygotsky, alternatively referred to as a sociocultural perspective or cultural-historical theory (Fleer & Pramling, 2015). Since a phenomenon such as learning is not available for us to look at and investigate directly, we have to constitute it in language. We do so through speaking about it in terms of something else, typically something more tangible and familiar. Some common metaphors of learning are knowledge construction and changed participation. The learning metaphor of the theoretical perspective we take in this study – appropriation – allows us to study learning through attending to what cultural tools and practices learners gradually take over (Wertsch, 1998). The metaphor of appropriation provides a concept for capturing the dynamics of learning; this process requires active sense making of the learner and is a gradual, often extensive process. In fact, it may be argued that we never fully appropriate complex cultural tools such as those of scientific thinking. This body of work is of course also developing over time, thus, there is no static body of knowledge to appropriate. What in this tradition is referred to as cultural tools, denote human inventions with which we perceive, understand and act. Particularly important is the tool-kit made up of language (Wells, 2007). Such cultural tools include distinctions, concepts, narratives, metaphors, and many others. Accordingly, learning chemistry, to use the example of the present study, means to appropriate concepts and distinctions central to this field of study. Being able to make use of cultural tools in contextually relevant ways are considered as an

indicator of the learner having – more or less, since this is never complete – appropriated these tools. Hence, learning is not understood from this theoretical perspective as something 'behind' or 'beneath' (the commonly applied metaphors for such reasoning in psychology) this use. The metaphor of appropriation allows us to analyse learning in terms of what is empirically available for observation. This theoretical perspective also has implications for our methodology. Since we are interested in the children's understanding, and since appropriation from a sociocultural point of view implies sense making rather than simply internalizing a content, the children were given opportunities to reflect on and nuance their understanding, with the aim of allowing us to approach the child's perspective.

In his work on concept formation, Vygotsky (1998) makes a distinction between what he refers to as *pseudo concept* and *concept proper*. The former denotes being able to give several examples of the same thing, without necessarily being able to clarify what these have in common. The latter denotes being able to discern what is common and thus characteristic of what is summarized under a label. This distinction will be useful in analyzing the children's reasoning in the present study.

Method and methodology

The drama activity was planned and carried out by the culture centre but the empirical data of the scientific study were generated through interviews with 6-year-old children. Interviews were conducted with 22 children before participating in a playfully enacted activity on basic chemistry at a culture centre, to map their understanding of basic chemistry and the concept of molecule. The pedagogic activity was enacted by a science teacher and two drama pedagogues, one of them dressed up and acting as a water molecule, and both the children and their teachers were invited to take part in the enactment.

The drama activity

During the activity, the children were introduced to the concept of molecule. This concept was exemplified by water molecule, sugar molecule, and color molecule. The children were told that everything consists of molecules, even if these cannot be seen even with a microscope, and that they are not alive. The children were also introduced to the ideas that molecules move in coincidental directions, and that they bump into other molecules, leading to a change of direction, and that the velocity of movement is a critical aspect related to the temperature and form of a substance, and that molecules can be mixed, a process dependent on temperature. The water molecule was enacted by a drama

pedagogue: as a figure with a red body (representing the oxygen atom) and white cushions around her arms (representing two hydrogen atoms). There was also a soft toy with the same color combinations, with the ears representing hydrogen atoms. The children also took part in dramatizing water molecules and their movement. This took the form of a molecular dance, with the children wearing blue caps, and the teachers taking the role of the glass containing water. The dance was filmed from above, making the children's movements resemble blue dots moving about. In a similar vein, the children took part in dramatizing sugar molecules; this time wearing red hats, while other children kept their blue caps to represent water molecules. The children and teachers subsequently enacted the mixing of sugar in water of low and high temperatures. Finally, experiments were carried out, where green food coloring was mixed in water of different temperatures.

A week after the lesson, 11 children were interviewed again, this time about the lesson they had attended and how they understood the concepts and processes covered. The reason for interviewing only a selection of the children a second time was partly for convenience and time, and partly to choose the children who had shown a particular interest in developing their ideas about water in the previous interview setting. Children who engaged themselves in the activity, expressed this verbally, with body language, facial expression and/or tone of voice. Verbal engagement took the form of expressions of curiosity and speculating about different possibilities. Lack of engagement was expressed by restlessness and limited interest in trying to answer questions that the researcher asked. For the present study, only the interviews conducted after the drama activity were used. More information about analysing how the children's understanding before and after attending the lesson differed can be found from a study by Åkerblom, Součková, and Pramling (2019). In the present study, we analyze more specifically how the children indicate that they understand the forms of representation used in the activity.

Ethical considerations

The ethical aspects and considerations of the study were handled according to current research ethical principles, as stated by the Swedish Research Council (2017). The caregivers of the participating children had given their written consent for their child's participation in the study. When conducting the study we were attentive to any indications from the children that they did not feel confident or not wanting to participate. None of the children showed such concern. In accordance with these ethical guidelines for research, every child was promised confidentiality, meaning that the names used in the excerpts are pseudonyms. The decision to not interview the children that did not show an interest was also considered to be ethically motivated (i.e., to not force children to do what they do not want to).

Analytical procedure

How children understand representations can be clarified, in part, through asking them more directly about this issue in interviews. Previous research shows that it can also be identified through analyzing how children use different kinds of meta-markers in their reasoning (e.g., in interviews). Already young children tend to use meta-markers (Goatly, 2011) to indicate that they do not intend their utterances to be, or by the interlocutor be, taken literally (for analyses, see Pramling, 2006; Pramling & Säljö, 2015). Meta-markers may include using terms such as 'similar to', 'a kind of', or with adults, 'metaphorically speaking', but also changing one's tone of voice, and using gestures may serve this function. Analyzing what meta-markers, if any, children use in their talk is thus key to untangling the issue of how the participating children themselves understand the representations employed in the lesson they are being interviewed about. However, communication cannot be understood as information transmission from sender to receiver. Rather, communication is a mutual and responsive activity (Linell, 2014). Methodologically, this entails the need to analyze what children say in interviews not as stand-alone concepts, but as part of the social practice of the interview (this is highlighted by our fourth category, if foreshadowing our results). This means that every utterance is read as a response to previous utterance(s) (Pramling & Säljö, 2015). Through her questions, the interviewer communicatively mediates (Wertsch, 1998) a particular perspective on what is to be talked about. How children respond to this mediation is much indicative of whether or to what degree they are sensitive to the mediation of speech. The interviews are therefore analyzed as sequentially unfolding, collaborative events. Several consecutive utterances are therefore analyzed: a topic is initiated (in interviews, typically by the interviewer), the interlocutor (in this case the child) responds, the interviewer follows up in response to the child's response; the child responds to the interviewer's response to his or her response to the previous question, and so on. If the interlocutor (in the third turn, so to speak) goes on, without objection or clarification of what she meant, this is read as indicating that she accepts how the other interlocutor has responded to her previous utterance (Wells, 1999).

Selecting the excerpts to be analyzed, have been done by the researchers, first individually and then collaboratively in data-sessions, with the aim of finding as rich as possible insight into the participating children's understanding of representations. More concretely, this means that all data has been transcribed and analyzed; the initial analysis was conducted on a case-for-case basis. This ensured that no child's way of understanding was excluded. In a follow-up analysis, the cases were pooled and read as one larger data set, with the intention of finding across-cases patterns (cf. Derry et al., 2010). Reviewing and analyzing data, first separately and then at joint data-sessions, work in preventing selective bias,

since mutual agreement is required among participating researchers, on the basis of their individual analysis.

Since, on the basis of our theoretical approach, children's understanding need to be analyzed and understood as responsive to the social situation of the interview as it unfolds (Schoultz, Säljö, & Wyndhamn, 2001), we cannot merely present our findings in a number of categories; these also need to contain excerpts from the actual interviews. For this reason, only some of the children are actually present in the excerpts presented. However, the categorization we have made is not specific to these children but are representative of what is evident also in the interviews with the other children interviewed. The categories are not based on pre-existing categories. Rather, they emerged during the collaborative analytical process. However, rather than completely inductively, given the theoretical premises of our study, the categories emerged abductively. That is, we make sense of the empirical data in terms of the conceptual resources of our theoretical perspective, but in a way that we are responsive to the nature of the data (the children's reasoning) rather than placing them in pre-existing categories. As the fourth category concerns a meta-issue, the categories are not mutually exclusive. The examples given in the results show the identified variety of ways the children in the interviews respond to the challenge of clarifying how they have understood the activity they have participated.

Using photographs could be seen as a case of photo-elicitation (Harper, 2002). He argues that this research method of inserting photograph(s) in interviews "evokes (interviewee's) information, feelings, and memories that are due to the photograph's particular form of representation" (Harper, 2002, 13). Another point with using photographs in interviews with children, Richard and Lahman (2015, 3) argue, is that it gives researchers "access to participant beliefs and values," and can work "to highlight participant voices through their choices of words". In the present case, the photographs were used not only to aid the children's remembering, but also to provide a mutual platform – a frame of reference – for the talk.

Transcription and translation

Since the original data is in Swedish, the transcripts have been translated. This may prove challenging, particularly when non-literal language such as metaphors or similes are used (Guldin, 2016). We have therefore paid great care to make sure the translations mimic as closely as possible the children's original Swedish utterances. The translation was done and critically reviewed jointly by the research group. Like the analysis, the translation is the result of an iterative process (Derry et al., 2010), where we have kept returning to and checking our analysis and translation against the data. In our transcriptions, we use

literate distinctions (such as comma, point, and initial upper-case letter) to make the transcripts more readable, despite such features not being present in oral discourse.

Findings

In this section, we present our analyzis in close proximity to excerpts from the empirical data. The findings are structured in terms of categories of ways of understanding representations as well as a meta-category, concerning the need to understand the children's conceptual understanding as situated in a communicative practice. Each category is presented through one or more excerpts from the data.

Discerning *that* something can be taken *as* a representation

In Excerpt 1, Barbara is asked about a picture of the drama-pedagogue, dressed to represent a water molecule:

Excerpt 1

11 I: *And do you remember what this is?*

12 Barbara: *It's a water molecule.*

13 I: *And why does it look like that?*

14 Barbara: *Cause that's how they look, that they would bounce away in another direction.*

15 I: *Bounce? What does bounce mean?*

16 Barbara: *Bounce means that they can go away in another direction.*

Asked whether she remembers what she sees represented in the photo (turn 11), Barbara responds that "it's a water molecule" (turn 12); thus, the child herself in the interview introduces this term. Asked why they look like they do in the photo (turn 13), Barbara first suggests that "'cause that's how they look" and then elaborates, saying "they would bounce away in another direction" (turn 14). The interviewer asks her what she means by "bouncing" (turn 15). In her response, Barbara clarifies that this "means that they can go away in another direction" (turn 16). That she uses the meta-marker 'means' indicates that she can distinguish between what is *said* and what is *meant*, an important distinction to make in handling representations; there is a dynamic and negotiable space between saying and meaning, or representation and represented.

In Excerpt 2, Chris is talking about a picture taken during the experiment of mixing sugar and water in different temperatures. Green food coloring was used to visualize the mixing process.

Excerpt 2

72 Chris: *Then it became green.*

73 I: *And what did it mean then, when it became green?*

74 Chris: *That it had spread. And it like water… the water was cold, then it became like a beam down, but if it was warm, then it became almost like a cloud… then it was almost like smoke.*

75 I: *Do you know why that became so then?*

76 Chris: *It was because the water was warm.*

77 I: *Yes. You said molecule, what is a molecule?*

78 Chris: *A molecule is a small, tiny, tiny, tiny, tiny, tiny… tiny, tiny, tiny part of something.*

79 I: *Of what? What can it…*

80 Chris: *Of just anything!*

Talking about what happened when they put coloring in water, Chris talks about how if the water was cold, "then it became like a beam down, but if it was warm, then it became almost like a cloud… then it was almost like smoke" (turn 74). In this way, he uses familiar phenomena to talk about what may be somewhat difficult to explain: what happened with the green color when added to the water. His use of similes ("beam", "cloud", and "smoke") is marked out with meta-markers ("like" and "almost like"). In this way, Chris communicates that he talks about something in terms of something else, more familiar, or easier to talk about, when trying to explain his impression of the experiment. A distinction is thus made between representation and represented. This could also be interpreted as Chris making a connection between two different modes of representation, which according to Gilbert (2005) is a requirement for understanding the phenomena being represented.

Difficulties with differentiating the representation from what it represents

In Excerpt 3, we enter the interview with Andy when he is asked about a picture where the children are enacting water molecules, wearing blue caps:

Excerpt 3

48 I: *But why did you wear such blue caps then?*

49 Andy: *Cause we were supposed to be water molecules.*

50 I: *Oh, what are water molecules?*

51 Andy: *They are such round balls, but they look like Mickey Mouse.*

52 I: *Aha, why is that?*

53 Andy: *Cause they live there…*

54 I: *Yes?*

55 Andy: *…and make the water blue.*

56 I: *Ah. How then?*

57 Andy: *Cause they are soft, they are really soft.*

Asked why the children wore blue caps on the picture looked at, Andy explains that "'cause we should be water molecules" (turn 49). Talking about what they "should be" (Swedish: "*skulle vara*") indicates that this is understood by him not, in fact, as how it is. Prompted by the interviewer to clarify what water molecules are (turn 50), Andy suggests "they are such round balls, but they look like Mickey Mouse" (turn 51). This utterance is somewhat ambiguous; on the one hand, Andy say that "they" (i.e., the water molecules) "are […] round balls"; on the other hand, he suggests, "they look like Mickey Mouse". The former indicates that he takes a feature of the representation literally: molecules *are* balls. The latter indicates that how the balls look (what they look like) is distinct from what they are. From this brief exchange, it is not clear-cut how Andy understands the features of the representation discussed (the drama pedagogue's dressed-up appearance). Asked "why" (turn 52) – the question does not make analytically clear what is asked: why the balls (or molecules) look like Mickey Mouse, or why molecules are round – Andy responds that this (whatever 'this' is) is "cause they live there… and make the water blue" (turns 53 and 55). What he means with saying that "they live there" is not entirely clear, but indicates that he sees molecules as animate. When he says that they are 'making' "the water blue" he probably makes a connection to the color of the caps. The colors used in the enactment were chosen for contrast and not to represent a trait of water molecules, but Andy interprets the color of the 'water molecules' as a reason for water being blue. Further challenged to explain what he means, by the interviewer asking "how" this is done, Andy suggests that this is because of them being "so soft, they are really soft" (turn 56). Here he interprets features of the water molecule as it is enacted by the drama pedagogue, being

animate and soft, as critical features of molecules. However, it cannot be excluded that Andy here is 'romancing', to speak with Piaget (1923/1926). That is, deliberately invents to fill out his slot in the evolving conversation.

In a later part of the dialogue, Andy is asked about water and what it is:

Excerpt 4

104   I: *Water then, what is it?*

105   Andy: *It is made of… it is water molecules.*

106   I: *What are molecules then?*

107   Andy: *It's those round, and if you first take red and then two eyes and a mouth, and then you have white, then it becomes a water molecule…*

108   I: *Where do molecules exist?*

109   Andy: *They exist in water.*

110   I: *In water, are they somewhere else?*

111   Andy: *No.*

112   I: *No?*

113   Andy: *They are in everything, everything that are lakes and rivers and streams and everything that is water.*

Asked what water is (turn 104), Andy responds that it "it is made by… it is water molecules" (turn 105). Him first saying that it *is made by* and then, after some hesitation, stating that *it is* water molecules may indicate that rather than seeing water molecules as parts, possibly in connection with other parts, making up water, water consist of molecules. Asked what molecules are (turn 106), Andy suggests that "it's those round" (turn 107), indicating that he takes roundness to be a feature of the molecule as such rather than a mode of representing. He continues to explain that "if you first take red and then two eyes and a mouth, and then you have white, then it becomes a water molecule" (turn 107). Here the representation and what is being represented appear to be conflated or collapsed into one and the same. No distinction between the two is made. Asked "where do molecules exist" (turn 108), Andy answers that "they exist in water" (turn 109), and after further probing, whether molecules exist anywhere else (turn 110), he first says "no" (turn 111), but following the interviewer's repetition in a questioning tone, "no?" (turn 112), he suggests that "they are in everything, everything that are lakes and rivers and streams and everything that is water" (turn 113). Analyzing the interview as a social

practice, it is noteworthy that the interviewer through repeating the child's response in a questioning manner, subtly indicates that this was not the expected or correct answer (cf. Aronsson & Hundeide, 2002). In response, the child gives another answer. While the interviewer asked the more general question about where *molecules* can be found, Andy, through his responses indicates that he talks within the premise that *water molecules* are what is talked about, and deemed relevant to talk about on this occasion. Whether he has appropriated a more general concept of molecule is not clear from this evolving conversation. However, he is able to generalize water molecules to different examples, even "anything that is water", which suggest he has not only appropriated 'water molecule' as a pseudo-concept in Vygotsky's (1998) sense, but also as a concept proper, but with a different meaning than the scientific concept.

Excerpt 5 is from a dialogue with Alex from the beginning of the interview, when the interviewer shows him the pictures and reminds him of the occasion and that the pictures were taken from a film that was recorded during the lesson:

Excerpt 5

5   I: *I have some pictures here… from when you were there, you know when we recorded and then we retrieved these pictures. Do you remember what happened there?*

6   Alex: *Hm, since it's blurry they probably moved quite quickly?*

7   I: *No, I think that just happens when you take [a still] from the film, I don't think he moved so much. This is probably [the science teacher], and he holds something. Do you remember what it was that he held? One of those small plates, wasn't it? What was on it, do you remember?*

8   Alex: *Mm… water.*

Looking at one of the pictures taken during the lesson, Alex suggests, "since it's blurry they probably moved quite quickly?" (turn 6). He thus connects the blurriness of the picture to the movement of the children in the lesson, that is, takes the picture as representational in this sense. However, the interviewer responds that "no, I think that just happens when you take [a still] from the film, I don't think he moved so much" (turn 7). From an analytical point of view, the problem is here to differentiate the features of the representation of what is represented from features that belong to the representational media (in this case the photo and how it has been generated). Hence, understanding that something is a representation of something is merely the first step: the next step is discerning what features of the representation represent the represented and what are irrespective of this (the 'white noise' of the representational media, so to speak).

In the next dialogue, Carla is asked about a picture where the children are enacting water molecules, wearing blue caps:

Excerpt 6

33 I: *How fortunate that you were on the picture. Why do you wear such caps then?*

34 Carla: *Hm... I don't know.*

35 I: *But how did you do then, when you played water molecule?*

36 Carla: *Mm, [the science teacher] and miss should stand as a water glass and we should move.*

37 I: *Aha, so you should be water molecules and move? How did you move then?*

38 Carla: *Quickly and slowly.*

39 I: *When did you move quickly?*

40 Carla: *When it was warm.*

41 I: *And slowly then?*

42 Carla: *When it was cold.*

Asked why the children wore caps in the picture looked at (turn 33), Carla responds that she does not know (turn 34). This indicates that the representational function of the caps (blue and red) in the activity is not clear to her. Trying to find a way forward in exploring the child's understanding, the interviewer asks a new kind of question, easier for the child to respond to, connecting to something Carla had herself introduced earlier in the dialogue: "but how did you do when you played water molecule?" (turn 35). Phrased in this way, the question asks Carla to render what she *did* (rather than what it may or may not have *represented*). Carla starts describing how one of the teachers and miss (i.e., the preschool teachers as colloquially referred to in Swedish as "*fröken*" [miss]) "should stand as a water glass and we should move" (turn 36). Following up, the interviewer rephrases Carla's description ("Aha, so you should be water molecules and move around?"), again using the expression 'water molecules', and asking a new question: "Then how did you move?" (turn 37). Carla responds "quickly and slowly" (turn 38). Responding to the interviewer's follow-up questions, "when did you move quickly?" (turn 39) "and slowly?" (turn 41), Carla is able to show that she has discerned the relationship between the children's embodied enactment (representation) and a feature of the represented phenomena, "warm" (turn 40) and "cold"(turn 42) temperatures.

Also representations can be represented

Alex is asked about a picture depicting himself and his peers enacting molecules in a glass:

Excerpt 7

53 I: *And you then, who were in there, what did you do?*

54 Alex: *Went around like this, dong, dong, dong...*

55 I: *What happened then when you went around? So fast then, what happened then?*

56 Alex: *Aah, we cooked out!*

57 I: *You cooked out?*

58 Alex: *...almost!*

59 I: *Oh...*

60 Alex: *Then we moved so quickly.*

61 I: *Ah, so you moved really quickly? It was fortunate that there was a glass so you just didn't disappear!*

62 Alex: *Yes, if there was no glass, tch, tch, tch, we would bounce against all the walls!*

Asked what he and his peers, who were inside the enacted glass, did (turn 53), Alex responds, "went round like this, dong, dong, dong..." (turn 54). Through onomatopoeia (sound mimicking: "dong") he represents with sounds what they enacted bodily in the lesson. As is common in children's explanations, he first gives a description ("went around"), followed by a meta-marker ("like this"), and then showing, in this case through sound making, or alternatively through showing with one's body (cf. Åkerblom, 2015). Challenging Alex to *explain* rather than *show* (enact) what then happened, the interviewer asks, "then what happened when you went round? That fast then, what happened then?" (turn 55). Alex responds with the somewhat cryptic suggestion that "we cooked out!" (turn 56). This suggestion is not entirely clear-cut to the interviewer, as evident in her asking, "you cooked out...?" (turn 57). Alex adds, with emphasis and a meta-marker, "almost!" (turn 58), and "then we moved so quickly" (turn 60). As a suggestion apparently making more sense than 'cooking out', the teacher summarizes and elaborates on Alex's suggestion, "Ah, so you moved really fast? It was fortunate that there was a glass so that you did not just disappear!" (turn 61). Alex confirms and elaborates, "yes, if there was no glass, tch, tch, tch, we would bounce against all walls!" (turn 62). Again, he uses onomatopoeia to represent what he understands would happen with the molecules if they

were not 'contained' in the glass. This may or may not be what he previously referred to as 'cooking out'.

The methodological meta-issue of studying children's understanding of representations

Excerpt 8 is from the later part of the interview with another child, Erik:

Excerpt 8

53 I: *You spoke before of, you said molecule. Can you tell me something about molecule, what it is?*

54 Erik: *It's... it's things that are in water.*

55 I: *Are there molecules anywhere else?*

56 Erik: *In the sea.*

Reconnecting to what Erik has previously talked about in terms of 'molecule', the interviewer asks him to elaborate on this notion (turn 53). Erik starts explaining what this is: "it's...", before hesitating and shifting to talking about where these can be found: "it's things that are in water" (turn 54). Asked whether there are molecules "anywhere else" (turn 55), he responds, "in the sea" (turn 56). Saying that molecules are "in water" could be understood as indicating a so-called container metaphor (Edwards, 1997; Lakoff & Johnson, 1980), according to which molecules are objects stored in a container (in this case water) made up of something else. Speaking within the mediation, established by previously having talked about 'water molecules', Erik give more examples of molecules "in water" ("in the sea"), rather than giving examples of molecules more generally, as asked by the interviewer (turn 55). This may be due to the mediation of the interview situation; alternatively, it indicates the child having appropriated molecule as a pseudo-concept, being able to give additional examples without necessarily understanding the concept of molecule as such (in Vygotsky's [1998] sense, a concept proper).

Discussion and implications

We were interested in how children understand a critical feature of science education that comes to the fore already in early childhood education: representation. Building on interviews conducted with 6-year-old children about the chemistry activity they had attended at a culture centre, we found some variation in what the children indicate that they have begun appropriating through participating in the playfully-formatted activity

(van Oers, 2014), where a feature of chemistry has been rendered in terms of *as if*. In some cases, representational features appear to have passed by some of the children, while other children indicate that they have discerned these. However, understanding representations is not a simple matter of understanding or non-understanding. In line with what is from a sociocultural perspective referred to as appropriation (Wertsch, 1998), people are in a constant process of becoming increasingly familiar with, for example, how to understand concepts. There is therefore no clear demarcation between understanding and misunderstanding. As indicated by the different features of representations discerned by the children in the present study, we can see how they are in such a process of appropriation where they have begun to single out features of representations while others may remain unrealized. That categories of understanding are not mutually exclusive and that an excerpt from the interview of a child may indicate more than one kind of understanding (see e.g., Excerpt 6) indicate that what children are here challenged to reason about is something in development, rather than fully formed conceptions.

Representational understanding, as indicated by the reasoning of the children in the present study, includes discerning: (i) *that* something stands for something else (i.e., works as a representation), rather than being the phenomenon as such or a direct replication of it, and (ii) that representations represent *some* features of phenomena (and not others) while also introducing features that are not features of what is being represented (see e.g., the examples of 'round balls' and 'the blurriness' in Excerpt 3, turn 51 and Excerpt 5, turn 6, respectively). Furthermore, simply realizing that representations are used, does clearly not necessitate appropriating all representations and features represented (see e.g., Excerpt 4, turn 107). Representations may take many forms; in the activity preceding the interviews with the children, several forms were used: dressing up as if a molecule, enacting with one's body, and speech, and in the interviews also sound-representation in the form of onomatopoeia (see Excerpt 7, turn 54).

Using meta-markers (Goatly, 2011), such as 'is like' or 'kind of', constitute an important feature of appropriating representational understanding. Using markers such as these or the distinction between 'saying' and 'meaning' (see Excerpt 1, turn 16) communicates an awareness of the non-corresponding relationship between representations and represented. Fostering such meta-awareness is arguably critical to early childhood science education (as to more advanced forms of science education).

As we have suggested, and as is informed by a sociocultural perspective (Aronsson & Hundeide, 2002; Wells, 2007), it is not clear-cut what conceptions children have appropriated (e.g., molecules). This is due to the fact that what children express in interviews is, at least partly, contingent on how they perceive the situation (Sommer et

al., 2010). They respond to questions posed as they understand these within the communicative framework or mediation of the interview situation (Pramling & Säljö, 2015). Hence, their responses and indicated understanding need to be understood as responsive to how they perceive the situation more generally. There is, arguably, not neutral context for studying children's understanding (Schoultz et al., 2001), since human beings by our very nature are social, responding to one another. Methodologically, this necessitates analyzing children's understanding in the context of how we generate such empirical data. In the present study, we have done so through conducting a sequential analysis of how interviewer and child collaboratively talk understanding into being. This is not to deny that children come to the interview situation with an understanding, only that there is no way of accessing this in any context-free way, and the interview situation as such constitutes an opportunity for learning, conceptual appropriation.

How children's understanding is intertwined with how the interview situation evolves is evident in the analysis we have made of Andy's (Excerpt 4, turns 108-113) and Erik's understanding (Excerpt 8, turns 54-56) in terms of the Vygotskian (1998) distinction between *pseudo concepts* and *concepts proper*. As we have argued, whether the two children exemplified here have appropriated the concept of molecule more generally, is not clear-cut. However, they are clearly in a process of appropriation, where some features are grasped while others are still somewhat unclear.

What we have talked about in this study in terms of as if and learning about something in the real world (*as is*) – and the awareness this implies as conceptualized by Varelas et al. (2010) as metaxis – relates to what other scholars have talked about in terms of link-making (e.g., Rocksén & Olander, 2017). That is, connecting what might otherwise for the learner be distinct domains of experience or understanding.

Our study has important implications for early childhood science education. First, using representations is unavoidable; the phenomena and processes explained by science tend not to be there for us to see in any direct way. Thus, we have to represent. Since representations highlight some features of what they represent and push other features into the background, or make them invisible, it is critical to engage children in meta-talk about representations and what features they do and do not represent, and what are features of the representations as such, as distinct from features of what is represented. Hence, conducting activities on two levels, as it were, about the phenomena and processes explained by science, on the one hand, and how we communicate, illustrate and make sense of these, on the other, becomes critical.

Being a case of early childhood education, the issue of play is particularly important. Early childhood education in the Swedish context where we have conducted our study, but also

in many other countries, has positioned play at the centre of how it organizes for children's learning and development. So how does play work in the present case? The enactment of the drama pedagogue, embodying a water molecule and the children engaged in pretending to be water and sugar molecules, respectively, clearly made sense to the children. In terms of Ødegaard's (2003) distinction, in the activity preceding the interviews, dramatizing took the form of being *experiential*, not merely *presentational* in nature. That is, the dramatizing of the activity made the children participants with agency to act, rather than merely presented with something ready-made to receive and understand. In the interviews afterwards, they remember these as-if activities and indicate that they have understood that these stood for (i.e., represented) something else having to do with molecules. In fact, all the participating children indicate that they, to some extent, have appropriated the notion of molecule (Åkerblom et al., 2019). At the same time, these playful modes – as do all representations already discussed – introduce some novel features that may come to be taken literally, that is, as in a more direct sense depicting what is being talked about. Again, this highlights the need to shift between engaging *in* an activity (e.g., acting *as if* in an imaginary realm) and *about* the activity (meta-level talk).

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