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ORIGINAL PAPER

Preschool children's conceptions of water, molecule, and chemistry before and after participating in a playfully dramatized early childhood education activity

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Abstract

The present study reports an empirical investigation into concept formation of young children. Based on interviews conducted before and after participating in a playfully enacted chemistry lesson at a culture center, it is analyzed how 6-year-old children conceptualize water, molecule, and chemistry. Theoretically, the study is informed by Vygotsky's cultural-historical perspective on concept formation. The empirical data consist of pre- and post-interviews with children and documentation of their participation in the intermediate activity. This documentation is used in the post-interviews as a mutual ground for talking with the children about what they remember and how they understand the activity they participated in and what the activity intended to illustrate. The results are presented in terms of three inductively generated categories: 'everyday', 'experientially-based', and 'generalized experiences' concepts, respectively. The implications of these findings for early childhood chemistry (science) education are discussed.

Keywords Elementary chemistry · Children's conceptions · Interviews · Drama pedagogy · Vygotsky

The present study investigates how 6-year-old children understand some features of basic chemistry, namely the concepts of water, molecule, and chemistry (as such) before and after having participated in a playfully dramatized early childhood education activity at a culture center for children. How to make basic science applicable to young children in early childhood education is a pressing issue, as curricula tend to point this out as a domain to introduce children to and support them to start developing an understanding of. Teaching children about scientific knowledge, such as chemistry, actualizes an inherent tension, since scientific procedures and forms of explanations need to be rendered in a form that is

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true both to scientific knowledge and to what makes experiential sense to young children. Furthermore, there is no linear or causal relation between teaching and learning, and what sense children make and what they remember from participating in teaching events are open and empirical issues that we need to know more about. This study aims at contributing to illuminating these issues through analyzing what children say in interviews conducted before and after participating in a chemistry activity at a culture center for children, where a chemistry university teacher and a drama teacher collaborate on explaining and enacting (as will be explained below) some features of basic chemistry.

The article is structured in the following way. First, we locate the study in a wider discussion about diminishing interest in chemistry in growing generations. Second, we present previous research on children's understanding of chemistry and chemical processes. Third, we introduce our theoretical framework in the form of the Vygotskian perspective on concept formation. Fourth, we discuss our method and methodology. Fifth, we present our findings in the form of three categories of understanding, exemplified by, and analyzed closely adjacent to, excerpts from the interviews. Finally, we discuss our findings and their implications for our understanding of children's understanding and the development of early childhood science/chemistry education.

Background

When asked about the relevance of science, Swedish young generations state that science has low relevance for their lives. In an international comparative study called The Relevance of Science Education (ROSE), 15-year olds from 40 countries were asked about their attitudes to science education. The results show that the more developed a country, such as Sweden, the more negative and skeptical attitudes towards science. There was also a gender difference, with girls showing an even lower interest in (school) science than boys do and the trend is that the gap is increasing (Sjøberg and Schreiner 2010). Britt Lindahl (2003) also showed that the interest of Swedish students for physics and chemistry is low and decreases during the last years of compulsory school. As a probable result of the negative attitudes toward science, chemistry is a discipline that is seldom favored by high-school students when it comes to choosing what to study at the university level.

In order to change such trends and support learning and awareness of the presence and importance of chemistry in everyday life, a chemistry project was carried out at a culture center for children. The overarching ambition of the project has been to raise children's interest in chemistry, with the intention, in the long run, to make more young people interested in studying chemistry at the university. Briefly, chemistry can be understood as the study of how different substances are constructed, processes and change, and about what happens when different substances meet; with the processes often described with verbs such as solve, mix, absorb, melt, freeze and evaporate (Sundberg, Areljung, Due, Ottander and Tellgren 2016).

The aim of this empirical study is to investigate how children participating in a playfully dramatized teaching activity make sense of the concepts of water, molecule and chemistry, before and after the educational intervention, made evident by the language they used and how they use these terms. Therefore, the research question asked is:

> How do children conceptualize water, molecule, and chemistry before and after participating in a playful dramatization of chemical concepts and processes?

Children making sense of science

What it means to invite children to experience the world of science and make sense of invisible phenomena, for example, those conceptualized in terms of molecule, has interested many scholars. The fact that children have their own, rich conceptions of the surrounding world was something that Jean Piaget showed in his pioneering work, when he described how children reason about different natural phenomena (Piaget 1971). Through interview studies, Piaget saw that children's conceptions of various aspects of the world often differed from what was scientifically accepted. A considerable amount of research has since been carried out with the aim of understanding what children know about the world. The ways in which their intuitive conceptions differ from scientifically accepted ideas have been extensively observed and discussed in research on learning in science education (e.g., Driver and Easley 1978; Osborne and Freyberg 1985; for an overview, see Duit 2009). However, while children's thinking in these studies was often considered as an obstacle to be overcome in teaching, more recent research value children's rich conceptualizations and consider these to be important, both to listen to and value (Robbins 2005, p. 153). For example, Christina Siry (2011, p. 2407) suggests, with reference to Joe Kincheloe, that research on children's thinking should begin with the assumption that young children are capable of producing new knowledge about science phenomena.

The ways in which children understand the phenomena and processes explained by science have consequences for how instruction is organized for children and what they are supposed to learn. If children are positioned as naïve, with deficient thinking skills, teaching will have the aim of overcoming their misconceptions, to be successfully replaced by the scientifically accepted way of thinking and explaining phenomena. In contrast, if children are perceived as resourceful and their thinking seen as rich and diversified, teaching will need to relate to these conceptions as resources for developing children's thinking further. This circumstance was explored by Kristina Andersson and Annica Gullberg (2014), who analyzed a teaching episode in preschool through two different analytical perspectives. From one of the perspectives, where the aim of teaching science was to develop children's conceptual understanding about floating/sinking, the teaching activity was conceived as unsuccessful. But from the other perspective, a feminist approach (Barton 1998), the children's feelings of participation within a scientific context were explored. The two analyses of the same teaching episode showed how different kinds of science were constituted, contingent on associated views of children. The first analysis did not indicate that the children's scientific thinking developed or that the children learned scientific concepts, but the second analysis showed that the children had gained a positive experience of the activity of "sciencing" and of thinking about density. The different results of the two analyses thus also highlight how what is taken as indicators of learning is theory dependent and could be connected to the present study and the discussion about how scientific procedures and forms of explanation need to make sense to young children, but at the same time be true to scientific knowledge.

In another study, Siry (2011) described how children in first grade made their own discoveries about floating in an experiment by finding a way to make all the available objects (such as a small magnet and a spoon) float, through creating a swirl in the water. The children's focus on preventing the objects from sinking made them try new ideas and ask new questions, indicative of complex and playful investigations about the relation between the density of objects and their possibilities of floating (Siry 2011, pp. 1021–1023).

A critique that can be raised against many studies on children's conceptions, including the Piagetian studies, is the tendency to often focus solely on the children without taking the communicative situation and communicative processes into account. A different perspective is provided by Lev Vygotsky (1987), who highlights the significance of context and the pedagogical relation between the adult and child. An important concept in this tradition is the Zone of Proximal Development, that is, how a more experienced participant (adult or child) can support a learner to further his or her reasoning or problem solving. Conducting research in the Vygotskian tradition, Marilyn Fleer (1995, pp. 341–342) found it to be more critical to focus on concepts than procedures in communication with children in science settings and her study illuminates the importance of introducing children to conceptual resources in order for them to start becoming members of the problem-solving practices of basic science. In another study with a group of 6-year-old children (Åkerblom 2008, p. 100), they were invited to reflect on what they *meant* when they used scientific terms after being introduced to critical aspects of gravity and the movement of planets. The results illuminated the fruitfulness of using reflection to make sense of scientific phenomena, and also revealed that the children, while reflecting on their own language, became more aware of it. Another study conducted by Fleer (2009, pp. 1085–1086) examined how very young children develop conceptual understanding in science, drawing on Vygotsky's writings on everyday and scientific thinking. Fleer concluded that the scaffolding of children's understanding of science needs to include playful investigations of phenomena, as well as systematic exploration of scientific terms. Hence, her research highlights the importance of science education for young children to contextualize conceptual knowledge in playful activity, a point highly relevant to our present investigation.

Language and the way children express their knowledge has been shown to play an important role in the sense they make of scientific contents. For example, Joan Solomon and Sue Hall (1996) stated that language is vital for articulating the tacit and linking thought to action. Vygotsky (1987, p. 276) made a distinction between the *sense* of a word and its *meaning* and described sense as the sum of all psychological events in consciousness. Vygotsky considered that every concept has its own meaning and its own sense. *Meaning* could be called the semantic form of a concept that is closely related to what we call the culturally agreed on definition of a word. The *sense* of a word is the personal, creative aspect that "enriches" meaning, depending on the context of use. Meaning and sense are further connected to what Vygotsky referred to as scientific and spontaneous concepts (Vygotsky 1987, p. 366). Scientific concepts are mostly acquired in a school setting, in contrast to spontaneous concepts that are formed more informally during our everyday life. A scientific concept could be associated with meaning and everyday concept with sense.

Previous research on children's understanding of and engagement with chemistry

Studies on children's understanding and ideas about chemistry, specifically about water and the concept of matter, have often focused on pupils in primary and secondary school. After studying pupils' learning paths in case studies, Allan Harrison and David Treagust (2001, pp. 79–80) drew the conclusion that chemistry teaching should aim at an understanding that changes of the properties of a substance (e.g., taste or temperature) should be explained as a particular action (on a micro level). They distinguished three levels on which chemical concepts may be taught and learned: sensory, atomic/molecular and symbolic. They also concluded that learning of chemistry is a very complex process, which must be studied from a variety of perspectives. In their empirical investigation, with the aim of enhancing students' understanding; metaphor, analogy and models were used, but also discussed in detail with the students. This approach to teaching, according to Harrison and Treagust (2001) also made the students more interested and motivated to understand. In another study, Harrison and Treagust (1998) discuss the use of models in chemistry teaching. They argue that models can help to explain science concepts in familiar, visual and tactile ways. However, at the same time, models are arbitrary and can be misunderstood. They emphasize that models should always be discussed and negotiated and pupils be made aware that they are merely models with limits. Interesting questions are what happens as younger children interpret models or representations and whether the implications mentioned by Harrison and Treagust are relevant for preschoolers as well. Garnett and Hacking (1995) reviewed previous research on student conceptions of matter and identified what they referred to as misconceptions concerning, for instance, the size of a molecule (e.g., that it is possible to see molecules through a microscope), that matter is continuous, and that the reason for movements of atoms/molecules is that they are alive. Garnett and Hacking (1995) also discuss how many studies have reported the use of everyday language in a scientific context as a source for misinterpretation. They exemplify with the term *particle*, which in everyday language refers to a small piece of a solid substance, while the meaning of particle in scientifically accepted language would be atom, ion or molecule. Hence, the same term with different meanings in everyday and scientific discourse, respectively, may pose difficulties in understanding.

Although different kinds of water phenomena were not the primary in focus of the chemistry activity in the present investigation, such phenomena were often described by the children in the pre-interviews and could therefore be perceived as part of their experience base. Because of this fact, some previous research about children's understanding of such phenomena will be reviewed here. Russel Tytler (2000) made a comparison between how children from year one (between 6- and 7-year olds) and year six (12- to 13-year olds) understood the concepts of evaporation and condensation. He categorized the children's explanations of what happened with the water and called one of these categories "It's just like that" (Tytler 2000, p. 452). This category is not an explanation, but rather an acceptance of an event. Other categories were the *category of association*, where an association was offered as an explanation for the phenomenon, and a category where the children would speak of *the water cycle*. In the investigation, Tytler found that the children from year one often used association as if it was an explanation and together with this category, the water-cycle explanation was the most common. Tytler (2000, p. 464) concluded that even quite young children were capable of making sense of the water-cycle image. Tytler also points to the significance of narratives and everyday phenomena in framing children's interpretations. Varda Bar and Anthony Travis (1991) saw that young children would have a rather scientifically acceptable conception of boiling and about the change of liquid into gas. The children that were interviewed often used scientific notions like *vapor*, *mist*, *steam*, or *air*, but they used them with their own sense. In another study on children's conception of water phenomena, Bar and Galili (1994, p. 162) identified "stages in understanding" of evaporation and condensation: The stages were that *water disappears*, that *water is absorbed into surfaces*, that *water is transferred to another location*, that *water disperses into air*, and the idea of phase change. They also found that the children that had a conception of *air* as something were not likely to hold the first two ideas. Mesut Satkes, Lucia Flevares and Kathy Trundle (2010), who conducted semi-structured interviews with 22 children, examined how preschool children made sense of the mechanisms of rainfall.

They saw that most young children knew that rain is water, that it comes from the sky, and sometimes connected rain with clouds. How the children made the connection had to do with their conceptions of what clouds are made of: solid, made by water, containing water or made from smoke. Satkes et al. (2010, p. 543) claim that the difficulties the children had with explaining the mechanisms of rainfall had to do with the lack of understanding other aspects of the water cycle (like evaporation and condensation). The children's causal explanations tended to increase with age and many of the 6-year olds were able to understand the basic elements of the water cycle. Satkes et al. (2010, p. 544) also made the conclusion that children's previous experience of the phenomenon as well as cultural and geographic environment plays a significant role in their conception of the water cycle.

Theorizing concept formation

The theoretical point of departure for the present study is Vygotsky's theorizing on the formation of concepts. According to Vygotsky (1987), the motor for developing concepts lies in the dialectic relation between everyday concepts and scientific concepts (p. 169). Everyday concepts are something that children spontaneously create as they experience the world. When children express themselves, using their own concepts, they are not initially conscious of the function of these concepts, the relations being established later in more formal teaching activities (p. 214). Everyday concepts are rich with experience, contextual and practical associations, according to Vygotsky (1987). In contrast, scientific concepts are conscious and deliberate, generalized and with socially agreed meanings. Both ways of making sense of the world originate in encounters on the social plane but the concepts develop in different ways. Thinking and language interact at the moment when a verbal thought is formed. Following Vygotsky's notion, we are interested in how children of a preschool age make sense of water. In other words, we are looking for children's verbal thoughts about water. As the children verbalize their thoughts about water, they conceptualize it. In Vygotsky's view, a concept is a generalized representation of a thing (Vygotsky 1987, p. 170), implying that the aim of learning and teaching is to form bonds and relations between representation and reference. Vygotsky also argues that when a child acquires new words, they gradually become more and more generalized. "Functional meaning" plays a very important role in children's thinking (until the early school age). When asked to explain a word, the child will tell what word that the object designates can do, or—more often—what can be done with it (Vygotsky 1987).

Method

The present study is an investigation of how a group of 6-year-old children make sense of chemical processes and the concepts of water and molecule taught in an educational activity held at a culture center for children. The group of 22 children was enrolled in a preschool class, a preparatory year in the transition between preschool and compulsory school (see Björklund and Pramling 2014, for a presentation of this institution). All the children were interviewed before the activity about their conceptions of water, and 11 children were interviewed again a week after the activity took place. On that second occasion, the children were shown pictures from their visit at the culture center and were asked individually to recall the activity and their understanding of the purpose of the activity. The research was carried out in several steps: pre-interviews, chemistry lesson performed in the culture center (see below) and post-interviews. The lesson was planned and organized by the drama teacher in collaboration with the university chemistry teacher. The interviews were carried out by two of the researchers conducting the study.

All the interviews were conducted individually with each participant in a semi-structured way. The interviews were recorded and subsequently transcribed. Pre-interviews with 22 children from the preschool class focused on the children's conceptualization of water; more specifically, how they defined the concept of water and what they use water for. The children were also asked about what they meant when using some of the expressions. The pre-interviews lasted about 15 min each.

For the post interviews, 11 children were selected. Only the children showing an interest in speaking about water were asked to participate in the second interview. The post-interviews were divided into two parts. The first part of the post-interviews aimed to find out what the children remembered from the lesson. The interviewer asked the children to reflect on pictures taken during the lesson, focusing in more detail on the parts about molecules as dramatized (see below) at the culture centre. The second part of the post-interviews investigated to what extent the children had developed the concept of water after having experienced the lesson/performance on chemistry/water. These interviews were conducted 1 week after the lesson/performance and lasted between 10 and 15 min.

Ethical considerations

The ethical aspects and considerations of the study were handled according to current ethical principles for research (The Swedish Research Council 2011). The parents of the participating children had given their written consent for participation in the study. In addition and in accordance with the ethical guidelines for research as stated by the Swedish Research Council, every child was promised confidentiality, meaning that the names used in the excerpts are fictive.

Description of the lesson

In the activity, the core concept for the children to discern and learn was the *molecule*, introducing the water molecule as an example. The children were told that *everything consists of molecules* and there is no limit to how many times a substance may be divided. *Molecules exist even though they are not visible*, not even through a strong microscope. They have been around since ever and are *indestructible*, but they are *not alive.* There are *different types of molecules*. Besides water-molecules, the children were introduced to concepts such as *sugar-molecules* and *color-molecules*. Molecules *move* in coincidental directions and as they move they bump into other molecules and change direction. The *velocity* of the movement is a critical aspect that is connected to *temperature* and *form* of the substance. Molecules can be *mixed* and this process is dependent on the temperature. The activity was divided into four parts that we will refer to in the following way:

- Introduction
- Experience
- Experiment
- Summary

In the introduction, the water-molecule was enacted through embodied means by a drama teacher, as a figure with a red body (representing the hydrogen atom) and white cushions around the arms (representing two oxygen atoms), as well as in the form of a soft toy having the same colors, shape, mouth and two eyes, meaning that the parts representing oxygen atoms resemble the ears of the figure. The water molecule was also represented as a drawing with one white circle connected to two smaller read ones symbolizing the formula of water. In the experience-part, the children themselves were invited to represent water molecules and their movements in a molecule-dance that was filmed from above. In the sequence, the children wore blue caps and their teachers formed the sides of a glass with their bodies. In the film, the children moving looked like moving dots. In the same manner, the children enacted the solution of sugar molecules. Four children were asked to act in the role of sugar molecules and given red hats, while the rest of the children wore blue caps to represent water molecules. The children enacted the mix of sugar in water in low and high temperature. Also this activity was filmed from above. The mixing of sugar in water of different temperature was also carried out as experiments in three groups. A thermometer and green food coloring were used to measure the temperature of the water and to visualize the mixing process, respectively. In the experiment part, the mixing of sugar in water of different temperature was carried out as experiments with the children divided into three groups. A thermometer and green food coloring were used to measure the temperature of the water and to visualize the mixing process, respectively. The activity was summed up with a discussion with the children.

Findings: ways of conceptualizing water

In this section, we present the findings in terms of the three ways of conceptualizing water, analytically identified in the data. Each category is introduced, and reported through analysis of excerpts from the interviews. Each category is also discussed in relation to findings from previous research. The excerpts have been chosen to illustrate the categories, but the categorizations were based on the entire corpus of interviews. The distribution of cases in each category is presented in Table 1.

Water conceptualized in everyday terms (7/22) The children placed in this category do not indicate that they have reflected over water, or realize that water could be thought of as "something". When they are asked about their experience with water, they focus mainly on the function or how it appears: Water is something you *drink*. They also seem to find it difficult to speak about water. This category of answers resembles the category of explanation identified by Tytler (2000) when asking preschool children to explain evaporation and condensation. He named the category *it's just like that*, after the way the children reasoned. But there could be a number of other reasons for the children's apparent reluctance to speak to the researcher, such as shyness.

Table 1 Distribution of conceptions among the categories

Conceptions	Number
Water conceptualized in everyday terms	7
Water conceptualized in terms of lived experience	13
Explored generalized science	2
Total	22

Examples from the transcripts:

Interviewer: What is water?
Anna: Something that you can drink.
Andy: I don't know, I never thought of it.

Interviewer: What is water made of?
Andy: It is made by nothing; it is just made by water.

Water conceptualized in terms of lived experience (13/22) The children indicating conceptions of water categorized in the second group, when compared to the answers represented in the first category appear to be more motivated and interested in elaborating on their thoughts. Water is perceived as something in the surrounding world, which could be experienced in a variety of ways. It is spoken of as something you can drink, which overlaps with parts of utterances represented in the first category, but in addition, they speak about their embodied experience of water. The children speak of the properties of water on a macro level and about the function of water. This category shows similarities to another category identified by Tytler (2000), where *associations* were used as if they were explanations. The chemistry content in the excerpts representing the second category of the present study is expressed as verbs and concern phase change, mixing and the water cycle. Although most children are not familiar with the concept of chemistry, when asked to guess what it means they speak of it as some kind of activity. When Bea is asked about the properties of water, she answers: "Water is opaque, it may be deep and salt in the sea, it can fall in a waterfall, but also as rain". Ben speaks of the changing properties of water: "It looks blue but it can be green. Water is sometimes cold and sometimes a bit hot. Water in the tub feels super-hot but in the sea it feels super-cold". He also comments on the taste of icicles, saying "icicles taste like water". Bo, below, is asked what water is made of, when he says that he does not know he is encouraged to "guess":

Bo: Cloud?
Interviewer: Cloud…yes, can you tell me how you mean?
Bo: The clouds soak all the water and then drop it down.
Interviewer: Yes? What is it then, when it falls down?
Bo: Raindrops…

When asked to elaborate he says: "The clouds soak the water and then it rains down like raindrops". Later in the interview, Bo mentions *steam*:

Bo: The cloud has soaked a lot of water… Then it has soaked a lot of steam.
Interviewer: You said *steam*, what's that?
Bo: It is sort of when it becomes really warm then… A little bit of water is transformed to steam that can… that rises. So water is rising instead of going downwards.

Barbara is asked what water is made of and answers:

Barbara: Water is made of oxygen.
Interviewer: What is oxygen?
Barbara: Something you breathe, you breathe air!
Interviewer: You mean that oxygen is in water?
Barbara: Yes!

She shows awareness of the chemical level of water and knows that water, in some way, is made by oxygen, but she does not exactly know in what way. When asked about chemistry and what the word chemistry means, the children in the second category say that they do not know, but when asked to guess, some of them say that it is like stirring, mixing or making experiments with water, suggesting that they use the notion of chemistry as a pseudo concept, which means that they can give several examples of (doing) chemistry but without being able to generalize what is common to these activities (cf. Vygotsky 1998, p. 59). To conclude, the children whose utterances are represented in this second category indicate that they have rich experiences of water and when invited to elaborate, they develop ideas on a more abstract and conceptual level.

Compared to the children in the previous categories, the two children in the third category, *Explored generalized science (2/22)*, have more elaborated ideas about water, ideas that they use to make sense of the physical world. They speak about water as an observed phenomenon and of different ways to explore and understand this phenomenon, similarly to the children in the previous category. I In addition, they show an awareness of the micro-level of water. When one of the children, Carla, expresses her idea about what water consists of, she calls it *monopoles* although she shows awareness that it might not be the right word. Hence, the children in this category also indicate a certain linguistic awareness about the terms they use to speak about water, chemistry and molecules. When asked about chemistry, Carla speaks of the phenomenon of *surface tension* using the correct term:

Interviewer: Do you know what chemistry means?
Carla: Chemistry is surface tension.
Interviewer: How do you mean?
Carla: Chemistry makes the water striders float.
Interviewer: The water striders float? What are water striders?
Carla: They are small animals living on top of the water. They have small feet and glide on the surface tension. When the surface tension disappears they go down from the water…

Chris speaks about the *forms* of water:

Chris:…water can become different forms.
Interviewer: Yes? How is that?
Chris: It can become steam, or ice.
Interviewer: Or ice…, is it water then?
Chris: Mm, it is different things that water can become sometimes. If it is cold enough, water becomes a… to a… to ice and if it is warm, then water can become steam!
Interviewer: So, the ice out here, is it water? [The interviews were carried out on one of the first days of winter, with snow on the schoolyard]
Chris: It is frozen water!
Interviewer: Frozen water? How does that happen?
Chris: Because it has become… It has become cold enough for it to freeze and then it turns into ice.

He also tells the researcher about how he makes experiments:

Chris:…sometimes I use to make experiments.

Interviewer: So you make experiments? Can you tell me more? What kind of experiments?
Chris: I experiment a little bit, with water to see how it can be with water and, and how it can't be with water, so that I can examine with it.

When asked about chemistry he answers "chemistry is when you make questions".

The different ways of making sense of water, illustrated by the children's utterances in the three categories, can be described as going from the level of sensory experiencing of water and its properties, to gradually developing a more generalized concept of water. As water is discerned as something in itself, it is also possible to speak about it, using pseudo concepts (cf. above). As Vygotsky suggests, to clarify a concept is an intellectual operation that is much harder than expressing what can be done with what the concept refers to. Instead of explaining what the concept designates, in this case the concept of water, the children explain its properties or what can be done with it (cf. Vygotsky 1987). There is a significant difference between the children's abilities to define the concept of water, when asked about it, and to describe its functional meaning or its properties, with most of the interviewed children automatically proceeding to reason about the functional meaning of water.

What did the children learn from partaking in the chemistry activity?

Post-interviews were conducted with 11 children (see method), using pictures taken during the teaching activity as a mutual points of departure. The children were asked about what they remembered and they were supposed to reflect upon the pictures taken during the chemistry lesson, with the aim to explore what opportunities helped the children develop concepts in chemistry and how they responded to these opportunities. In the post-interviews, all the 11 children use the expression *water molecule*, but in quite different ways and with what seem to be different senses. They are also able to elaborate on the connection between the movement of water molecules and temperature, as exemplified in the following excerpt where Andy is shown pictures in which the children act as water molecules:

Interviewer: …I have another picture here, where you can see even better… what are you doing there?
Andy: Playing water molecules too.
Interviewer: Ah, yes… what happened then, when it was cold, how did you do then?
Andy: Then we did slowly.
Interviewer: Then, as it became warmer and warmer, how did you do then?
Andy: Fast!

In the pre-interview, when Andy is asked what water is made of, he answers "It is made of nothing; it is just made of water", but in the post-interview he shows an awareness of a connection between water and water molecules. When Andy is asked what a water molecule is, he answers "they are things that are in water" and that "water molecules could be found in the sea". Thus, he is using a culturally prevalent form of metaphor—a so-called container metaphor (Lakoff and Johnson 1980)—according to which molecules are *in* something, in this case water, rather than making up that substance. There was a variation between how the children conceptualized the water molecule. The following utterance from the interview with Bill exemplifies shifting between (perhaps conflating) different levels of description: molecules *are* (round balls) and molecules *resemble* (Mickey Mouse). It further appears that he conceptualizes molecules as being alive and having the properties of being blue and soft:

> Bill: They are such round balls, although they resemble Mickey Mouse.
> Interviewer: Why is that?
> Bill: Because they live there and make the water blue.
> Interviewer: How?
> Bill: Because they are soft, really soft.

Bo answers in the following way:

> Interviewer: Water molecules, what's that?
> Bo: Hm… water! Blue caps since water molecules are blue. Just like small drops of water, only tinier.

The two children, who in the pre-interviews spoke of water in a generalized way, are also able to use the notion of water molecule as a scientific concept, like Carla below, who also remembers and corrects her own previous utterance:

> Carla: I remembered that I told you the last time that it was water *monopoles* but it was water *molecules.*
> Interviewer: It is just water molecules that are…
> Carla: …no, there are sugar molecules, apart from that I don't know much more about molecules. There is a molecule in us that has been in the dinosaur, so there might be a water molecule from a dinosaur.
> Interviewer: Do you remember where we can find molecules?
> Carla: In the air, air molecules. And if water starts to boil it turns to mist that goes up in the air. They can go up there in the clouds and then they rain down.

Carla is aware that she knows just a little bit about molecules and that there might be more to know. In doing so, she identifies a learning gap, something that can be particularly productive when trying to learn more. She understands that there are different kinds of molecules, what she refers to as sugar molecules and air molecules, and that there can be water molecules in the air as well. Also Chris understands that there are many kinds of molecules and that they are incredibly small:

> Interviewer: What is a molecule?
> Chris: A molecule is a little, tiny, tiny, tiny, tiny, tiny… tiny, tiny part of something.
> Interviewer: Of what? What can it…?
> Chris: …of anything!

When Chris states that molecules are parts of anything, he is generalizing over a set of cases and uses the notion of molecule as a concept proper (Vygotsky 1998, p. 60).When asked about the purpose of the chemistry activity, the children give answers that were qualitatively different. Some of the children focus on what they had seen, played and experienced; like the children below, describing what they had experienced rather than giving explanations:

Berta: I liked to be there and watch, sit and watch and see. We were watching those, water molecules, sugar molecules!
Bekim: We looked at theatre with Karl-Berit! [i.e., the enacted molecule, see description of the lesson above]
Bim: We played that we were a glass of water!

But the two children from the third category answer in a qualitatively different way, focusing on the chemistry content of the activity; Chris saying that "we made chemistry tests" and Carla stating that "We spoke about chemistry."

When asked about what happened in the chemistry experiment carried out during the lesson, many children speak mainly about the green color, here exemplified by Bill:

Bill: They squirt out green.
Interviewer: Why did they do that?
Bill: Because they, they wanted to see, all the children to see that it was green.
Interviewer: What happened with the green?
Bill: It became green.

Some of the children, like Bim in the excerpt below, express the awareness of a connection between temperature and how the green color behaved:

Bim: She is testing how warm or cold the water is.
Interviewer: What did you do then?
Bim: We put in some candy color.
Interviewer: What happened with the candy color?
Bim: In the cold glass they move slowly and in the warm glass the candy color moved quickly. The cold was a bit lighter and the warm was dark.

Another child, Chris, is able to speak about the molecular level in the experiment part:

Interviewer: Do you remember something else from the experiment you made?
Chris: That we mixed a lot of molecules. Water with sugar molecules and sugar molecules mixed with water and then sugar molecules with water. And candy color, candy color molecules were mixed together.
Interviewer: What happened with the color?
Chris: Then it became green.
Interviewer: And what did that mean then, when it became green?
Chris: That it had spread. And it, like water… the water was cold, then it formed like a beam, down… but when it was warm, then it became almost like a cloud… then it became almost like smoke.

Inferring from the excerpt, it seems that Chris understands the purpose of using the candy color in the experiment, which was to show that sugar dissolves faster in warm water due to the rapid movement of the water molecules and slower in cold water due to the slower movement of water molecules. He understands that the shapes of green color in the water show where the sugar molecules are, forming a "beam" in cold water and a "cloud" in hot water, using these metaphors as parts of his explanation. In the end of the post-interview, the children were asked about water again, in the same way as in the pre-interviews. Three of the 11 children answer in the same way as they did before the intervention, like Barbara:

"Water is blue and fun to play with, water is blue when it is cold…", speaking about her former experiences with water on a macro level. Nevertheless, all the other eight children in the post interview mention that water "is made of water molecules", which is something that suggests they had developed their conception of water and/or that they interpreted the questions differently after the activity.

Discussion

The present study aimed at exploring what conceptions of water, molecule, and chemistry the children convey before and after participating in a playful dramatization of chemistry, and if the children's conceptions change from before to after participating in the lesson.

If pooling the children's reasoning, based on the pre-and post-interviews, the result can be used to illustrate the nature of appropriation (James Wertsch 1998), that is, how children develop their use of concepts in order to generalize experience on a more abstract level, making sense of chemical concepts and processes. In the nature of this process, and in the case of the appropriation of scientific concepts, children first learn that there is something that is called 'molecule' (or "monopoles", as it may be) and then may be able to give first one, and then several examples of this, before developing the ability to understand the concept in the abstract (i.e., irrespective of any particular example). We found that the experience and conceptions that the children had before the activity were closely related to what they discerned in the activity.

When it came to the notion of water, most children could discern water as something and describe properties of water in terms of their first-hand experiences before the chemistry activity. They spoke about water in different ways, but all with a focus on its concrete functions and properties, as everyday/spontaneous concepts rich with experience, contextual and practical application (Vygotsky 1987). However, two of the children, Chris and Carla, would use the concept of water in a more scientific way, speaking about what the concept means, and showing an awareness that there is an explanation to phenomena such as forms of water or surface tension; they also use language in an expansive way that transcends the local contexts of the lesson and the interview, respectively. Chris even explores the phenomenon of water by staging experiments to find out "how it can be with water and how it can't be with water" (see above) in making sense of his experience. In the transcripts, there are many examples of the children using scientific expressions as pseudo concept (Vygotsky 1998), that is, when they know that the word they use denotes something, and may be able to give several examples (of molecules), but it is not clear to them what it exactly means, what is the common conceptual basis, of these examples. One example is Barbara's use of the expression *oxygen*, or when Bo speaks of *steam* in both interviews, having an idea about what context they fit in, and expressing a vague idea about what they mean. Carla is approaching a scientific understanding of the concept of molecule, but still claims that she realizes that she does not know enough about molecules, thus identifying a learning gap, which shows that she is able to speak about her own understanding on a meta-level. Being able to speak on this meta-level has been shown to be very productive in children's learning (e.g., Åkerblom 2015).

The same development can be seen in the post interviews in relation to the concept of molecule. Most children indicate that they had not heard the word before the activity, but afterwards they were familiar with the notion of molecule, as evident either by them spontaneously mentioning it themselves or in responding to a more direct question about it. However, for some of the children, molecule denoted something very concrete, contextual and practical that they conceptualized in everyday terms, taking the metaphoric representation at face value, like the water molecule having properties such as being blue or soft. After having experienced the lesson at the culture centre, the children showed that they had grasped the points made in the part we named Experience part. This was the part where the children themselves acted as molecules and experienced being either a water molecule or a sugar molecule in a glass of water. The aim of this activity was to highlight the relation between temperature and the speed of molecules. In other words, all the children realized that the speed of molecules is connected to temperature. However, there were some ideas, often discussed as alternative conceptions, regarding the properties of molecules that were unintentionally supported during the Introduction and the Experiment part of the lesson. Also, in order to make basic science applicable to the children, an actor impersonating the water molecule was used to playfully connect to something known and attractive to the children. Many children appreciated the figure and said that it was funny when "she pretended to be a water molecule", which indicates them being aware of the metaphoric/representational dimension. Presenting chemistry in such a playful mode could probably enhance children's positive feelings towards chemistry, but at the same time, as explanations of chemical processes or about properties and function of the molecule as such, the presentation might have added to the children's confusion, and, as we have already mentioned, fostered what is often referred to as misconceptions, since the cues about how to actually interpret the dramatization were not very clearly given. There is an inherent tension at play in early childhood science education, since scientific procedures and forms of explanations need to be rendered in a form that is true both to scientific knowledge and to what makes experiential sense to young children. As Andersson and Gullberg (2014) point out, on some occasions, children's feelings of joy and participation within a scientific context might also be an adequate goal. Hence, there may be other goals with early childhood science education than only the development of children's conceptual understanding.

Some implications for teaching emergent chemistry

Since there is no linear relation between teaching and learning, what sense children make and what they remember from participating in teaching events are open and empirical issues that we need to know more about. In this study, some points that have implication for teaching emergent chemistry were highlighted. For instance, we see that it is possible for children to hold and develop complex and rich ideas and concepts, and if children are seen as resourceful and their thinking as rich and diverse, teaching will be manifested differently than if children are positioned with deficient thinking skills. The role that everyday experience of phenomena play in conceptual development, as understood from a Vygotskian perspective (Vygotsky 1987), imply that children in early years should be provided with opportunities to make such experiences in different fields and be supported in reflecting on these experiences. How to facilitate children making sense of the world, including developing concepts, through playful dramatization, is still an open and challenging question in need of more research. Some questions for further research are whether the patterns here identified are consistent with other groups of children, differing in experience, and whether the understandings developed by the children participating in dramatized activities remain over longer stretches of time. Presumably, having made sense of what was experienced, children would be expected to show these insights over longer time; however, whether this is really so is an empirical question for further research. Finally, and arguably, there is more to learning science than appropriating facts; particularly with young learners, finding ways of engaging them in and becoming interested in and aware of scientific perspectives, may be even more important. Dramatizing appears to be a productive approach to foster such awareness and engagement in young children.

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