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Article

Preschool Class Children and Grade One Pupils' Questions about Molecules from a Digital Interactive Session at a Culture Center in Sweden

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Abstract: This study focuses on preschool class children and grade one pupils' questions about the natural sciences. The article presents the questions that preschool class children and grade one pupils asked via a chat function in connection with a digital interactive lesson about molecules arranged by a culture center in Sweden. The results of the thematic analysis are discussed in relation to their didactic implications for natural science teaching with young learners. The most relevant conclusions are that children drew from their own experiences when approaching molecules, they could generalize their experiences and apply them to other contexts, and they needed time to process the content and then ask questions. Therefore, the authors suggest the use of children's questions as a useful pedagogical tool for helping young children understand abstract concepts such as molecules. Furthermore, follow-up interviews with children are suggested as a means of mapping the origin of such questions.

Keywords: preschool class; chemistry; questions

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1. Introduction

In Sweden, preschool education is provided by municipalities for children aged between one and five years old with an attendance rate of about 85% [1]. The Swedish preschool curriculum states as a goal that education at this level should "contribute to children developing an understanding . . . of simple chemical processes" [2] (p. 14–15).

Within compulsory school, there is a first year that is voluntary for children before they start grade one, known as preschool class or förskoleklass [1]. The Swedish preschool class curriculum states chemical phenomena as central content in the field of nature [3]. This study focuses on preschool class children (aged 6 years old) as well as grade one pupils (aged 7 years old) and the questions they posted about molecules.

Although preschool class is not compulsory, it helps prepare children for starting school. Such preparation is needed because of the differences between both stages. While play has a central role in the child's development during the preschool stage [2], school has more structured teaching that aims for the child to achieve the criteria for assessment in each subject in each course [3]. It is also known that if a child encounters a major difficulty during the transition period, this can have a negative impact on the child's learning and development [4]. Hence, supporting the transition from preschool to school is important [5].

From a cultural–historical perspective, play has a key role in the mental development of a child [6]. Children continually move between reality and imaginary situations in play, and this builds their capacity for thinking with concepts in science [7]. In the same way that children combine their prior experiences into a new concrete situation through play, science can also be conceptualized as an imaginative act [7]. For example, although children

cannot see molecules, they can be introduced through a dramatization in which an actor is dressed up and behaves as a water molecule and moves at different speeds depending on temperature.

However, since the project took place in the middle of the COVID pandemic and followed the guidelines of the health authority that recommended avoiding physical contact with the participants [8], the only possible way to collect data was using digital technology. Therefore, this article can only present the questions that the children asked via a chat function connection with a digital interactive lesson about molecules arranged by a culture center in Sweden.

2. Previous Research

2.1. Children's Understanding of Molecules

Although molecules are central content in chemistry education, it has been shown that preschool children struggle to understand the submicroscopic level, which they cannot see [9]. How children understand such an abstract concept is an important prerequisite for teaching, guiding how teachers can support children in their emerging understanding of concepts. Åkerblom et al. [10] studied children's understanding of water and chemistry before and after participating in a drama activity focusing on the water molecule in a children's culture center. The study noted that the children showed different qualitative understandings of the water molecule. The children understand water in the following ways: through everyday understanding, their own experiences, and exploratory generalized understanding.

Within the category of everyday understanding, the children had difficulty expressing what water is. The children reasoned about the function of water as something we drink or how water manifests itself. What water consists of was not something the children reasoned about, nor did the children make any connections between water and the molecule concept.

As for the category of children who give an account of their own experiences, where most answers were found, the children pointed to the function and properties of water. Here, the children reasoned that water is something that surrounds us and that exists in different variations.

Finally, within the exploratory generalized understanding category, water is understood as something that can be studied, and the children's responses reflect refined ways of explaining the material world. Here, the children reasoned about the components of water and described, as in the previous category, water in different forms. What distinguishes the children's answers here is that they use scientific terms and show an understanding of their meaning, for example, about water's surface tension (when a child explains how water striders can float above the water's surface).

Overall, the children's understanding of water moved from being experienced sensuously to a more generalizing way of understanding.

Åkerblom and Pramling [11] analyzed how six-year-olds reasoned about their experiences and how they understood the content after participating in a drama activity focusing on molecules at a culture center. The starting point for the project was to see how the children manage the relationship between imagination (as if) and scientific content (as it is). Between these poles (the world "as if" and "as it is"), a tension field was described, which the children dealt with by reasoning in different ways: pretending to be molecules, using familiar phenomena such as similes to reason about things that are challenging, coordinating "as if", but also taking part in what the drama teacher imagines. In summary, Åkerblom and Pramling [11] found that the children used linguistic resources that they could master at the time, such as similes, to approach the scientific content, which would otherwise have required other linguistic resources to reason about. The researchers discuss the children's navigation between "as if" (the fantasy used in the pretend world they use in their play and stories) and "which it is" (the real world they perceive through their senses in reality) in the same way scientific phenomena that children experience through their senses need to be described in a manner so that children can actually understand them. Since

most of the articles are in Swedish, three references from English-speaking publications that have addressed similar topics can be found in the following references: [12–14].

The above results show that molecules as content can be understood in qualitatively different ways by younger children. After participating in a drama activity, children approach this scientific content by reasoning with the help of different linguistic expressions, such as similes, which take place in the tension field between fantasy and reality. Therefore, children's linguistic expressions in different forms can act as a kind of guide for how they approach or understand content. Children's questions can be considered a form of such linguistic expressions and, regardless of the "teaching form" (whether it is a digital lesson or a drama activity), constitute a prerequisite for teaching. It is also relevant at a time when teaching takes place through digital forms to investigate how children perceive different content and what questions they ask about the content because there may be differences compared to learning taking place without a digital interface.

2.2. Children's Questions as a Starting Point for Teaching

The questions that teachers ask in science teaching to develop children's understanding have been the subject of research [15,16]. Conversely, children's questions, as a starting point for science teaching, can be significant for children's meaning-making and understanding of the content. Within the Swedish preschool context, Thulin [17] investigated what kind of questions children (3–5 years old) ask during an activity as part of themed work about what soil is and how soil is created. Of the over 200 questions asked, the study shows that children most commonly ask the following questions:

- Questions related to the content (173 questions: about doing something with the content, about knowing something about the content, about understanding something about the content, about relating the content to their own or common experience, about being involved in the content).
- Questions related to tools (22 questions: about getting to use tools, about understanding how to use tools, about sharing tools).
- Questions not related to the content (11 questions).

Furthermore, the children's questions increased the longer the theme work went on, which can be understood as the children "...need to be introduced to a field of knowledge, be able to relate experiences before they can ask questions about it" [17] (p. 36). In summary, Morais et al. [14] shows that most of the children's questions relate to content (knowing something about the content) and processes (doing something about the content). Children's interest in learning about content is of didactic importance for various reasons. This has consequences for teachers' didactic choices both before and during science teaching. It is also significant from the children's perspective to know about the children's (pre)understanding of the content.

In another project with a focus on ecology, Halvars [18] investigated how preschool children ask questions and create meaning in encounters with trees. The project, which used an exploratory working method, lasted for a school year, in which 28 children and three preschool teachers participated. In encounters with trees, children make connections to their own lives (for example, the family circle), their own bodies (based on form and function), the trees' internal and external systems, living conditions for animals that are around the trees, and how the trees communicate. This study also makes visible content-specific aspects, where the children mostly relate to the content based on their own experiences.

Hansson et al. [19] compiled children's questions and situations as potential science learning situations. This was carried out within the framework of the "preschool upgrade", which includes qualifying courses for teachers in many subjects and school forms such as science, mathematics, technology, or reading techniques, as well as special teacher training. In this case, the participating preschool teachers themselves identified situations and children's questions. A total of 295 questions with chemistry and/or physics content were found. Of the 295 questions, 107 questions/situations had potential chemistry content, and 209 had potential physics content. In terms of chemistry content, most questions/situations

dealt with various substance and material properties or phase transformations. There were also questions/situations about chemical reactions.

Overall, the studies above point to children's questions as a starting point for science teaching. Children's questions can be seen here as linguistic expressions of children's perspectives, which science content interests them or how they understand and approach science content. The children's questions, after being interpreted, can function as a didactic tool for teachers' planning and how they can challenge children through teaching.

The purpose of this article is to study preschool class children and grade one pupils' questions during a digital interactive chemistry lesson and to categorize them to later discuss the didactic implications for science teaching at this stage.

3. Method

3.1. Data Collection

In May 2020, during the ongoing COVID-19 pandemic, a culture center located in a major Swedish city broadcasted an interactive lesson digitally via its website. The content of the lesson consisted of the following elements:

(a) A transmission of a pre-recorded dramatization on the theme of molecules (gestalting, a molecular dance, and an experiment). Drama educators from the cultural center acted in the dramatization, where they pretended to be solid, fluid, and gaseous water molecules and moved at different speeds as the temperature increased [10].
(b) A chat function where the participating preschool classes/schools could ask questions. The chat function ran throughout the entire broadcast.
(c) A review where chemists from a technical university answered the children's questions that had been asked in the chat.

The natural science content for the lesson was molecules, and previously, the lesson had been given on location (IRL) for interested classes in collaboration between a cultural center and a technical university. The interactive lesson given on site is usually offered for preschool children and for grade one pupils.

What makes this intervention unique in comparison to other instructional films about molecules is its multimodal format. Children are first introduced to molecules through a dramatization in which a person acts as a water molecule. Then, the children are asked to represent a water molecule in a solid, liquid, and gaseous state, moving at different speeds according to the temperature. Finally, the children observe through an experiment how a sugar cube melts faster in hot water than in cold water, and the same happens with food coloring.

Around 515 classes were registered for the lesson, consisting of 13,499 children and 1321 teachers from preschool classes and grade one classes from different parts of Sweden, amounting to a total of 14,770 participants. In connection with the lesson, questions could be asked in the chat. Since the children could not type the questions themselves, they raised their hands, and their class teacher typed the questions they asked one at a time in the online chat. The questions written in the chat constitute the total collected material for the study, which unfortunately shows that not all the classes asked questions. The questions formulated in Swedish were translated into English by the second author and then checked by the first and third authors.

In this study, unfortunately, there are no data about whether the questions arose during the lesson and/or as part of the science teaching in the participating classes. The same applies to whether the children formulated and/or wrote the questions themselves in the chat or with the help of the teachers. The recorded questions can therefore be seen as expressions of what the children (group) wanted to know more about regarding molecules in connection with the digital lesson. Thus, the questions asked are an "active" document that represents the children's existing perceptions and thoughts about molecules. Asking questions can be seen as part of the children's sense-making about the content of "molecules".

3.2. Ethical Considerations

The Swedish Research Council's [20] good research practice guidelines were followed. The participants were informed that the activity was connected to research purposes, and by signing up for the virtual session, they consented to participate in the study. The identities of the students formulating the questions have been kept anonymous since the data collected did not provide names at all. The objective of the research was to build knowledge about natural science didactics within the field of chemistry.

3.3. Data Analysis

In order to understand the meaning of the children's questions and what it is the children wanted to know more about regarding molecules, the children's questions need to be interpreted. A thematic analysis was used as an analysis method. Säljö [21] wrote that this method is suitable for distinguishing and analyzing different patterns or themes. The different themes must capture something valuable in relation to theory and the research question/s, and this method can be used based on different theoretical frameworks.

As the children's questions were asked in a digital interactive context, these are discussed in relation to a sociocultural perspective [22], which regards learning as social, where different participants interact with others in a specific context. Through interaction with others, for example, knowledge and ways of thinking are shared. Knowledge of molecules is potentially increased by taking part in the content of the digital lesson. The digital lesson constitutes the specific context in which the participants (children, teachers, researchers, drama pedagogues, the content) communicate through the chat and the questions that are asked.

Artifacts are cultural products that humans have created and are important tools for interaction. Through these, knowledge is transferred or mediated to the participants in a specific context. Artifacts can, for example, be linguistic, mental, or digital [22]. The children's questions can be seen here as linguistic artifacts and the chat as a digital artifact. The concept of "molecules" is a mental artefact that is significant for teaching chemistry. These artifacts enable the participants to interact and knowledge to be (re)created in a specific context. Through the content of the digital lesson, knowledge about molecules was mediated, and the questions asked in the chat mediated knowledge about the children's understanding of molecules.

4. Results

The questions were recorded in the order that they appeared in the chat. After the broadcast, an excerpt was also provided with all the questions asked in the chat by the person in charge of the cultural center. In this way, a double check took place so that no questions would be overlooked. In the chat, the name of the school and/or the teacher and the question itself appeared. The school/teacher's name was initially included to ensure that no questions were missed, but was then deleted and does not appear in the results presented. If the same question was asked several times, it was only included once, generating 53 different questions.

Afterwards, each question was summarized in terms of content. Upon repeated reading, questions dealing with similar content could eventually be sorted under the same subtheme. The subthemes were compared with each other and arranged according to different content themes. Finally, six different themes crystallized: *the origin of molecules*, *molecules and their properties*, *molecules as constituents*, *reactions and interactions of molecules*, *molecules and science,* and *other questions*. In the next step, these subthemes were sorted.

4.1. The Origin of Molecules

The theme summarised in Table 1 includes a small number of questions. These questions can be interpreted as having an ontological and causal nature, where children want to know more about the background of molecules and what caused their creation. Based on these questions, we conclude that the children relate to molecules as part of the

universe and try to understand their place in the universe historically (from the beginning, where do they come from) but also what causes their emergence (how do they appear, how are they born, how are they created). Most questions begin with the question word how.

Table 1. The origin of molecules' theme, subtheme, and examples.

Theme	**The Origin of Molecules**
Subtheme and examples	Background and becoming - How are molecules born? - Where do molecules actually come from? From the beginning? - How did water molecules appear? - How long have molecules been around? - How are molecules created?

4.2. Molecules and Their Properties

Within the theme on Table 2 are the second most frequently asked questions. These questions focus on the classification of what molecules are based on, as well as what properties molecules are assumed to have. The questions indicate that the children want to understand the nature of molecules. The questions asked about their properties concerned their weight, size, appearance, and structure. They can be summarized as having a comparative and measurable character, and these too usually begin with how to obtain answers to how molecules are made up; for example, questions beginning with "How much weighs…" and "How big…" were asked. These questions can be understood as the children relating to molecules through ideas and experiences connected to their own world, for example, whether they eat or get sick. In summary, the questions within this theme are about arranging, defining, comparing, and determining the nature of molecules based on their different properties; "are they alive or are they a thing?" and "are they red…?" are some of the questions asked.

Table 2. Molecules and their properties' theme, subthemes, and examples.

Theme	**Molecules and Their Properties**
Subthemes and examples	Taxonomy/classification - What are molecules? Are they alive or are they a thing? - Are there sickness molecules? Weight - How much does a molecule weigh? - How much does a sugar molecule weigh? Size - How big can a molecule be? - How big is a molecule? Are there different sizes? - How big is a glass molecule? Appearance - How do air molecules look like? - Are there other-colored molecules? - Are water molecules red for real? Structure - Can we take a molecule? - Why do molecules not have a brain? - How can water molecules go up and down? Vulnerability - Can molecules be sick? Nutrition - Do molecules eat?

4.3. Molecules as Constituents

The majority of the children's questions were within this theme on Table 3. The questions concern the relationship between molecules and the rest of the world and other things. The questions were about where molecules can be found, whether they are constituents of different things, and to what extent ("how many molecules. . .?") they can be found in different things.

Table 3. Molecules as constituents' theme, subthemes, and examples.

Theme	Molecules as Constituents
Subthemes and examples	Constituents - Are there water molecules in everything? - Are there molecules in the molecules? - What is a sugar molecule made of? - Are there molecules in all the liquids? Object - Does light consist of molecules? - Are there molecules in pencils? - Are there molecules in computers? - Are there molecules in paper? - Are there molecules in glass? - Is lava a molecule? Living things - Do flowers also have molecules? - Are insects made of molecules? Which ones? - Are bacteria made of molecules? Body - Does sweat have water molecules? - Does COVID have molecules? Space - Are the molecules all over the universe? - Are there molecules in space? - Are there molecules in black holes? - Has the vacuum no molecules? Physical phenomenon - Does energy consist of molecules? - Does electricity consist of molecules? - Does light consist of molecules? Quantity - How many molecules are there in a sugar cube? - How many molecules are there in the body? - How many molecules are there? - How many water molecules are there in the world?

The question "Does light consist of molecules?" is represented under two different categories, as it is difficult to know which "kind" of light the children were referring to (whether they meant a candle or, for example, sunlight).

4.4. Reactions and Interactions of Molecules

The theme on Table 4 points to the children's curiosity about what happens when molecules come into contact with other substances or are even in different states. Within this theme, the children can be interpreted as having an ambiguous idea of molecules. In part, questions such as "What does it look like when the water molecules are mixed?" indicate an understanding that molecules interact with their environment and come into contact with other substances. In this sense, molecules are assigned an active role. In part,

other questions may point to the passivity of molecules when they are exposed to various actions. The following example can illustrate this: "What happens to the water molecule when we drink the water?" refers to an external influence where someone else's actions will affect the state of molecules.

Table 4. Reactions and interactions of molecules' theme, subtheme, and examples.

Theme	Reactions and Interactions of Molecules
Subtheme and examples	Contact with other subjects - What happens with water molecules when we drink water? - What happens to water molecules when we finish drinking water? - How does it look when we mix water molecules with sugar?

4.5. Molecules and Science

A few questions had a scientific focus and concerned how we acquire knowledge about the natural sciences, as summarised on Table 5. One question concerns how our knowledge of molecules can be guaranteed and has an epistemological character. The other question is more general and refers to one child wondering about the science of chemistry.

Table 5. Molecules and science's theme and examples.

Theme	Molecules and Science
Examples	- How do we know that there are molecules? - How does chemistry work?

4.6. Other Questions

The questions within the theme on Table 6 differ from the others, as they are of a practical nature and refer to the execution of the digital lesson. In summary, the content of the questions has an indirect relationship or a nonexistent connection to molecules. One of the questions concerns the props, for example, "the green" that is in front of the acting drama teachers, and the answer can be seen as important for understanding what happens during the lesson. Another explanation could also be pure curiosity about what "the green" is. The latter question can also be interpreted as the children knowing that there is usually a real audience during lessons in the cultural center. The children may thus seem to relate to previous experiences; possibly they have visited the culture center and seen various performances that are now part of the digital lesson.

Table 6. Other question's theme and examples.

Theme	Other Questions
Examples	- What is the green thing in front of you? - Are there students with you now?

5. Discussion

With reference to the purpose of the study, the children's questions show that molecules are a subject that interests the children, as most of the questions were about molecules. In previous studies, there have been similar results [17]. Both the themes and subthemes point to variation in the content of the questions. The questions illustrate different aspects of molecules; some of the questions are about understanding what a molecule is in order to use molecules to understand material things or phenomena. Only a few questions have a general science focus or do not relate to the lesson's content.

Like previous studies, the children started with their own experiences [10,18] when they wanted to know more about molecules. Here, this relates to the children asking

questions about molecules in relation to things they recognize (pencils, computers, light, sugar, glass) or to situations that they themselves have been involved in, for example, being sick or eating. Properties have also been shown to be a starting point when children reason about water molecules [10] or ask questions about chemistry content [19]. Also, in this study, the children asked questions about the properties of molecules, such as their appearance, weight, and size. The questions about properties seem to be a way for the children to classify what molecules are and relate them to other things they know. The properties function as a comparison between different things and phenomena. Furthermore, connections to one's own body [18] can also be seen, as some of the questions contained concepts such as the brain, sweat, coronavirus, bacteria, and sickness. In summary, the various connections (experiences, properties, the body) to molecules can act as a way for children to create connections between what they know and a possible new area to learn about. Asking questions thus functions as a tool to explain one's world.

Some of the children's questions specifically concerned the water molecule, while the rest were about other kinds of molecules or questions about molecules in general. The fact that the water molecule was depicted in the digital lesson could explain why certain questions concerned the water molecule. On the other hand, the questions that did not focus on water molecules in particular show that children can generalize their experiences and apply them in other contexts. In terms of teaching, this means that the water molecule is an excellent subject for challenging children's thoughts about what molecules are and how they form building blocks for the creation of various known things, materials, etc.

The children's questions are also of didactic value, as they show what interests the children and how they approach chemistry content. The different themes and subthemes summarize aspects of content that teachers can build their teaching upon, for example, when introducing different content. What the children ask for can also be a way to take part in the children's pre-understanding and conceptual understanding, as well as possible misconceptions. These are all equally important aspects of work dealing with natural science.

From a sociocultural perspective [22], the children's expression of what they want to know more about molecules can be understood as the children being knowledgeable participants in a scientific context. Their thoughts and questions are valuable building blocks in the creation of knowledge about important content regarding natural science. Asking questions is thus a linguistic tool for interacting with others about important cultural content in natural science. The chat functions as a receiver in the interactive context where knowledge is created between the different participants: on the one hand, the children (and teachers) who ask the questions, and on the other, the chemists who answer the children's questions. The chat enables interaction so that different ways of thinking about molecules are shared. As several different classes participated in the interactive digital lesson, this knowledge was spread between schools. The interactive lesson as a whole (dramatization, chat function with questions, explanations) constitutes a digital artifact that enables interaction where knowledge is distributed between different participants. Knowledge is thus not "static", but is created and re-created through questions and shared by many different participants (each within their own context).

Molecules are an abstract subject. This digital lesson can be a way of introducing and/or illustrating this abstract content through multimodal forms, corroborating how visual computer animations have previously been shown to help [23]. The digital lesson itself can be experienced as abstract because much of its content (dramatization, experiments) is pre-recorded. If the lesson had been given on site in the cultural center, the children could have "hands-on" experiences in, for example, the molecular dance (the movements of molecules at different temperatures). Instead, the children could interpret the content of the lesson digitally. Possibly, the children would have asked different questions if they had been there after acting as the molecules themselves or experimenting. At the same time, the chat, as a digital forum, enabled the various participants to gain access to other people's questions and ways of thinking.

In addition, the questions asked in the chat were answered orally (the vast majority of questions) and in writing (all the questions). That way, all classes could take part in the content. Even though the chat function was available throughout the broadcast, it still represents a limited amount of time to formulate and ask questions while taking part in the lesson. The children may have needed time to process the content and then ask questions. Research shows that children ask more questions the longer you work with an area [17]. Conversely, classes that have previously worked with this chemistry content may find it easier to formulate questions in the context of the interactive lesson. This generates new questions, which puts the focus on teaching: what understanding do the children have when they are to take part in digital "lessons", or in what way are the children's questions developed based on digital lessons? Based on a sociocultural view of learning, it is of interest to follow some classes more closely to study their interaction in the classroom and how questions are created during a digital interactive lesson.

Limitations of the Study

Although access to interactions between the teacher and the children is not possible because of the circumstances of the digital chat, which only allowed access to the online text, the fact that a high number of participants posted questions ensures that the data have a high level of reliability.

Unfortunately, no follow-up interviews with the children and their teachers were carried out due to time constraints. Nevertheless, access to these data would certainly enrich the analysis.

6. Conclusions

The results of the study can be summarized in the following three points: First of all, the children drew from their own experiences when approaching molecules. Secondly, the children were able to generalize their experiences and apply them to other contexts. Thirdly, the children needed time to process the content and then ask questions.

Therefore, the use of children's questions as a strategy for supporting young students' understanding of scientific concepts is suggested as a useful pedagogical tool. As pointed out by [24], it is not enough that children participate in science activities; their teacher needs to engage them in discussion and problem-solving situations to find answers to the questions posed that are meaningful for them.

A suggestion for future lines of research could consist of follow-up interviews with the children participating in the activity in order to expand on the children's explanations about their questions and try to understand where they come from.

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