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*Express letter*

# Exploring preschoolers' conceptions about the viscosity of honey

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**Abstract:** Fluids' viscous behavior is apparent in many everyday life situations, for example, in squeezing shampoo from a bottle or spooning honey from a jar. As a result, it is quite reasonable to assume that students develop (pre)conceptions to explain such phenomena even before they enter kindergarten or elementary school. As yet, however, empirical studies on children's conceptions regarding the viscous behavior of fluids are remarkably scarce. The present study aims to address this research gap on an exploratory level. More precisely, we conducted a qualitative interview study in which we explored the conceptions about the viscous behavior of honey among N = 6 preschool children attending their final year in a kindergarten in Hamburg (Germany). For stimulating the conversation during the interviews, an easily noticeable phenomenon in which the viscous behavior of honey can be observed (dropping two identical spoons into a honey-filled and a water-filled glass) was demonstrated to the participating children. In summary, the analysis of the transcribed interviews revealed three distinguishable conceptions of the children about the viscous behavior of honey: (1) The viscous behavior of honey results from its stickiness, (2) from its additional physical characteristics, and (3) from its use in everyday life. In this Express Letter, we present the design and results of our study in detail. Recommendations for future research in science education are outlined at the end of this paper.

**Keywords:** students' conceptions, preschoolers' conceptions, viscosity, preschool science education

## 1. Theoretical background and aim of the study

Since the late 1970s, a substantial body of research has been conducted that addresses students' or children's conceptions in science. Even though the term *conception* is not defined uniformly within academic literature [26], it is typically used within science education research to address underlying patterns in students' or children's explanations of scientific facts and phenomena [7, 32]. More or less, these patterns diverge from the scientific concepts that students should learn in school science lessons and, therefore, can hinder their learning progression [12, 24]. In addition, there is a common-sense notion in the educational research discourse that students' minds are not blank sheets of paper on which new information can simply be penned [4]. Instead, children possess various experiences of natural phenomena in their everyday lives and have specific preferences, interests, and attitudes regarding scientific issues even before attending kindergarten or elementary school [1]. As a result, children enter school science lessons with a variety of (pre)conceptions about scientific facts or phenomena that have been shaped by their day-to-day experiences [19, 24]. Beyond that, students' or children's conceptions in science are not always stable entities that have been formed over time in their minds. In fact, their conceptions sometimes arise ad hoc when students try to explain a given scientific phenomenon [24, 31].

Science teachers need to take these conceptions seriously, especially since, according to the model of educational reconstruction [10], they play a crucial role in developing and implementing learning opportunities within school science classes that truly support students in better understanding scientific facts or phenomena. Consequently, it is advantageous for science teachers to posses extensive knowledge about students' conceptions. Many conceptions that teachers are likely to encounter in the science classroom are well described in science education anthologies [3, 8], in textbooks for preservice teachers on science teaching [28, 32], and in topic-specific bibliographies or electronic databases [5, 9]. However, there is also a broad variety of these conceptions that science teachers encounter in their day-to-day teaching that have (almost) not been covered by science education research, especially conceptions regarding scientific phenomena that students frequently observe in their daily lives but that are (currently) rather subsidiary topics within school science education. One of these rather subsidiary topics is the viscous behavior of fluids [11]. Viscosity—as property of gases or liquids—is a measure of a fluid's resistance to deformation [13, 18]. Therefore, in everyday language, viscosity is also referred to as the "thicknesses" of a substance, since fluids with a high viscosity show a reduced flowability compared to fluids with a low viscosity (e.g., heavy oil vs. water). Given the fact that fluids' viscous behavior is evident in many everyday life situations (e.g., spooning honey from a honey jar or squeezing shampoo from a bottle), it is quite reasonable that students develop (pre)conceptions in order to explain phenomena of this nature. As yet, however, empirical studies on students' conceptions regarding the viscous behavior of fluids are extremely scarce. The only study we know of in this regard is the investigation by Faltin and Feser [14] on secondary school students' conceptions about the viscous behavior of fluids. In their study, the authors were able to identify four distinguishable conceptions that can be characterized as follows (for a detailed description see [14]):

1. Some secondary school students (erroneously) link the viscous behavior of a fluid to its density. In doing so, some students refer to a fluid's mass density, while others refer to its particle density.
2. Some secondary school students explain the viscous behavior of fluids as related to the fluids' ingredients. They argue that fluids exhibit a viscous behavior if they consist of specific (submicroscopic) components.
3. Some secondary school students relate the viscous behavior of a fluid to stickiness. They reason that "thick" fluids are often also "sticky" but are unable to explain this any further.

4. Some secondary school students explain a fluid's viscous behavior based on the extent to which it is compressed. They argue that, for example, if ketchup has been "heavily pressed" into a bottle, it is difficult to make it flow it out.

Since the students surveyed in this previous study by Faltin and Feser [14] had already received substantial learning experiences within science classes (at the time of the data collection, they were attending their ninth school year), it appears quite reasonable to assume that the above listed conceptions developed from both previous learning in the science classroom and from their everyday life experiences. In particular, the conception that a fluid's density or (submicroscopic) ingredients explain its viscous behavior includes facts about matter and its interactions that are commonly covered within the school science curriculum and that seem (not) to be properly understood by the surveyed students.

With the study presented in this Express Letter, we aim to add to this previous research. More precisely, we conducted a qualitative interview study in which we explored the conceptions about the viscous behavior of fluids among preschool children. In doing so, we investigated, on the one hand, to what extent the results of the study by Faltin and Feser [14] might be transferable to preschool children. On the other hand, we investigated whether additional students' conceptions could be encountered by interviewing children who have not undergone substantial learning experiences during school science lessons. Within our study, we focused on preschool children's conceptions of the viscous behavior of honey. This focus is based on the fact that honey is a fluid differing significantly from water or other everyday fluids (e.g., milk, juice) regarding its viscous behavior and that it is familiar to most preschool children from their everyday life. Therefore, it is, from our point of view, reasonable to assume that preschool children possess (pre)conceptions regarding the viscous behavior of honey.

## 2. Method

In order to address the research gap detailed above, our exploratory study was guided by the following research question:

**(RQ)** What conceptions can be inferred from preschool children's explanations regarding the viscous behavior of honey?

To answer this question, we interviewed a convenience sample of N = 6 preschool children attending their final year of kindergarten. All interviews were conducted in September 2021, and at the time of the data collection, all participating children went to the same kindergarten in Hamburg, Germany. Data collection was carried out in accordance with the legal and ethical standards for educational research in Germany [34]. All children were interviewed voluntarily and anonymously, and only if their legal guardians gave written consent to participate after they had been comprehensively informed about the aim and approach of our study. As detailed in Table 1, the sample includes four girls and two boys aged 4–5 years (∅ = 4.8 years; SD = 0.4). Moreover, the average duration of the interviews was 6.8 minutes (SD = 0.6 min).

The interviews were conducted with the participating children individually and took place in a separate room of the kindergarten. In order to stimulate the conversation at the beginning of the interview, an easily noticeable phenomenon of everyday life was demonstrated to the children, which allowed them to observe the viscous behavior of honey. As shown in Figure 1, two identical glasses were filled with water and honey. Subsequently, two identical spoons were dropped into the glasses from the same height. Therefore, in this demonstration the children could observe that as soon as the spoons were immersed into the fluids, they sank at different rates.

**Table 1.** Summary of the interviewed children

| Pseudonym | Gender | Age | Interview duration |
|---|---|---|---|
| Anna | ♀ | 4.5 years | 6.4 min |
| Eva | ♀ | 5 years | 6.2 min |
| Frederik | ♂ | 5 years | 6.4 min |
| Hila | ♀ | 5 years | 6.8 min |
| Lilia | ♀ | 4 years | 6.9 min |
| Max | ♂ | 5 years | 8.0 min |

After the demonstration, the children were asked to describe their observations in their own words. If their description referred to an observation other than the slow sinking of the spoon in the honey-filled glass, their observation was valued by the interviewer and the demonstration was repeated while asking the children to watch it again and to check whether they observed anything else. Once the children stated that they observed the spoons sinking to the bottom at different rates, they were asked if they knew why the spoons behaved this way and, if so, how they would explain this observation.

During the interviews, the children's statements were audio recorded. In addition, relevant nonverbal expressions of the children were protocolled (e.g., pointing gestures during their explanations of the spoons' motion). The collected data were transcribed verbatim [16] and analyzed using the method of qualitative content analysis according to Kuckartz [20]. In doing so, we developed a two-dimensional coding scheme based on the questions asked of the children during the interview ("What did you see?" and "Do you know why the spoons behave like this?"). Furthermore, we used the strategies of summary and subsumption [29] to inductively generate valid subcodes for each dimension of our coding scheme.

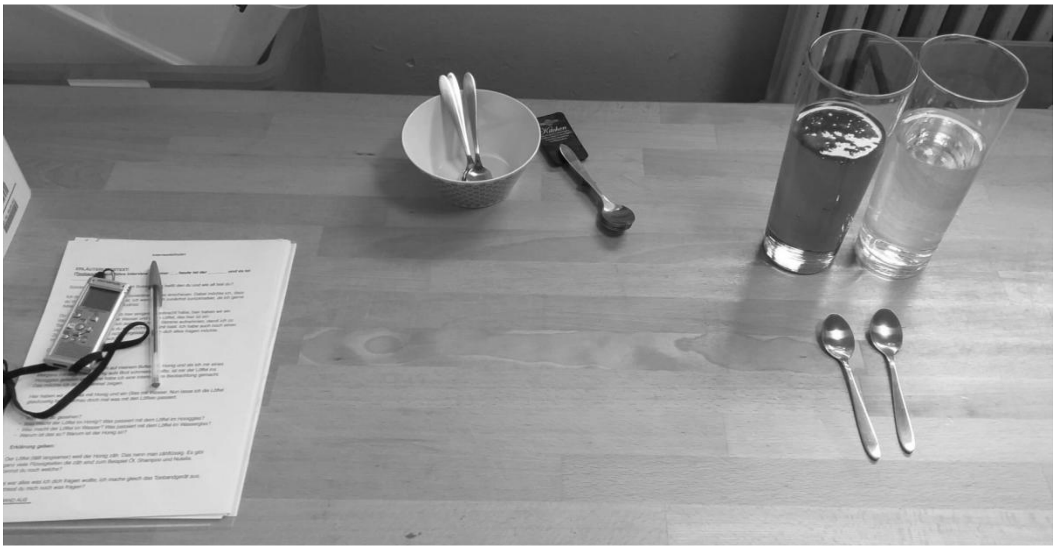

**Figure 1.** Setup of the demonstration shown to the children: dropping two identical spoons into a honey-filled glass and a water-filled glass

The transcripts were coded in their entirety using the developed coding scheme. In order to evaluate the quality of the coding procedure, both the intercoder and intracoder agreement were determined (time interval between the first and second coding: 3 weeks). During both evaluations, 100% of the transcripts were double coded. The intercoder agreement reached a κ-coefficient of 0.76 and is thus sufficient [35]. For the intracoder agreement, $\kappa = 0.89$ was obtained. Therefore, the intracoder agreement can be considered excellent [35].

The last step of the analysis was interpreting and evaluating the interviews in-depth based on the transcripts' coding in order to infer underlying patterns within the children's explanations. This evaluation was accomplished, adjusted, and validated by both researchers discursively [21].

## 3. Results

Among the six children, only two (Frederik and Lilia) instantly noticed that the spoon in the honey-filled glass sank more slowly than the spoon in the water-filled glass. During the first demonstration, Frederik said, "Look! That one goes down really fast and that one goes down slowly," and, analogously, Lilia said, "Wow, that one is slow and that one is fast!" The remaining children initially noticed something different: for example, the visual effect that the spoons "grew big" (Hila) when dropped into the fluids or that the sound of the spoon hitting the bottom of the glass was "[not] so loud" (Max) when it was filled with honey. The demonstration was repeated up to three times for these four children. However, only after the children were explicitly asked whether one spoon was faster or slower than the other did all four children affirm and correctly allocate that the spoon in the honey-filled glass sank more slowly than the spoon in the water-filled glass.

Through our analysis of the transcribed children's explanations (see Methods), we were able to infer three distinguishable conceptions about the viscous behavior of honey, which can be stated as follows:

1. The viscous behavior of honey results from its stickiness.
2. The viscous behavior of honey results from its additional physical characteristics.
3. The viscous behavior of honey results from its use in everyday life.

In the following sections, we provide a summary of these three conceptions, supplemented by exemplary case descriptions and transcript excerpts (grammatically corrected, partly reduced, and approximately translated for illustrative purposes).

### 3.1. The viscous behavior of honey results from its stickiness

Four of the interviewed children (Eva, Frederik, Hila, Max) pointed out that they thought the honey's stickiness caused the spoon to drop slowly. They stated that because the honey was sticky, it hindered movement and, therefore, slowed the spoon. For example, Eva said that "this one was very fast […] and this one was slow […] because honey is a little bit sticky […] [and] water is not sticky." Particularly, Max distinguished between sticky and nonsticky fluids in a more generalized way. During the interview, he mentally checked whether other fluids (shampoo, hazelnut spread) were sticky or not in order to decide whether a spoon would also slowly sink in these fluids. When the interviewer recognized Max's strategy of checking for stickiness, she challenged him with the example of oil, a viscous but not sticky fluid. Max seemed to struggle with this example, presumably because his strategy no longer worked. However, instead of wondering why a spoon also slowly sinks in oil, he listed further sticky substances that he knew (lollipops, chewing gum) and that fit with his idea that stickiness can hinder motion:

| | |
|---|---|
| **Interviewer:** | Do you know why that is? |
| **Max:** | I know, because the honey sticks and water does not stick. […] Hazelnut spread sticks. […] Umm, shampoo sticks. |
| **Interviewer:** | Okay, and oil? Is oil sticky? |
| **Max:** | Umm, no. |
| […] | |
| **Interviewer:** | Ah, okay. You said earlier that honey is sticky, which is why the spoon sinks slowly. Do you know why a spoon also slowly sinks when dropped in oil? |
| **Max:** | Because when… I don't know. […] Lollipops are also sticky and you can't walk when one sticks to your shoes. […] Also chewing gum. |

### 3.2. The viscous behavior of honey results from its additional physical characteristics

Besides the idea that the viscous behavior of honey results from its stickiness, Frederik, Lilia and Hila also tried to explain the slow movement of the spoon due to further physical characteristics of the honey. Frederik stated that "the honey stays like this and therefore the spoon is so slow." Most likely, his phrase "stays like this" refers to the honey's reduced flowability (compared to water), especially since during his description, he tilted the honey-filled glass back and forth in order to illustrate for the interviewer what he meant. Lilia made a statement quite analogous to Frederik's and, furthermore, generalized that "honey always makes things slowly." Above all, it should be noted that from a scientific point of view, Frederik's and Lilia's idea that the flow behavior of honey is related to the slow sinking of the spoon is quite accurate, since viscosity is a measure of a substance's resistance to deformation at a given rate [13, 18].

In contrast, Hila's explanation of the spoon's slow sinking is not entirely accurate from a scientific point of view. She stated that the spoon sank slowly "because honey is sticky […] and it [the spoon] goes in there just a little." She then pointed the fingers of one hand into the palm of the other to illustrate the dipping of the spoon onto the honey's surface. Thus, Hila's idea seems to be that the surface of the honey affects the spoon's falling. On the one hand, Hila's idea—that fluids can vary in their surface characteristics, which makes dipping a spoon easier or less easy—is quite accurate [27]. However, on the other hand, this does not explain why the spoons, when completely immersed in honey and water, sink at different rates. In order to do so, Hila would have needed an idea regarding honey's flowability, which Frederik and Lilia both had.

### 3.3. The viscous behavior of honey results from its use in everyday life

Last but not least, two children (Anna and Lilia) reasoned that the different ways in which honey or water are usually consumed (e.g., as a food or beverage) explains why the spoon in the honey-filled glass sank more slowly than the spoon in the water-filled glass. This reasoning is evident in the following transcript excerpt:

**Interviewer:** Slowly, right! And Anna do you know why that is?
[…]
**Anna:** Umm, water seems like something for drinking […] and this [the honey] is something to eat. […] My mommy always says I have to eat it [a piece of bread spread with honey] using a fork.

Most notably, the above quote from the interview with Anna indicates that the underlying pattern in her explanation of the spoons' sinking derives from her day-to-day experiences. Based on these experiences, Anna—and analogously Lilia—categorized honey as a food and water as a beverage and presumably used this categorization in order explain (to herself) the varying behavior of the spoons within the two fluids.

## 4. Discussion

Based on the analysis of the interview transcripts, we discovered that preschool children hold different conceptions about the viscous behavior of honey. The children we interviewed either stated that they believe it results from its stickiness, that it is a result of further physical properties of honey, or that the viscous behavior of honey derives from its use in everyday life. Therefore, in conclusion, our study revealed both a similar finding to those reported by Faltin and Feser [14] (the conception that fluids' viscosity is related to their stickiness), as well as conceptions of children regarding the viscous behavior of fluids that have so far not been reported in science educational research.

However, there are several limitations to the results of our study that should be considered. First of all, since our study is exploratory, it was based on a small convenience sample of N = 6 preschool children attending the same kindergarten in Hamburg (Germany) at the time of the data collection. Consequently, the results of our study are not representative, in particular the quantity of children listed in the results section, whose statements during the interviews revealed specific conceptions regarding the viscous behavior of honey. Arguably, when interviewing a larger and/or more diverse sample of preschool children, additional conceptions about honey's viscous behavior will emerge as well as a different frequency pattern regarding the conceptions that our study revealed. In addition, children's conceptions are not necessarily generalized and robust entities in their minds. Instead, they can also occur spontaneously and be rather specific to and grounded within the context in which they occur [23, 31]. Therefore, since we only interviewed the participating children once and showed them a specific demonstration revealing the viscous behavior of honey, it is not possible to draw conclusions regarding the stability as well as situation-dependency of the conceptions we identified. Accordingly, future science education research is necessary to investigate to what extent the findings of our study are (un)stable or (not) dependent on the situation in which they have been observed.

Nevertheless, it is especially noteworthy that both our study and the study of Faltin and Feser [14] revealed that some children (or students) erroneously believe that the viscous behavior of honey is caused by its stickiness. Based on this finding, it may be reasonably to assume that such a conception regarding fluids' viscosity is widely held among children and adolescents. This assumption should be investigated in further (confirmatory) research.

Furthermore, if this assumption can be verified, future research in science education should also address the design and effects of learning environments focusing on fluids' viscosity. It should be investigated (1) how such learning environments should be designed in terms of both learning objectives and teaching methods depending on which students are being taught (e.g., elementary vs. secondary students), (2) which further properties of fluids should be delimited or related to fluids' viscosity within such learning environments to optimize students' learning progression (e.g., fluids' adhesiveness or density), and, most importantly, (3) how teachers can properly manage students' conceptions regarding the viscous behavior of fluids when implementing such learning environments (e.g., how to deal with students confusing viscosity and stickiness). The starting point for such research efforts might be existing concepts and recommendations on how to cover viscosity within the science classroom (see, for example, [6, 15, 22, 25, 30, 33]). Based on our findings, these concepts and recommendations may be adapted and/or refined following a design-based research approach [2, 17] in order to develop and implement learning environments that effectively navigate students toward a deeper and scientifically backed understanding of the viscous behavior of fluids.

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