General Chemistry Students’ Perceptions of the Particulate Nature of Matter in Different Physical States

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Background

According to Johnstone’s Triplet Theory, chemistry can commonly be represented at 3 levels: macroscopic, sub-microscopic or particulate, and symbolic (Johnstone, 1991).

![Johnstone’s Triangle with water examples](image)

Understanding chemistry requires one to fluently navigate all three levels, but students tend to struggle with the particulate level the most.

Particulate Nature of Matter

The particulate nature of matter (PNM) is a central concept to the teaching and learning of science (Harrison and Treagust, 2002) and understanding chemistry (Yezierski and Birk, 2006). By the time that students leave secondary school, they are expected to have a firm understanding of PNM (American Association for the Advancement of Science, 1993). Using particulate level drawings and interviews to elicit student understanding of chemistry is a common approach in chemistry and science education, but there are not many studies that actually combine the two techniques.

Methods

The study took place in a second semester General Chemistry class. Ten students volunteered to take part in the study.

![Interview prompt](image)

During the interview had started, students were asked to envision themselves able to see individual particles and then answer the questions from this perspective. Follow up questions were also asked to probe each student’s understanding further.

Data Analysis

Each participant’s transcribed interview data was used alongside the corresponding drawings and analyzed based on three criteria:
- Drawings depict the appropriate orientation of particles in each of the phases.
- Descriptions of drawings were checked for conceptual accuracy and consistency.
- Correct reasoning for the orientation of particles as drawn

![Drawings from student](image)

The drawings were coded either correct or incorrect based on particle spacing in l, s, and g phases, and dissociated, hydrated ions in the aqueous state.

<table>
<thead>
<tr>
<th>Physical State</th>
<th>Number of Pictures</th>
<th>Correct</th>
<th>Incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Liquid</td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Solid</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Aqueous</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>33</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1: Table of drawings

Common incorrect features that were not included in the student drawings were:
- no space between solid particles
- no water particles in aqueous drawings

![Explanations](image)

Common reasons that were given for the difference between the gas, liquid, and solid phase include:
- Kinetic energy
- General reference to energy
- Temperature
- Density

“Temperature changes the density of the like, particles in most states in a certain area...When temperature is higher, the density gets, like, more, like, dense, you know.”

Discussion and conclusions

- The majority of students seemed to understand the arrangement of particles in the gas, liquid, and solid state. However, they were not always able to explain particle arrangement.
- The aqueous state was most problematic for students in all three sections of the study.
- When drawings, descriptions, and explanations were considered together, most of the participants lacked consistency in their understanding.
- Some students used macroscopic reasoning in sub-microscopic contexts, both consciously and unconsciously.
- Few students referenced the kinetic molecular theory when asked about the difference between physical states.
- Academic language (chemical vocabulary) was not always used appropriately. This shows that students are not fully understanding certain concepts.

Implications

- Students hold both correct and incorrect ‘pieces’ about the various phases of matter. It is important to identify and address the incorrect ones.
- It is necessary to ascertain students’ prior knowledge and plan instruction accordingly.
- How we assess our students is as important (if not more important) as how and what we teach.
- Although challenging, interviews can be an effective way of assessing students.

Future Work

- The intersection of linguistics and comprehension of fundamental chemistry concepts
- Progression of understanding of physical states from middle school to college

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References