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Cloudy Judgment: Helping Students Deeply Understand Cloud Formation

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Cloudy Judgment

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HELPING STUDENTS DEEPLY UNDERSTAND CLOUD FORMATION

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ABSTRACT: Weather is ubiquitously experienced, yet generally misunderstood by students. We present the well known "cloud in the bottle" activity, but do so in a manner that mentally engages students to a greater extent, identifies commonly held misconceptions, and moves students to a deeper understanding of cloud formation. *This activity promotes National Science Education Standards A, B, D and G and Iowa Teaching Standards 1, 2, 3, 4, and 5.*

Drop a match, twist a cap, squeeze a bottle and watch what happens. Making a cloud in a bottle can be done easily and is often done without much mental engagement on behalf of the students. However, students in our classes fail to let go of some of their deeply held views about how clouds form and how weather works. By eliciting and using student ideas, the teacher can guide students to confront their misconceptions about clouds and learn fundamental ideas about weather and their own learning.

In this activity, students identify scenarios matching their prior conceptions of cloud formation, create tests, collaborate with classmates, and develop a more accurate understanding of cloud formation. Throughout this activity, the teacher's role is essential in identifying misconceptions and using those and other ideas to scaffold students to more accurate ideas about weather and learning.

Identifying student misconceptions is a crucial first step in creating highly effective science lessons. Common misconceptions related to clouds, like those appearing in Figure 1 often stem from observing everyday phenomena such as seeing steam rise out of a boiling container. Furthermore, students see condensed water as clouds, but incorrectly think they are seeing water vapor which is invisible (Henriques, 2000). Activities where students must make decisions and put forth ideas, such as in the activity presented here, enable teachers to identify and address misconceptions that hinder student learning.

FIGURE 1
Common Misconceptions about Clouds

- Clouds form by boiling vapors traveling into the air
- Clouds are made of cold, heat, fog, or snow
- Clouds are water vapor
- Empty clouds are refilled by the sea (water stays as a liquid through the entire process)

The activity described below is an inquiry-based exploration in which students experience a targeted phenomenon and are compelled to make sense of that experience. This concrete experience and mental engagement provide a foundation from which students and teachers draw during the concept development phase of the learning cycle that follows the activity (Karplus, 1977; Colburn & Clough, 1997). Thus, this activity focuses on investigating factors involved in weather (e.g. density, particle movement, heat and pressure) to set students up for concept development.

Prior to this activity, students should have a clear understanding of density (i.e. not simply knowing the equation and being able to plug-and-chug numbers) including how temperature, and the spacing of particles in a given volume affect density. Students must also conceptually understand the water cycle and how heat affects the movement of water molecules. Throughout this activity, students work to explain the process of cloud formation as a result of water moving through states of matter. Each of the following days will be outlined based on a 50 minute class schedule.

Day One: Forming Ideas

During the first day, students are given five scenarios appearing in Figure 2 and asked to thoroughly explain their thoughts and ideas. We suggest having students explain their thoughts and illustrate their ideas with drawings and words. This improves students' mental engagement and aids the teacher in identifying student thinking. While students respond to the stems in Figure 2, we walk around the room observing and listening to students and, when appropriate, engaging in discussion regarding their answers. This makes clear to students we are genuinely interested in their ideas, promotes on-task behavior, and places us in a position to quickly assess students' thinking.

As students complete this task, they are directed into groups of two to share ideas and illustrate them together on a whiteboard. Student discussion results in thinking, elaboration and refinement of their initial ideas, and presents further opportunities for us to monitor student thinking and on-task behavior. Eventually, the groups are brought together as a whole class for a discussion and sharing of ideas. Typical student responses include:

- I think the sun evaporates more water when the ground is hot then when the ground is cold because the sun evaporates water and takes it to the sky which forms clouds.

FIGURE 2: Scenarios
Why do clouds appear on some days and not others?

· *Scenario #1: Generally speaking, high pressure is associated with fewer clouds and low pressure is associated with more clouds. I think this because…*

· *Scenario #2: On a hot day, the temperature is too high for small water droplets to condense and form clouds. I think this because…*

· *Scenario #3: The sun evaporates more water when the ground is hot than when the ground is cold. I think this because…*

· *Scenario #4: When no dust or smoke is in the sky, water vapor condensing to form water droplets is more difficult. I think this because…*

· *Scenario #5: None of these scenarios captures my idea. I think…*

- The pressure in the clouds has to be more than the pressure under them.
- When it is too hot, some water vapor can't stay in the air.
- High pressure means good weather and low pressure means rain, so there would be more clouds.

We use student responses to guide students to create their own cloud in a bottle to test their ideas. For example, we have each group of two students, using ideas the class has generated, to carefully write out procedures regarding how they might make a cloud appear in a bottle using the materials provided in Figure 3. Other reasonable and available materials may be given to students upon request if they have a justifiable rationale for their request. The students' procedures should include detailed plans and rationales for how to test each scenario in Figure 2. Students must have these procedures approved by their teacher prior to initiating any testing. When students seek our approval for their proposed test, we ask questions to address any conceptual or safety issues. For instance, common questions we ask include:

FIGURE 3
Materials for Each Group

- *2 liter plastic bottle with the label removed.*
- *Hot plate*
- *Ice*
- *Matches*
- *Plastic baggie (1 quart size)*
- *Water*

- What safety issues do you need to consider when doing this activity?
- You mentioned hot water. Why wouldn't you want to heat water above 50 degrees Celsius?
- Why would you want to transfer the hot water to the plastic bottle instead of just heating the bottle directly?
- How might you handle the hot water?
- How will you ensure you are using the matches safely?

Day Two: Form a Cloud

After greeting students, we have them retrieve their proposed designs for testing the five scenarios. Students are given 5-10 minutes to make any changes in their designs prior to beginning, but reminded they must first receive teacher approval before beginning. As students are setting up and performing their tests, we move around the lab area posing open-ended and thought-provoking questions to better understand students' thinking. Because students are often uncertain and hesitant, we use encouraging non-verbal behaviors and excited voice intonation when interacting with students (Clough, 2007) as well as wait-time I and II (Rowe, 1986). Examples of questions we ask include:

- How do you think changing the temperature of water would affect cloud formation?
- If you want clouds to form best, what do you think must be done to the water?
- How could you test the other scenarios not already tested?
- How might you account for the results you are obtaining?
- Given your results, what do you infer is the role of _______ in cloud formation?
- How might particles in the air play a role in forming a cloud (*As we light a match and blow it out as a demonstration for a small group of students)*?

As students finish their tests, the teacher asks them to return to their seats and again write an explanation with words and drawings of the results of each of their tests. Students are asked to share results of their tests with fellow classmates, leading into a discussion of how clouds are formed. During the discussion, we again pose extended-answer thought–provoking questions, use appropriate wait-time, and exhibit encouraging voice intonation and non-verbal behaviors to encourage student responses (Clough, 2007):

- What did you determine impacts the formation of a cloud?
- How do you account for hot water seeming to create more of a cloud than when you used cold water?
- How do the particles of hot water compare to the particles of cold water?
- Why would the particles of the water become more compact when higher in the atmosphere?

Scaffolding questions if needed:

- How does the temperature where clouds typically form compare to the ground temperature?
- What happens to spacing between particles of gases as they cool?

Day Three: Bringing it all together and making connections to the nature of science

The third day of the activity is devoted to consolidating ideas from students' experiences in the lab and pushing them to understand influential factors of weather. The teacher must make explicit the connections between students' tests and influential factors such as density, heat, particle movement, and pressure. Importantly, we cautiously use this activity to draw students' attention to the role of pressure in cloud formation as misconceptions may be created by what they have seen in the bottle's closed system.

During the concept development phase of this activity, the role of the teacher is to ask questions and raise situations that promote the desired conceptual understanding. While at times presenting some information is necessary, the concept development phase of the learning cycle is *not* simply a time to lecture about what students should have determined in the exploratory activity and accurate science ideas. The following questions illustrate the way we create a logic flow that promotes mental engagement and helps students make the links that together result in conceptually understanding factors that impact cloud formation:

- What does increasing the temperature do to water molecules?
- If molecules are moving faster, what happens to the spacing between molecules?
- When the volume increases because molecules are more spaced out, how is the density affected?
- If the density is less, what would you expect to happen to the water?
- We know the temperature is much cooler higher up in the lower atmosphere. When water molecules cool, what might happen?
- How do we know clouds are made of little drops of liquid and not of gas?
- What evidence do we have that clouds are made of little drops of liquid?

Scaffolding questions if needed:

- What did you notice on the sides of your plastic bottle?
- Why might these drops of water form on the side of the bottle?

We spend extensive time guiding students to make the crucial connections between these ideas. While simply telling students these connections takes less time, research makes clear that simply telling students answers does not often result in desired conceptual understanding (Minner, Levy & Century, 2010). Scaffolding questions such as those illustrated above demands that teachers accurately determine students' thinking, understand the intermediate steps from students' ideas to the accepted science concept, and ask questions in a logically tight sequence and at the appropriate time. This often requires backtracking when students' thinking begins to go astray.

If through discussion, students encounter disagreement or bewilderment, the teacher should ask students what they could do to best address the disparity between their ideas. Most students will realize they could retest their ideas in the lab. The teacher could also ask key questions that help students link evidence from their lab experiences to intermediate understandings along a path to the accepted science ideas. The teacher must also draw students' attention to the link between their experiences and how scientists handle disagreements by going back to retest when the evidence is inconclusive.

We acknowledge how this approach demands that teachers themselves deeply understand the science content, the logical connections underlying accurate science ideas, and pedagogical skills necessary to move students along productive paths. This is why inquiry science teaching is far more difficult than simply presenting information (Clough, 2006a), but the mental links that *students* make along the way is also why effectively teaching science through inquiry results in deeper conceptual understanding of science content (Clough, 2006b; Minner, Levy & Century, 2010).

To check for depth of understanding, ask students to write and illustrate how the water cycle, heat, and density are all related. Asking students how this activity helped them more deeply understand how these ideas are connected directs students' attention to the value of the activity and creates a foundation for future reference as students continue to learn more about the weather using the same ideas. After assessing students' understanding of the influencing factors of weather, we address the new ideas for students by asking questions such as:

- Why was particulate matter a necessary piece to form a cloud?
- What did you notice when you squeezed the sides of the plastic bottle?
- Why do you think did applying pressure affect the cloud being formed?
- How is forming a cloud in a bottle different than forming a cloud in the sky?

As a part of the discussion about weather ideas, students' attention can be drawn to how they have experienced science through inquiry. Questions may include:

- How have your thoughts about how clouds form changed since you first read the scenarios presented at the beginning of this activity?
- In what ways does evidence and reasoning account for how your ideas have changed?
- What is the value of expressing your pre-existing ideas about cloud formation before you began testing?
- How would your learning have been different if we would have given you a step-by-step procedure to follow?
- Why do scientists benefit from learning together and building consensus?

Conclusion

While students have a great deal of experience with weather, students often have numerous misconceptions. Accessing and using student ideas to drive an investigation of clouds can help students confront their previous ideas. However, simply doing an activity will not be enough to overcome misconceptions. Teachers must continually ask open-ended, thought-provoking questions (as outlined in this article) to push students to mentally engage and deeply reflect on how and why their ideas are changing. As with any lasting conceptual change, the learning cannot end with the activity, but must continue throughout the school year.

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