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Jerrid Kruse
Le Mars Community High School

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Introducing Students to Polar and Non-Polar Interactions through Inquiry

by **Jerrid Kruse**

ABSTRACT: Almost half of all chemistry teachers do not use inquiry in their classroom. Teachers cite classroom management, safety, and workload as reasons for not implementing inquiry techniques in their classroom (Deters, 2004). These teachers may resist laboratory-based inquiry finding it too daunting for themselves and their students. However, both students and teachers can progressively move to laboratory-based inquiry by first starting with less demanding science inquiry. This article describes an inquiry atmosphere created in a discussion classroom setting where students only minimally interact with materials. Students investigate macroscopic properties of water and hexane at their desks and the teacher performs a highly interactive demonstration to assess and increase student understanding. *This article promotes National Science Education Content Standards A and B, and Iowa Teaching Standards 1, 3, and 6.*

Introduction

Content Standard B of the National Science Education Standards (NRC, 1996) addresses, in part, an understanding of the structure and properties of matter. An understanding of polar and non-polar interactions is helpful in understanding everyday natural phenomena such as solubility and melting/boiling points. Unfortunately, polarity is often taught in a dry didactic manner, and sometimes followed by a verification laboratory experience. However, by beginning with an inquiry interactive demonstration using substances with differing polarities, students are more engaged, curious, and eager to arrive at accurate conceptions concerning polarity and molecular interactions. Also, by directing students to observe characteristics, and predict and explain outcomes using molecular interactions, the following activity and demonstration promotes an inquiry-based environment as described by Content Standard A of the National Science Education Standards (NRC, 1996). Having made predictions about the phenomena under investigation, students have a vested interest in the experience. Meaningful and long-term learning is largely dependent upon being mentally engaged in learning.

Investigation Set-Up

The activity starts with each group of two students being given a dropper bottle of water and a dropper bottle of hexane and several cotton swabs. The students are then asked to make and write down observations about the two liquids. Typical student observations include: hexane evaporates faster, hexane is more "runny", water beads up, hexane has an odor, both are colorless liquids, etc. Some creative students may notice that the two do not mix when placed on top of each other. While working with chemicals, students should be wearing approved protective eye-wear, and using only cotton swabs to manipulate the chemicals.

Teacher Role during Investigation and Discussion

While students are making observations the teacher circulates throughout the class pushing students to make better observations by posing questions such as: "*How could you quantify that* *idea*?" when students comment that the hexane evaporates faster (ie: time the evaporation rate) or "*What might affect your observations*?" followed by "*How are you accounting for these factors*?". The teacher gain greater insight into what students are thinking by asking questions such as: "*How do you account for the difference you are seeing*?" or "*How can both of these liquids behave so differently*?" Teachers can use knowledge gained from these questions to frame the resulting class discussion and to address student ideas (Penick, Crow, Bonnstetter, 1996). The teacher should also circulate through the class to monitor student on-task behavior, and carefully judge when the class is ready to move on so class time is maximized.

By asking questions the teacher is modeling curious and thoughtful behaviors that are crucial for inquiry. Students must learn to ask productive questions in inquiry, and the teacher should model productive questions while continually encouraging students to formulate their own questions (Jelly, 1985). By waiting silently for at least four seconds and looking expectantly after a question or a response, teachers encourage students to provide ideas or to elaborate on ideas already provided (Rowe, 1986). When students propose answers to questions, the teacher needs to model positive listening habits and again wait to promote more than one student answer. Encouraging multiple students to respond to questions is important so that the teacher has an idea of what most students are thinking, while avoiding basing the class' understanding on the response of one student.

As the students put forth their observations the teacher should write all ideas on the board without judging them. This is crucial to create a supportive classroom environment that encourages multiple student responses (Penick and Bonnstetter, 1993). Through effective questioning students' ideas, including contradictory ideas, can later be addressed when students have lost track of who put forth a particular idea.

When the students have no more ideas to add to the board the teacher can ask, "*What might be causing these differences*?" This question might seem to be "jumping the gun" for student understanding, but student responses to this question provide the teacher with valuable insight to student thinking, on which he/she can base the next question in the discussion. Determining student thinking is

Safety Considerations when using Hexane

Because hexane is a flammable liquid special care must be taken to prevent accidents during this activity:

⃠ No open flames should be used and teachers should read all warning labels as well as the MSDS for hexane.

⃠ Students should not directly smell the hexane and teachers should demonstrate wafting as the appropriate technique to smell a chemical.

⃠ Students should not be provided with excess amounts of hexane. This can be accomplished by filling dropper bottles only half full with hexane or by supplying students with only a few drops at a time. The teacher can circulate around the room with a dropper bottle of hexane and students can request additional drops as needed. This prevents students from being able to "play" with the hexane once they have made their observations.

⃠ Students should only perform streak tests using cotton swabs and should place used cotton swabs into a metal garbage can; used coffee cans work well for this.

Hexane works best for this activity because it demonstrates evaporation properties as well as non-polar properties; however, if hexane is not allowed in your school, this activity and demonstration can be done as follows:

⏩ Use acetone instead of hexane during the activity to provide students the opportunity to investigate evaporation rates. Remember, acetone is still flammable. Acetone cannot demonstrate polar/non-polar interactions as it mixes with water.

⏩ Use vegetable oil during the demonstration of non-polar/polar interactions in the test tubes with food coloring.

necessary for creating deep understanding and reshaping student thinking. By actively seeking out student thinking the teacher can encourage the student to test their idea's limits and naïve conceptions can be eliminated (Watson and Konicek, 1990). Even if students struggle to provide possible causes for the differences they have observed, the question raises an issue they now see as worth exploring.

Once all student ideas have been discussed and the rationale for each has been investigated through teacher follow-up questions, the students may or may not be on the right track to an accurate understanding. If students are on the right track the following demo may solidify their confidence in understanding polar and non-polar interactions. If the students are not on the right track (a more common occurrence) the demo provides a concrete experience for helping students move to an accurate understanding.

Concrete Experience: Magnets and Toothpicks

Students are shown a beaker of magnets and a beaker of toothpicks. The teacher asks the students to predict what will happen to each beaker when dumped onto the table. Students have no problem with the fact that the magnets will stick together in a clump while the toothpicks will spread out on the table. Now the teacher poses questions to help students make connections between what they have just seen, and the abstract ideas being addressed with the water and hexane. "*How are the water and hexane like the magnets and toothpicks*?" The teacher must wait, and accept all answers, and provide follow-up questions such as: "*What aspects of the magnets and water are similar*?" or "*What is your rationale for that idea*?" or "*What evidence do you have that water, like the magnets, sticks together*?"

The teacher helps the students see that the water and the magnets each have the property of sticking together, which leads students to the connection that water might have poles just as does a magnet. Students are now directed to their observations of hexane. In response to questions such as "*How might we explain that hexane doesn't appear to stick together?*", or as a reflection of their own thinking, students often arrive at the possibility that hexane does not have polar or attractive properties.

Reinforcement and Assessment of Student Understanding: Demonstration

Now, as a demonstration, show the students two large test tubes, one with about 25 ml of water, and one with about 25 ml of hexane. During the demonstration, students within splash range should be wearing appropriate eye protection. Make labels or tell students what each test tube contains. Show the students a container of blue (or any color) food coloring. Ask, "*What do you think will happen if a few drops of the food coloring are added to the water?*" Students readily know that the water would turn blue. Then ask, "*What do you think will happen if I add food coloring to the hexane?*" Use wait-time to encourage students to think and speculate. Probe student thinking, but do not confirm or reject student comments. By not confirming or rejecting comments the students continue to be mentally engaged instead of simply waiting for the demonstration to be complete (Moscovici and Nelson, 1998).

Students will eagerly provide their views, and after all predictions are made for each, further explore their ideas by posing a question such as, "*For those of you who think . . . what is your reasoning*? Students will now be extremely attentive (they have a vested interest in the outcome) as you add a few drops of food coloring to the hexane. After the students have watched the food coloring sink to the bottom while the hexane remains clear, use a think-pair-share strategy for the following sorts of questions. "*How can you account for what you just observed? What do you think will happen if I pour the water into the beaker with the hexane? How might you explain your reasoning?*" Having students first think alone and then share their ideas with another student is valuable for eliciting thinking that might not be shared in a large group setting. As the teacher walks around during this think-pair-share, valuable insight into students' thinking can be gathered.

After generating ideas in pairs, students are again interested in seeing the outcome of the mixing. When the water is poured into the beaker the water turns blue, the hexane remains clear, and the two are separated with hexane on top. A discussion of density could be explored at this point to talk about why hexane is above water, but I have not typically done so. Once the two have been mixed ask, "*Why do the hexane and water not mix?*" If necessary, revisit the toothpicks and magnets as an aid to help students make the desired connections to polar/non polar interactions. As a final challenge, ask the students, "*What can we assume about the blue dye?*" If students have trouble coming up with the idea that the blue dye must have poles like water, use another concrete example. Using a magnet coated in plastic ask the students, "*What will happen if I put this piece of plastic in with the magnets and dump them on the table?*" Students have no problem saying that the plastic piece will bounce away and the magnets will stick. Unbelievably, the plastic sticks to the magnets and the students come to the conclusion that the plastic is magnetized. Return to the blue food coloring and water. Pose the question, "*If the blue food coloring sticks with the water, what can we say about it?*" Help students see that they can assume the blue food coloring has poles similar to water.

Now students are likely curious as to how some chemicals have poles and some do not. Discussions of electronegativity, charge separation, and dipole moments are helpful in expanding students' understanding, and the experiences provided in this article can be used as a reference for discussion and later revisited with a deeper understanding by students. That students raise so many questions during this activity further illustrates the engaging nature of the inquiry approach to teaching about polar/non polar interactions. The power of well implemented inquiry is that students have a greater desire to know and are thus mentally engaged.

Final Thoughts

This activity makes an excellent introduction to a unit in polarity or bonding. Once students are introduced to the idea that molecules can have poles and that these poles can influence macroscopic properties, a rationale for learning about electronegativity and molecular geometry is established. The activity and demonstration usually last about one hour and provide common experiences for all students to reflect on concerning molecular interactions. Using exploratory experiences such as these, teachers can help students build more accurate conceptions of abstract science content (Colburn and Clough, 1997).

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Jerrid Kruse is a recent graduate of Iowa State University. Jerrid is beginning his first year as an instructor at the LeMars Community Middle and High School, teaching 7th-grade Science and 9th-grade Physical Science. In addition to teaching sciences, Jerrid is also the LeMars tennis coach.