Density with Intensity

Graphic by Joe Taylor

by **Michelle State** and **Laurie McGhee**

ABSTRACT: This article presents a guided-inquiry activity where students apply their emerging understanding of density. Students are presented with the question of how different solids and liquids will arrange themselves when placed together. However students are not allowed to physically put them together. With teacher guidance and scaffolding, students determine that they can solve the problem by calculating and comparing the densities of the various substances. This activity would best be used in grades 8-12 in the application phase of the learning cycle, or modified to become a summative assessment for a density unit. This article also discusses the crucial role of the teacher and critical teacher behaviors and interactions to ensure successful implementation of this activity. *This article promotes Middle School National Science Education Content Standards A, B, and G, High School National Science Education Content Standards A, B, and G, and Iowa Teaching Standards 1, 2, 3, 4, 5, and 6.*

Conceptually understanding density and how it may be quantified are important for understanding the natural world and phenomena in students' daily lives. The following is a mentally engaging activity designed to reinforce concepts previously taught regarding density.

Day 1

We begin the activity by having students form groups of two. We permit groups no larger than two because the activity does not require three individuals and would therefore lead to off-task behavior. Groups are used because of the valuable meaning created through interactions with each other. Each group is presented with the same three solids and three liquids, each with a different density. The liquids we normally use in this lab are water, vinegar, and vegetable oil or corn syrup. We do not tell students the identity of the liquids. While students often speculate what the liquids are, we simply tell them the identities of the substances are not important for this activity. Because the liquids are treated as unknown substances, we have students wear safety goggles throughout the activity to promote proper laboratory safety behavior. The solids should include at least one item that can be easily measured to determine its volume and at least one item where water displacement must be used to determine its volume.

We have students examine the solids and liquids and record their observations on white boards (small boards made of the same material as classroom marker boards) or large sheets of butcher paper provided by the teacher. The students complete this task in their groups of two, and then share their observations in a whole class setting. This increases the participation in the whole class setting. If needed, the teacher can guide the discussion by asking the following questions:

- What similarities/differences do you notice?
- Which objects are more similar to one another?
- What about the objects are similar or different?
- What physical properties did you observe?
- How do the different liquids flow compared to one another?

Students' responses to the previous question often include describing the liquids as 'thick', 'syrupy', or 'runny'. We ask students to clarify these words by asking:

- What do you mean by 'thick', 'syrupy', and 'runny?'
- How is the thickness different for each type of liquid?
- How do the masses of the solids compare or contrast?"

From this discussion the teacher can steer student thinking to the problem of the activity. The teacher presents the question, "If I put all of these solids and liquids together, how do you think they will arrange themselves?" The students discuss their ideas in groups, drawing the arrangements on their white boards or sheets of butcher paper. During this time we walk around observing and listening to students to gain valuable insight into their thinking.

As students finish, we instruct them to display their drawings at the front of the classroom. Drawings often show several of the following: thicker liquids separated from the less thick liquids; similar thickness liquids mixed; solids all at the same level; larger volume or more massive objects at the bottom; and/or smaller volume or less massive objects at the top.

We then review the different arrangements and have groups provide a rationale for how they arranged the different substances. We ask, "Why did you draw some of the liquids separated and/or mixed together?" In their responses, some students may use a form of the word "density" or say that "one liquid is thicker than another liquid and will not combine." We ask students to elaborate in the following ways:

- What do you mean by the term 'dense?'
- How do you know if something is denser than the other?
- Elaborate on experiences where you have seen or have not seen thicker liquids on top or below less thick liquids."

We continue guiding students to notice similarities and differences among the groups' arrangements. For instance, we might ask, "How is this arrangement similar/different to the previous groups' arrangement?" If students are having trouble noticing the similarities and/or differences, we scaffold back with more focused questions such as:

- How is the arrangement of liquids in this drawing similar to and different from the arrangement in other drawings?
- Why are some solids in certain liquids and not others?
- For those groups who think……what is your reasoning?

Depending on the timing of class, this could be an appropriate point to end the first day.

Day 2

On day two we place our students' drawings at the front of the room and begin by posing the following problem that must be solved.

- Looking at your arrangements you drew yesterday, how could we determine how the liquids and objects would arrange themselves without physically putting them together?

The students will unlikely answer right away, and may not make the connection to density. This can be frustrating, but using appropriate wait-time and not telling the students how to proceed is crucial. Students' answers may go in two directions at this point. The students may reveal misconceptions concerning density such as larger-sized or heavier objects sink and smaller-sized or lighter objects float. This indicates that students do not conceptually understand density. If this is the case, we abandon the activity and instead draw students back to previous density lessons and reteach this difficult concept.

Another possibility is that students' responses hint at sinking objects or liquids having a higher density, but the precise connection is unclear. In this situation, we ask students to elaborate on their responses, or we ask a question that helps raise the idea of density. For example,

- In your drawings I notice some of the objects are sinking or floating. What might account for this?

If students use the word "density" or the idea of density, then ask,

- What does 'density' mean?

We write down students' ideas and definitions on the board. When students explain "density," they often do so in terms of the mathematical equation they have learned from previous class discussions and laboratory activities. We attempt to help students make an important link by asking questions such as:

- How does the density of two objects relate or differ if one object floats/sinks/suspends within the other?
- How might the concept of density be related to this problem?

While these questions may appear somewhat leading, they may be necessary to help students begin thinking about the connection between the densities of the solids and liquids and how they will arrange if physically placed together.

Students now can begin their investigation in earnest. We establish only two stipulations for their work. First, students can only work with one solid or liquid at a time. This is to ensure that students do not determine the actual arrangement of the solids and liquids by simply placing them together. Second, students must ask for any equipment they wish to use. This is done so students will critically think and problem solve in selecting materials necessary for finding the mass and volume of the different solids and liquids. Last, students must decide what to write down in their lab journals and information they regard as important or relevant for future use.

Students will typically ask for balances or scales to find mass. A common misconception teachers will find is hearing students use the terms weight and mass interchangeably. Addressing this common misconception is important. When students use these terms interchangeable, we ask them questions such as:

- How are the concepts of weight and mass the same/different?
- How is a scale different from a balance?

Students may become stuck when they are finding the volume for the different solids and liquids. Some students may not connect past mathematical equations that could help them find the volume of regular shaped objects. Other students may not connect past discussions of how to find the volume of irregular objects. If we notice several groups having this problem, we have students stop what they are doing and, as a class, discuss ways to calculate volume using what was learned in past lessons.

As students work on their investigations and calculations, we walk around from group to group posing questions and ensuring student mental engagement in the activity. This portion of the activity can take one to three days depending on how much time the students need to find the densities of all the solids and liquids. Some groups finish much earlier than others. This can be remedied by closely monitoring each pair and with those that finish quickly, have a discussion about the value of collecting multiple measurements of volume to help ensure accuracy.

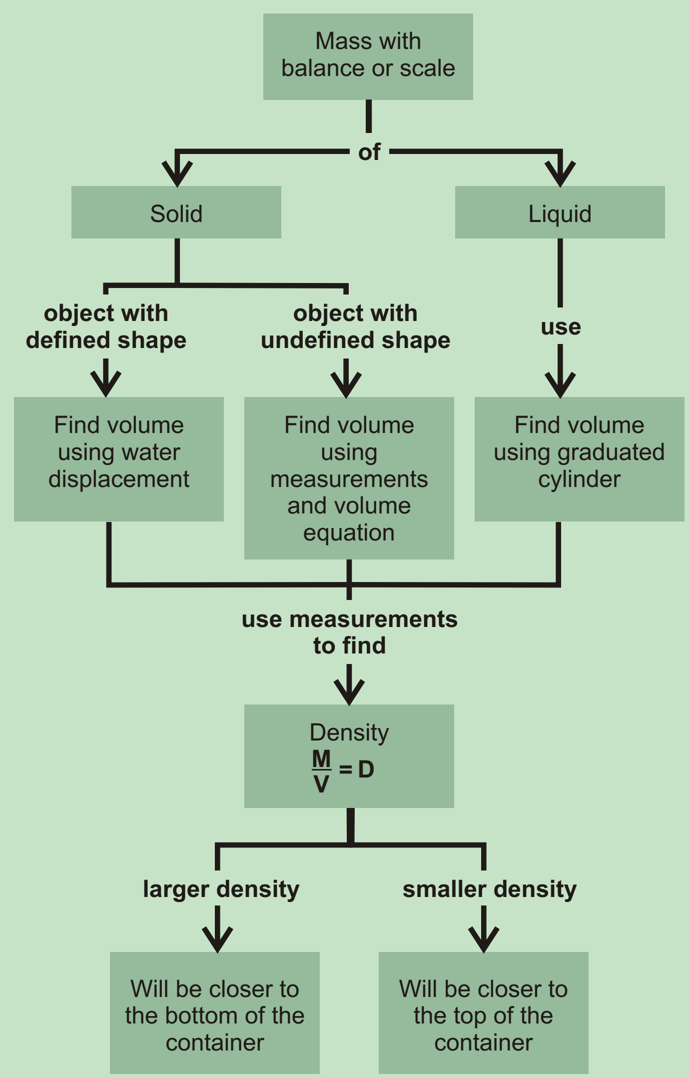
When students feel they have completed their measurements and density calculations, we hold a class discussion regarding how the students will report their findings. Each pair of students will turn in a report containing the following:

- a flow chart of steps of how to determine how the solids and liquids will arrange (see Figure 1);
- data collected;
- results and analysis; and
- a final drawing of how they interpreted their data of the solids and liquids to arrange when put together.

This report is in addition to the students' laboratory journals where they have been recording all that they have done and their thinking during their investigation. When discussing with students the expectations of the final lab report, we

FIGURE 1

Sample flow chart of how solids and liquids will arrange



draw students' attention to the differences between the final lab report and how the students actually conducted their investigations. This is a key nature of science idea and is essential for students to understand how published and reported science work appears much cleaner and straightforward than the actual research (Clough, 1997). To draw students' attention to the differences between public and private science, we ask questions such as the following:

- How is your final lab report similar to and different from how you actually conducted your work?
- What did your final lab report include and what did it omit from what appears in your lab journal?
- How can published lab reports misrepresent what actually doing science is like?"

After students have turned in their lab report, we then do a whole class presentation of how the solids and liquids will arrange themselves when put together. Students are always excited with anticipation, curious to see how the way they arranged the substances will compare to what is observed. After the presentation we have students write a final paragraph of how their predicted arrangement agreed or disagreed with what they observed. We have students consider what might account for their predictions matching or not matching the observed arrangement of the substances. Significant value exists in permitting additional time for students to reexamine their measurements and calculations and reassess their predictions.

The Role of the Teacher

Throughout our writing we have tried to illustrate what we do during the activity to promote creativity and mental engagement. While the activity itself is interesting to students, developmentally appropriate, and focuses on promoting science content, we know from education research and our own experience that desired outcomes will not occur without the aid of effective teaching behaviors. Activities alone do not foster meaningful learning; the role of the teacher during this activity is essential and the most important piece. Clough, Berg and Olson (In Press) write that "Teachers exert the greatest influence in the classroom through the way they mentally engage students in a lesson". Several research-based teacher behaviors implemented collectively are needed to establish meaningful interactive environments:

- asking thought-provoking questions,
- using wait-time,
- presenting positive nonverbal expressions, and
- the manner that the teacher responds to students' ideas.

Together, these behaviors have an enormous impact on the classroom environment, in determining what students think, and in helping students make desired connections (Clough, 2002; Clough, 2007; Clough, et al., In press; Southerland, Kittleson, Settlage, & Lanier, 2005).

Questioning » We seek to pose thought-provoking and open-ended questions. These "productive" questions promote reasoning, engage students, help students take note of details they might overlook, and are suitable to the types of experiences students have with the subject (Elstegeest, 1985). These types of questions often start with "why," "how," or "what" (Elstegesst, 1985). An example is, "What do you expect would happen if…?" These types of questions will help us assess students' prior experiences and misconceptions. We also use this line of questioning to scaffold questions to help students make desired connections.

Wait Time » Although asking thought-provoking questions is important, we must follow them with appropriate wait-time before and after student responses. By increasing wait-time after a question from one to at least three seconds, student responses were found to increase 300%-700% (Rowe, 1986). Using wait-time will also decrease the number of "I don't know" responses from students (Tobin & Garnett, 1984).

Nonverbal Behavior » Nonverbal behaviors are an essential component of communication in the classroom. Our use of positive facial expressions, gestures, eye contact, voice tone, and movement around the classroom are all important communicators to the students (Smith, 1979). A positive, excited face promotes a safe feeling for a student to suggest their ideas and answers. We also use non-threatening, inviting gestures, such as counting students' answers on our fingers to make explicit that several answers exist for out questions and to encourage other students to respond. We also make appropriate eye contact with students by consistently scanning the room back and forth, leaning forward when students are speaking, and raising our eyebrows to show interest. This provides an added boost to students that we are waiting for "their" answer. Our using a positive tone of voice that portrays energy and enthusiasm; consistently conveying a desire and willingness to help students. Last we deliberately move around the room, in and out of rows, unafraid to position ourselves at similar physical levels as students. We do this to keep students' attention and effectively manage the learning environment.

Conclusion

Keeping the National Science Education Standards (NRC, 1996) in mind, we developed this activity to be more congruent with our goals for students (e.g. critical thinking, communication, collaboration, a deep understanding of fundamental science concepts, etc); as well as how people learn. However, mindful of the teacher's central importance in education reform, we also carefully considered how we interact with students. While all science teachers strive to find, develop and implement engaging activities, what teachers do while implementing the activities has the most significant impact on student learning.

References

Clough, M.P., Berg, C.A. and Olson, J.K. (In Press). Promoting Effective Science Teacher Education and Science Teaching: A Visual Framework for Teacher Decision-Making. *International Journal of Science and Mathematics Education*.

Clough, M.P. (2002). Using The Laboratory To Enhance Student Learning. In Bybee, Rodger W. (Ed.) Learning Science and the Science of Learning, 2002 NSTA Yearbook. National Science Teachers Association, Washington, D.C.

Clough, M.P. (2007). Synergistic Relationships: Why Effective Teaching is Complex. *Iowa Science Teachers Journal*, 34(3), 2-3.

Elstgeest, J. (1985). The right question at the right time. In W. Harlen (Ed.), Primary Science: Taking the Plunge, (pp. 36-46). Oxford: Heinemann.

Gallimore, R. & Tharp, R. (1990). Teaching mind in society: Teaching, schooling, and literate discourse. In L. Moll (Ed.), Vygotsky and education: Instructional implications and applications of sociohistorical psychology (pp. 175-205). Cambridge, UK: Cambridge University Press.

Penick,. J. & Bonnstetter R. (1993). Classroom Climate and Instruction: New Goals Demand New Approaches. *Journal of Science Education and Technology*, 2 (2).

Rowe, Mary Budd. (1986). Wait-time: Slowing down may be a way of speeding up. *Journal of Teacher Education*, 37(1), 43-50.

Smith, H. (1979). Nonverbal communication in teaching. *Review of Educational Research*, 49 (4), 631-672.

Southerland, S. A., Kittleson, J., Settlage, J., & Lanier, K. (2005). Individual and group meaning-making in an urban third grade classroom: Red fog, cold cans, and seeping vapor. *Journal of Research in Science Teaching*, 42, 1032-1061.

Tobin, K., & Garnett, P. (1988). Exemplary practice in science classrooms. *Science Education*, 72, 197-208.

***Michelle State** and **Laurie McGhee** both teach at Del Valle High School in Del Valle, Texas. Michelle teaches chemistry, pre-AP chemistry, and AP chemistry. She can be contacted at michelle.state@del-valle.k12.tx.us. Laurie's focus area is in the biological sciences. She can be contacted at laura.mcghee@del-valle.k12.tx.us.*