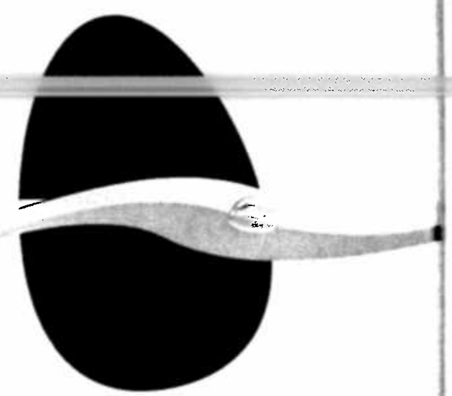
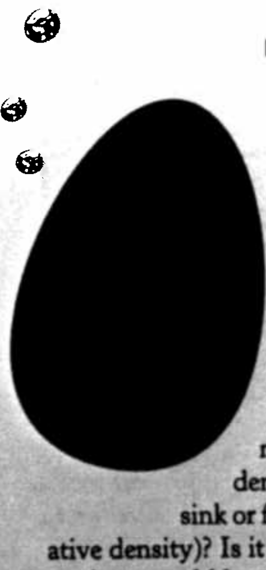
BEYOND PREDICTIONS



By Dennis W. Smithenry and Jenny Kim

A variation and expansion of the traditional "sink or float" activity



The classic sink or float activity, in which students test predictions of the buoyancy of various objects, is a staple in K–2 classrooms (Banchi and Bell 2008; Watson 2008). Students enjoy getting their hands wet in a tub of water. Teachers appreciate having their students purposefully engaged in a hands-on activity. Yet, besides having students experience how to make and test predictions, do students learn anything about why things sink or float (e.g., opposing forces, comparative density)? Is it even possible to expect that young students could learn any aspects of such difficult concepts? I (Professor Smithenry) pondered these questions with a student (Ms. Kim) in my science methods course as she prepared to teach the sink or float lesson

In the end, we found that it was possible to design and enact a lesson that modified the activity to teach more than the science process skill of prediction. We will explain this science lesson and discuss how Ms. Kim's kindergarten students built a working, conceptual model that allowed them to understand how a hollow object could be made to sink by adding mass to its inside.

Professor Smithenry's Perspective

Beyond Process Skills

It is important for teachers to clearly identify what it is that they want their students to learn in any science lesson (e.g., process skills, scientific concepts). For the process skill, Ms. Kim knew that she wanted students to learn how to make predictions and then test them. As for the scientific concept, although Ms. Kim knew that density helps explain why things sink or float, she wondered whether this would be too difficult for kin-

To help with our own conceptual understanding, we first explored why the concept of density helps to explain why things sink or float. We did so by developing a model (Figure 1) that contained a *greatly simplified* representation of three substances: liquid water, an object that floats on water, and an object that sinks in water. Each representation (a) incorporated the idea that all matter is made up of particles that are too small to be seen by the naked eye and (b) illustrated how closely the substance's particles are packed together. (Note: In the case of water [H_2O], each black dot represents one particle [or molecule] of water that, in turn, contains two hydrogen atoms bonded to a central oxygen atom.) For the object that sinks in water, the model suggests that its particles are packed more closely together in comparison to the packing of the water particles. Because of this difference in particle packing, the object is denser than water and it sinks. For the object that floats in water, the reverse is true.

Suppose the object that floats on top of the water is a piece of plastic. In this case, the plastic contains particles that may consist of millions of carbon and hydrogen atoms bonded together into long chains. In comparison to a water particle, the mass of each plastic particle is a million times greater. Yet, millions of water particles—which have a greater mass than one plastic particle—can fit into the same space that one plastic particle occupies. So, in this scenario, the net effect is that the liquid water has more mass packed in a similar volume, which is the reason why the water is denser than the plastic and causes the plastic to float.

Kindergartners cannot be expected to understand this. Research literature indicates that most young children do not view matter as being made of discrete particles that are too small to be seen by the naked eye (Driver et al. 1994; Keeley, Eberle, and Tugel 2007). Although students view matter as being continuous, the research does suggest that the earliest notion of density appears for children between the ages of 5 and 7 as they begin to refer to an object as being "heavy for [its] size" (Driver et al. 1994; Smith, Carey, and Wiser 1984). With this in mind, we tried to think of ways to use certain aspects of the particulate model that would build on the kindergartners' nascent notion of density.

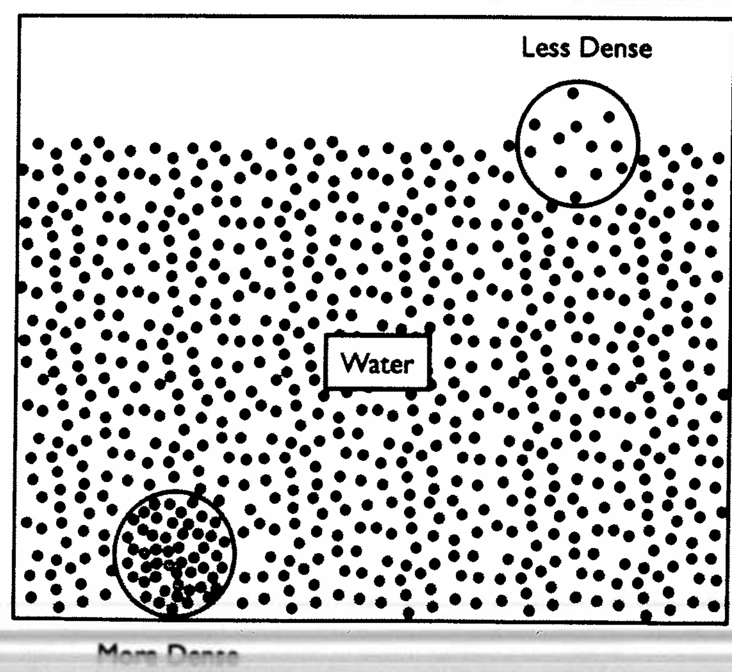
Developmentally Appropriate Lesson

According to Smith, Carey, and Wiser (1984), children younger than age five typically ignore an object's size and focus on its "felt weight" (by picking up an object and hefting it) when predicting whether certain objects will sink or float. They commonly propose that lighter objects float and the heavier ones sink. As children grow older (between ages five and seven), they begin to incorporate both ideas of felt weight and size into their earliest notion of density (Smith, Carey, and Wiser1984). This aforementioned notion has been labeled *heavy for size*. Thus, when children of this age are asked to predict whether an object will sink or float in water, they still have the tendency to heft the object, but also make note of its size. Interestingly, a recent study (Kloos 2008), which used a new experimental context, showed that children as young as age three were capable of distinguishing objects with salient differences in density. These new results suggest that children may develop an intuitive sense of density at a young age.

Knowing that kindergartners would be likely tuning into an object's mass (no matter what their current notion of density was) when asked to predict if it will sink or float in water, we refocused our attention to the concept of mass as represented in the particulate model in Figure 1. In doing so, we realized that, at the microscopic level, mass could be related to the number of particles (atoms) that the object contains. This realization gave us the idea that we might have students vary the mass of an object by changing the number of particles that one object contains at the macroscopic level. Why not use a hollow container that floats, and then add units of a different material until

Figure 1.

Particulate model used to explain sinking and floating.



it sinks? In this way, the students would be changing the density of the container (i.e., the container's volume would stay the same while the total mass increases) by changing just one independent variable (mass).

Instead of giving students a range of common objects in which both mass and volume is varied (e.g., golf ball, [illegible]) as in the typical sink or float activity, we played with the idea of giving students one plastic egg and a pile of marbles. With these materials, the students would only be varying the mass of the system (by changing the number of marbles within the plastic egg) while keeping its total volume constant. In addition, as they added more marbles to the egg, the students would see that there was some point when the system began to sink—this point would relate directly to how many marbles (mass) they added. At least with this scenario, if the students explained that "heavier objects sink," Ms. Kim would only need to attach the caveat "of the same volume" to make their explanations scientifically accurate. What is more, we found that this type of activity would allow Ms. Kim to introduce a powerful, easily-understood, driving question into her lesson: How many marbles must be added to make the plastic egg sink?

Ms. Kim's Perspective

The Lesson

To begin the lesson, I told my students we would be studying sinking and floating. I told them that they would be scientists during the lesson who observe carefully, record what they observe, and think about what they are doing. As the anticipatory set, I asked, "Do you sink or float in the swimming pool?" I could tell that some students were uncertain of the verbs in my question, so I asked the students why children use "floaters" in the swimming pool. Several responded that they needed floaters because they could not swim on their own. I then stressed that floaters allowed children to *float* at the top of the water; without them, children might *sink* to the bottom of the pool.

Then, I introduced the plastic egg. I asked whether they thought the egg would sink or float in a tub of water. We took a blind vote, and there was a tie; nine students predicted that the egg would float and nine predicted it would sink. When I put the egg into a tub of water and it floated, the class expressed surprise and excitement. I then showed my students how to record this result on a data chart.

Rather than asking them to explain why the egg floated, I opened up the plastic egg to show them that it only contained air and asked them to think about the following question, "How do you think that we could make this egg sink?" The students had several ideas. Frank suggested that we put rocks inside it. Blanca proposed that we should add ice cubes. Heidi wanted to add coins. Shinji recommended that we add chocolate! I acknowledged these answers, and then pulled some marbles out of my pocket, telling them that I had also thought that we should add something inside the egg. At this point, I prepared two eggs without telling the students how many marbles I had added to each. I shook the eggs to let them know that the eggs now contained marbles and proceeded to put them into the water. They observed that one floated and one sank. They were amazed!

After my students quieted down, I announced that they would work in pairs to determine how many marbles it takes to get the egg to sink. I divided the class into nine pairs and handed out a data sheet. I had each pair record the result for an egg with no marbles and then discussed how to test and record the results for an egg with one, two, and three marbles. Last, we reviewed how to work appropriately with the given materials (e.g., do not splash water or throw marbles, take turns).

CAUTION

Once each pair had gathered their materials, I instructed them to begin by placing one marble into the egg. I circulated among them to ensure that they were placing an X in the float column of their data sheet for an egg with one marble in it. After checking in with each pair, I instructed them to finish the investigation. As I continued circulating, I heard students talking about the investigation and sharing their ideas. Some were predicting before they added the egg into the water whether it was going to sink or float. Others were debating whether an egg had really sunk if it was not fully immersed.

When most had finished their last test, I instructed each pair to clean up any water spills and then come sit on the carpet. Once everyone was

PHOTOGRAPH COURTESY OF THE AUTHORS

Students watch a plastic egg sink in a tub of water.

Figure 2.

Completed sink or float class data chart.

	Sink	Float
		X
		X
		X
	X	

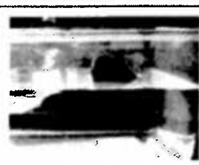
seated, I revealed a big chart that I had made before the lesson. This chart was similar to the students' data tables. I asked them to report their findings and we filled in the chart (Figure 2). Then I asked them to think silently about the following question: Why do you think the egg finally sank with three marbles? When I let them respond, Jose said, "It was heavy." Sabina agreed with Jose, and then offered more detail, "With one marble it was a little heavy and sinking a little; with two marbles it was a little bit heavier and sinking a little more; and with three marbles, it was even heavier and sank." The students liked this answer so I recorded it on the board. I then pointed out that as we added more marbles, the egg's weight had increased, but its overall size (volume) had remained the same.

After this discussion, I had the students go back to their seats and complete a two-part assessment. In the first part, students were asked to (a) recall whether an egg with two marbles would sink or float and (b) predict whether an egg with five marbles would sink or float. In the second part, they were asked to draw in a specific number of marbles that one plastic egg might contain if it were floating and another if it were sinking. I ensured that they understood how to complete each part of the assessment and then allowed them to work on their own quietly.

After the lesson was over, simply out of curiosity, I tried to make further sense of the kindergartner's observations. Specifically, I wanted to confirm through measurements that the density of the plastic egg with two marbles was less than the density of water and that the density of the plastic egg with three marbles was greater. To do so, I used an electronic balance to measure the mass (grams) of the egg with the various combinations of marbles. I also estimated the volume (milliliters) of the egg by filling each half of it with water and pouring both amounts into a graduated cylinder (note: one milliliter equals one cubic centimeter). Because the marbles were placed inside the plastic egg, its

Figure 3.

The calculated densities of the plastic egg with various numbers of marbles.

	Observation	Mass	Volume	Density	Comparison	Float or sink?
Plastic egg		7 g	66 cm^3	0.1 g/cm^3	less than density of water (1.0 g/cm^3)	float
Plastic egg + 1 marble		32 g	66 cm^3	0.48 g/cm^3	less than	float
Plastic egg + 2 marbles		57 g	66 cm^3	0.86 g/cm^3	less than	float
Plastic egg + 3 marbles		82 g	66 cm^3	1.2 g/cm^3	greater than	sink

total volume remains the same regardless of the number of marbles placed within. As shown in Figure 3 (p. 51), my calculations confirmed that the density of the plastic egg system becomes greater than the density of water when it contains three marbles.

What Students Learned

In the first part of the assessment, 17 of 18 students marked correctly that the egg with two marbles would float. These same students also marked correctly that the egg with five marbles would sink. In the second part of the assessment, 16 students drew correctly one or two marbles into the egg that was floating. Of these same students, 10 students drew greater than three marbles (up to 7!) in the egg that had sunk, with the remaining 6 students drawing three marbles.

For several reasons, we feel that the assessment data clearly illustrates what the students took away from the lesson. Although it is likely that the students already came to this lesson with the idea that objects with more mass sink, the data suggests that the students were able to see how incremental changes in mass could make a hollow object go from a floating state to a sinking state. The results also indicate that most students had a firm understanding of the data that they had collected during the experiment. Last, the assessment data suggests that the students did not need to conduct more tests to make the connection that if more than three marbles were added to the egg, it would sink. This last finding implies that these kindergartners were able to extrapolate from their collected data and make accurate predictions about how the number of marbles affected the plastic egg's buoyancy.

Summary

By thinking about the concept of density and taking into account the research on children's ideas about this concept, we were able to unpack the typical sink or float activity and realize that it has students unscientifically making comparisons between objects by changing two independent variables (mass and volume) at one time. With this realization, we were able to modify the activity so that students were making comparisons in which they were only changing one independent variable (mass). The end result went well beyond the common "prediction" objective found in the classic sink or float activity.

Ms. Kim's students developed a working, conceptual model that allowed them to correctly answer untested questions about the plastic egg system. When the students explained that the egg was getting "heavier," they were basing this explanation on having purposefully increased the egg's overall mass (by adding marbles) while keeping its volume constant. Even though the students were unaware that they were increasing the egg's *density*, they were experimenting with the idea that putting more mass into a given space can make an object sink. And this idea, like planting seeds, will serve them well when they *are* formally introduced to the concept of density in later grades. ■

Dennis W. Smith ([illegible]@elmhurst.edu) is an assistant professor in the Department of Education at Elmhurst College in Elmhurst, Illinois. Jenny Kim (kim_jenny@cusdk8.org) *is a fifth-grade teacher at Montclaire Elementary in Los Altos, California.*

References

Banchi, H., and R. Bell. 2008. The many levels of inquiry. *Science and Children* 46 (2): 26–29.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* New York: Routledge.

Keeley, P., F. Eberle, and J. Tugel. 2007. *Uncovering student ideas in science: 25 more formative assessment probes,* vol. 2. Arlington, VA: NSTA Press.

Kloos, H. 2008. Will it float? How invariance affects children's understanding of object density. In *Proceedings of the 30th Annual Conference of the Cognitive Science Society,* ed. B.C. Love, K. McRae, and V.M. Sloutsky, p. 687-692. Austin, TX: Cognitive Science Society.

Smith, C., S. Carey, and M. Wiser. 1984. A case study of the development of size, weight, and density. *Cognition* 21 (3): 177–237.

Watson, S. 2008. Discovery bottles: A unique inexpensive tool for the K–2 science classroom. *Science and Children* 45 (9): 20–24.

NSTA Connection

Download a blank data chart and assessment worksheet at *www.nsta.org/SC1010.*

Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Content Standards

Grades K–4

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry

Standard B: Physical Science

- Properties of objects and materials

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academies Press.