



PCK Tools

Density: Instructional Support Abstract

Density is defined as the mass per unit volume of a given substance. On paper, it seems simple enough: Determine the mass and the volume of a particular substance and calculate the density. It seems simple—if students understand the concepts of mass and volume and how to determine them, but students have much difficulty with this.

Mass is a property that reflects the quantity of matter within a sample. The mass within a sample could refer to the mass in a single atom that we cannot see, or the mass of vast quantity of atoms that make up an object such as a rock that we can experience or perceive. *Mass* is different from *weight*, in that the weight of an object is the force that gravity exerts on the mass of the object. Thus the mass of an object such as bowling ball would be the same on both the earth and the moon, but the weight of the bowling ball would be different since the force of gravity of an object is different on the moon than on Earth.

Volume is the space that matter occupies. Since these two physical properties affect density, it is not surprising that the densities of different objects or materials differ, whether they be different planets, different gases, different rocks, or different atoms.

Note that the inclusion of both mass *and* volume in determining density can sometimes fool students when they are asked to compare densities of different objects because a smaller object may have more mass packed within it (e.g., more mass per unit of volume) than a larger object. Moreover, a student may be very adept at determining density and still not be able to apply mass per unit volume as a property of a substance or object. Many teachers report that middle-school students struggle with both the calculation and the concept of density. While the research is limited, there are studies that offer some insights into challenges associated with learning about density as well as suggestions for improving students' understanding of density.

Research on the Teaching and Learning of Density

Student Conceptions about Mass, Volume and Density

In interviews with three different classes of 7th graders (a total of 60 students), Rowell and colleagues (1990) learned that over 80% of students held misconceptions about volume. When asked questions about the amount of water that would be displaced by two different objects, students gave a variety of reasons for their answers. Thirty-five percent thought the amount of water displaced was determined by the weight of the object. For these

students, heavier objects displace a greater volume of water. The remaining explanations were split among shape, volume, mass, and surface area.

Genarro (1981) asked 290 9th graders who had just completed a study of density using the *Introductory Physical Science* (IPS) curriculum a series of six questions. Approximately two-thirds of the students did not fully understand that the volume of water displaced by an object is equal to the volume of the object. This was despite the fact that the students had studied density in both 8th and 9th grades and had performed numerous experiments to calculate density using the water-displacement method.

Based on interviews and written responses from 30 8th graders, Smith, et al., (1997) contend that student ideas about matter, mass, and density not only are related but appear to mutually constrain one another. Those students who had come to believe that all matter must have mass and take up space had begun to differentiate between mass and density. The remaining students who thought matter existed that did not have mass or did not take up space struggled to differentiate between weight and density. The authors propose that students' evolving assumptions about matter often help to initiate student differentiation of the concepts of mass and density.

Teaching Approaches

Smith, et al., (1997) compared the effectiveness of two approaches to teaching density to 8th grade students. One classroom of students was taught using the *Introductory Physical Science* (IPS) textbook (Haber-Schaim, et al., 1987) and the second classroom of students was taught using a modified IPS approach.

The standard IPS approach aimed to develop understanding of density by requiring students to measure physical properties of different substances, providing students with formulas, and having students calculate density using those formulas. However, this approach failed to engage students' preconceptions of density that differed from scientist's conceptions.

The modified IPS approach also asked students to measure physical properties, but in contrast to the standard approach explicitly engaged students' initial understandings and presented multiple representations and conceptual models to begin to build a bridge between qualitative and quantitative conceptions. The modified approach incorporated a research-based instructional design framework from Posner, et al., (1982) that suggests that in order to move students from their incorrect preconceptions to more scientifically accepted conceptions, the students need to be dissatisfied with their current conceptions and also find a new alternative conception **intelligible, plausible, and fruitful**. For example, in the standard curriculum, it was assumed that students already had mastered an understanding of matter, volume, and mass. The modified version, in contrast, did not assume this and instead focused on helping students to construct an understanding of these concepts and addressed alternative student ideas that needed to be restructured or reorganized in the process of developing an understanding of matter and density.

Both groups made dramatic improvements in their quantitative understanding of density and their ability to make simple calculations of mass, volume, and density. When it came to qualitative understandings, however, the modified approach was much more successful. The main conclusion drawn by the authors was the importance of taking students' starting conceptions seriously by explicitly addressing those conceptions and allowing students the opportunity to think through and reason about the relative merit of their ideas.

Rowell, et al., took a very similar approach, stressing the importance of specifically eliciting and addressing students' conceptions, as well as providing students with a "new way" or better way of thinking about the concept. Their research focused on teaching students the concept of object volume being equal to displacement volume. These authors expected that the majority of students would begin the unit not understanding that the displacement volume would equal the object volume when an object is placed in water. The most effective approach the authors used in the three classrooms tested was to first teach students the "better theory," in this case that the displacement volume is equal to the object volume as opposed to being equal to the weight, shape, amount, etc. The next step was to use both the better theory—new way—and the students' initial conceptions—old way—to calculate displacement volume. This process was repeated a number of times for each of the student conceptions, and in this way, each misconception was publicly proven to be inadequate.

While both the Smith and Rowell studies were small in scale, they point to specific ways in which teachers might be able to improve students' qualitative and quantitative understanding of density based on an approach to learning that utilizes the conceptual change model of teaching and learning.

- First, assess your students before beginning the unit so you can identify what misconceptions exist. Most likely, they will carry some of the misconceptions mentioned above.
- Second, make a point of having students discuss those misconceptions in class.
- Third, create situations that will test those misconceptions and prove they are in error in explaining a specific phenomena.
- Fourth, teach them a better way of thinking about the concept and prove that this new approach can be used to explain specific phenomena that their preconceptions could not fully explain.

One activity for teaching the concept of density could be to have students measure the mass and volume of several pieces of the same substance, then do either of the following:

1. Divide the masses by the corresponding volumes and compare the results; or
2. Make a graph of the mass values (on the y-axis) versus volume values (on the x-axis) and note that the result is a straight line. The slope of the graph, which is a constant for all the data points, is the density.

References

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