Seeing Weight, Grasping Density

The Inquiry Project
David W. Carraher, Sue Doubler, Jodi Asbell-Clarke, Roger Tobin*
Analucia D. Schliemann*, Carol L. Smith**, Marianne Wiser***, Paul Wagoner
Chunhua Liu*, Sally Crissman, Nick Haddad, Sara Lacy, Lynn McCormack
TERC, Tufts University (*), U-Mass Boston (**), Clark University (***)

-What does it look like to begin reasoning early about density before definitions and formulas?
-What sorts of classroom activities and teaching approaches might support this?

Although it may be too early to formally introduce density in grade 4, it is not too early to begin reasoning about the concept.

In the present examples, density is broached indirectly in activities of: (1) ordering materials of equal volumes by weight; (2) ordering equal weights of materials by volume; and (3) inferring the materials of covered objects.

Students eventually realize that certain materials are relatively heavy or "heavy for their size" and that this is different from their scale weight.

In grade 5, this working knowledge of density comes in handy when students face issues related to change of state—for example, when liquid water transforms into a larger volume of ice having the same mass.

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1-Ordering Materials of Equal Volumes by Weight

Students are encouraged to place samples of different materials in order by their weight. Because each sample has the same volume, the order is also related to each material's density. The activity serves to introduce conventions by which physical quantities are represented through distances. It also sets the stage for discussions about the ratio of weight to size (volume) for different materials.

Teacher: "I want to see whether you can put the materials on the line, from from heavier to lighter."

Figure 1: A student orders the materials (from left to right): humus, water, mineral oil, sand. There then ensues a discussion as to whether the mineral oil and water should be exchanged.

How can I get the students to express the magnitudes of the *differences* in weights?

Teacher: "Ok, let's think about this. Can we tell how much more something weighs just by looking at the line?"

Figure 2: A student spreads out the materials evenly. Other students suggest alternative spacings. They come to the conclusion that the line needs to be a number line. Initially there is some doubt as to whether the numbers will represent distances (cm) or weights (g).

Some materials are heavier than others.

Teacher: Is he referring to weight or heaviness for size?

Figure 3: A students orders equal volumes of different materials by weight. A teacher might use the activity to introduce *heavy for size* (the ratio of weight to volume) as a bridge between weight and density.

2-Ordering Equal Weights of Materials by Volume

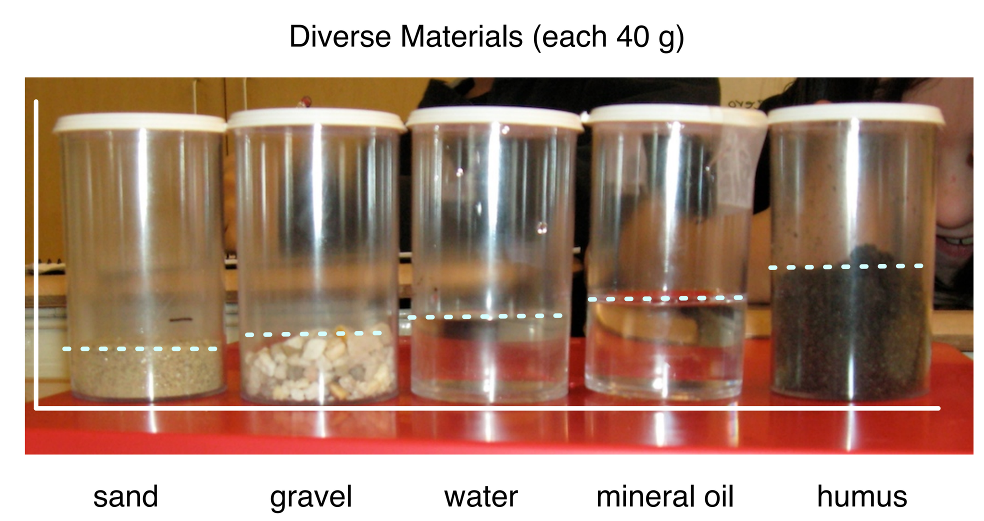

Figure 4: Students measure out 40 g of sand, gravel, water, mineral oil, and humus and examine the differences in volume. Why do some samples take up less (or more) space than others?

Students determine the volume of equally weighted samples of materials. This provides another context for exploring the relations among weight, volume, and material and to allude to density well before introducing a formal definition or referring to the division of an object's weight by its volume.

The weight of some materials is more spread out.

Teacher: This is like the ratio of volume to weight (the reciprocal of density)

Figure 5: A student orders equal weights of different materials by volume. Students sometimes are drawn to the ratio of volume to weight (how much the weight is spread out or distributed). This is the reciprocal of density.

3-Inferring Materials of Covered Objects

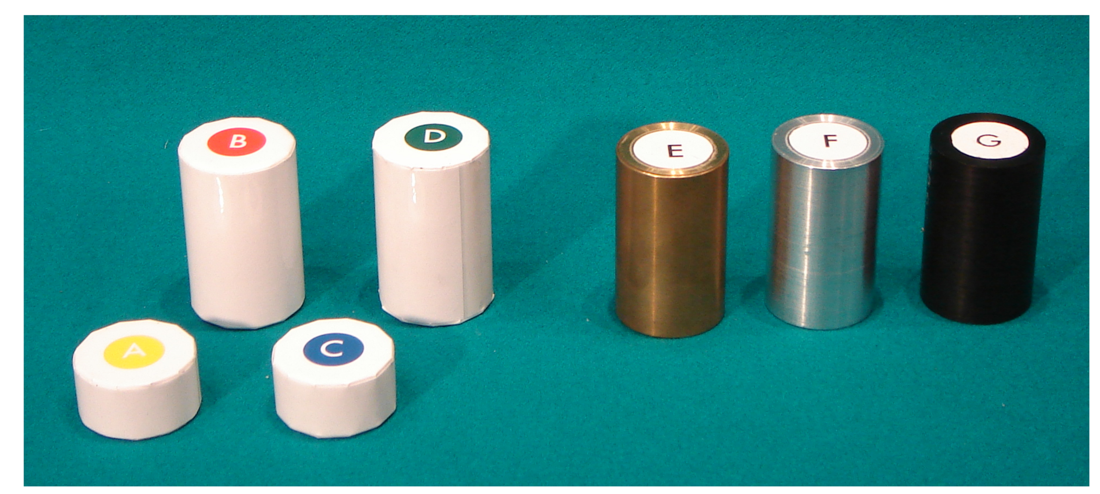

Figure 6: During individual interviews, students are challenged to determine whether cylinders A, B, C, and D might be made of brass (E), aluminum (F) or Delrin (G). A and C are 1/3 the volume (and height) of the other cylinders. Multiple copies of the smaller cylinders (A & C) are readily available.

Even though students could neither define nor calculate density, they were able to indicate their understanding through other means. Students were asked to determine possible materials for the four covered cylinders in Figure 6. It was relatively easy (86% correct) to reason about the case of cylinder B (aluminum) because the weight comparison on the balance scale was straightforward.

The short cylinders (A and C) could not be directly compared. (But there were multiple copies of the short cylinders!)

Of those students who had the insight to systematically stack copies of cylinders C, 88.7% correctly concluded that C could be made of aluminum. (Only 14.5% of those who did not stack made such an inference.)

The Inquiry Project students were better than the control students (53.7% vs. 27.8%) in inferring the material of C. They were also much more likely (48.1% vs. 22.2%) to spontaneously employ a correct stacking procedure in their problem-solving. Between the end of grade 3 to the end of grade 4, 40.0% of the treatment students improved on this task, as opposed to only 19.2% of the control students.

"Developmental Readiness"

The Piagetian Dilemma (Duckworth, 1979): "Either we're too early and they can't learn it or we're too late and they know it already".

How can students reason about *density* if they don't already have the concept?

The Learning Paradox (Bereiter, 1985): "if one tries to account for learning by means of mental actions carried out by the learner, then it is necessary to attribute to the learner a prior cognitive structure that is as advanced or complex as the one to be acquired".

Why teach students definitions and formulas they are not ready to understand?

The above are *false dilemmas* because they treat concepts as things students either do or do not know. Teachers can promote various forms of tacit understanding of a concept before the concept is explicitly represented.

The Inquiry Project

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The Inquiry Project—a collaboration between TERC, Tufts University, and two schools in Greater Boston—investigates students' scientific understanding from 8 to 11 years of age (Grades 3-5), with special emphasis on their evolving concepts of material, weight, volume, density and states of matter.

As a research endeavor, it aims to clarify how these concepts develop over time, how they can be successfully nurtured through instruction, and how they prepare students for later learning about the atomic molecular theory of matter.

As an endeavor in curriculum development and teacher education, it test ideas about the teaching and learning of these concepts.

Bereiter, C. (1985). "Toward a Solution of the Learning Paradox." Review of Educational Research 55(2): 201-226.

Duckworth, E. R. (1979). "Either we're too early and they can't learn it or we're too late and they know it already: the dilemma of 'applying Piaget'." Harvard Educational Review 49(3): 297-312.

TERC Tufts University

http://inquiryproject.terc.edu/
email: inquiryproject@terc.edu