Thoughts on Designing Learning Progressions for the Particulate Theory of Matter

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The goal of this talk is to stimulate discussion about how we might design long term learning progressions (spanning the K-8 years and beyond) that would allow students to more deeply understand important "big ideas" in science such as the particulate theory of matter. Such learning progressions are constrained (on one end) by what we know about student starting understandings about matter, physical quantities, measures and models in kindergarten and (at the other end) by what we think it is important for students to understand about the particulate theory of matter by the middle and high school years. We then need to imagine the possible pedagogical paths and intermediate understandings that might genuinely bring students from where they start to where we want them to go. The argument will be that it is important to think about learning over a broader time scale than we typically do if we hope to develop these understandings and to plan a coherent science curriculum. In addition, I will argue there are important foundational ideas that can be developed during the elementary school years that prepare students for learning about the particulate theory of matter in middle school, yet which rarely are. These include some core macroscopic understandings about matter, weight, and density, as well as epistemological understandings of the role of measurement, models, data, and argument in science. Although there are still big hurdles in developing an understanding of the particulate theory of matter, I will argue that overcoming these hurdles becomes *at least possible* if these foundational understandings are in place. Finally, I will argue that at all levels of the curriculum it is important to think about how developing children's epistemological and mathematical insights goes hand-in-hand with their constructing deeper understandings in science.

Background of speaker: Carol Smith is a cognitive and developmental psychologist at the University of Massachusetts/Boston who has done research over the past 20 years on children's conceptions of matter, weight, density, volume as well as their understanding of the role of models in science. She has participated in designing innovative instruction units and software to help students develop their understanding of weight, volume, and density as measurable and inter-related physical quantities and to help them understand the particulate theory of matter as an explanatory model. She has also studied the effectiveness of these instructional approaches in bringing about conceptual change. More recently she has worked on two committees for the National Academy of Science: one that was specifically charged with developing a learning progression for the particulate theory of matter in the K-8 years (see 2006 paper that appeared in the journal Measurement, listed below) and the other that was concerned more broadly with synthesizing the current developmental and science education literature that bears on what we know about how children learn science (see preprint of book Taking Science to School, edited by R. Duschl et al., available on the website of the National Academy of Science.)

Some relevant recent publications:

Smith, C., Maclin, D., Grosslight, L. and Davis, H. (1997) Teaching for understanding: A comparison of two approaches to teaching students about matter and density. Cognition and Instruction, 15 (3), 317-393.

Smith, C., Maclin, D., Houghton, C. and Hennessey, M.G. (2000) Sixth graders' epistemologies of science: The impact of school science experiences on epistemological development. Cognition and Instruction, 18(3), 349-422.

Smith, C. (2002). Conceptual change. In J. Guthrie (Ed.), Encyclopedia of Education, 2nd Edition. New York: MacMillan Reference.

Snir, J., Smith, C., and Raz, G. (2003) Linking Phenomena with Competing Underlying Models: A Software Tool for Introducing Students to the Particulate Model of Matter. Science Education, 87, 794-830.

Smith, C., Solomon, G., and Carey, S. (2005). Never getting to zero: Elementary school students' understanding of the infinite divisibility of matter and number. Cognitive Psychology 51, 101-140.

Smith, C., Wiser, M., Anderson, C., and Krajcik, J. (2006) (Focus Article of combined double issue of journal): Implications of Research on Children's Learning for Standards and Assessment: A Proposed Learning Progression for Matter and Atomic-Molecular Theory. Measurement, 14 (1&2), 1-98.

Smith, C. and Wenk, L. (2006--in press) The Relation Among Three Aspects of College Freshmen's Epistemology of Science. Journal of Research in Science Teaching (pp. 1-39)