Much Ado About Nothing

How children think about the small-particle model of matter.

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If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generations of creatures, what statement would contain the most information in the fewest words? I believe it is the *atomic hypothesis* (or the atomic *fact*, or whatever you wish to call it) that *all things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another*. In that one sentence, you will see, there is an enormous amount of information about the world, if just a little imagination and thinking are applied (Feynman, Leighton, and Sands 2011, p. 4).

What Richard Feynman referred to as the atomic hypothesis is perhaps more familiar to us as the small-particle model of matter. In its most basic form, the model states that all matter is made of particles that are too small to see, which have empty space between them and are in constant, random motion. As Feynman suggests, an understanding of this model equips students to explain a broad range of phenomena. The *Next Generation Science Standards* (*NGSS*) echo this sentiment:

> A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects (NGSS Lead States 2013, p. 43).

The small-particle model, depending on the level at which students engage with it, can be extremely complex. Historically, national standards have introduced the topic no earlier than the middle grades. The *National Science Education Standards* did not include it until grades 9–12, explaining:

> It can be tempting to introduce atoms and molecules or improve [grades 5–8] students' understanding of them so that particles can be used as an explanation for the properties of elements and compounds. However, use of such terminology is premature for these students and can distract from the understanding that can be gained from focusing on the observation and description of macroscopic features of substances and of physical and chemical reactions (NRC 1996, p. 149).

The *Benchmarks for Science Literacy* first mention the particle model in grades 6–8, stating, "By the end of eighth grade, students should have sufficient grasp of the general idea that a wide variety of phenomena can be explained by alternative arrangements of vast numbers of invisibly tiny, moving parts" (AAAS 1993).

In contrast, the *NGSS* introduce the small-particle model in fifth grade but discourage discussion of atomic/molecular mechanisms until later (NGSS Lead States 2013, p. 43). This recent shift in the national standards means that instructional materials that fifth-grade teachers can use to teach the small-particle model are sparse at best. Until instructional materials catch up with the *NGSS*, teachers will have to rely on their own resources even more than usual to design instruction.

A critical step in any instructional design process, regardless of the topic, is developing a firm grasp of how students are likely to think about the content. So, in considering the small-particle model, how do fifth-grade students begin to understand how matter is structured? What ideas are they likely to bring into the classroom? How can teachers assess student thinking? In this article, we address these important questions and provide practical guidance.

We begin, however, with two cautions. First, simply telling students the ideas in the small-particle model is highly unlikely to be effective. Students likely have tacit notions of matter. Therefore, students need oppor-