4th Grade Matter Unit
Student Misconceptions

Scientific Inquiry (AAAS, 1993, pp. 332 & 360)

Students of all ages may overlook the need to hold all but one variable constant, although elementary students already understand the notion of fair comparisons, a precursor to the idea of "controlled experiments" (Wollman, 1977a, 1977b; Wollman & Larson, 1977).

Upper elementary-school students can reject a proposed experimental test where a factor whose effect is intuitively obvious is uncontrolled, at the level of "that's not fair" (Shayer & Adey, 1981). "Fairness" develops as an intuitive principle as early as 7 to 8 years of age and provides a sound basis for understanding experimental design. This intuition does not, however, develop spontaneously into a clear, generally applicable procedure for planning experiments (Wollman, 1977a, 1977b; Wollman & Larson, 1977). Although young children have a sense of what it means to run a fair test, they frequently cannot identify all of the important variables, and they are more likely to control those variables that they believe will affect the result.

Upper elementary and middle-school students who can use measuring instruments and procedures when asked to do so often do not use this ability while performing an investigation. Typically a student asked to undertake an investigation and given a set of equipment that includes measuring instruments will make a qualitative comparison even though she might be competent to use the instruments in a different context (Black, 1990). It appears students often know how to take measurements but do not know when to measure or what to measure.

Students tend to look for or accept evidence that is consistent with their prior beliefs and either distort or fail to generate evidence that is inconsistent with these beliefs. These deficiencies tend to mitigate over time and with experience (Schauble, 1990).

Nature of Matter (AAAS, 1993, p. 336)

Elementary and middle-school students may think everything that exists is matter, including heat, light, and electricity (Stavy, 1991; Lee et al., 1993). Alternatively, they may believe that matter does not include liquids and gases or that they are weightless materials (Stavy, 1991; Mas, Perez, & Harris, 1987).

Students at the end of elementary school and beginning of middle school may be at different points in their conceptualization of a "theory" of matter (Carey, 1991; Smith et al., 1985; Smith, Snir, & Grosslight, 1987). Although some 3rd graders may start seeing weight as a fundamental property of all matter, many students in 6th and 7th grade still appear to think of weight simply as "felt weight"—something whose weight they can't feel is considered to have no weight at all. Accordingly, some students believe that if one keeps dividing a piece of Styrofoam, one would soon obtain a piece that weighed nothing (Carey, 1991).

Conservation of Matter (AAAS, 1993, pp. 336-337)

Students cannot understand conservation of matter and weight if they do not understand what matter is, or accept weight as an intrinsic property of matter, or distinguish between weight and density (Lee et al., 1993; Stavy, 1990). By 5th grade, many students can understand qualitatively that matter is conserved in transforming from solid to liquid. They also start to understand that matter is quantitatively conserved in transforming from solid to liquid and qualitatively conserved in transforming from solid or liquid to gas—if the gas is visible (Stavy, 1990).

Heat, Temperature, & Energy Transformations (AAAS, 1993, pp. 337-338)

The following research applies to middle school and high school students. It is included to alert teachers to some deeply held misconceptions that are often carry into adulthood.

Even after some years of physics instruction, students do not distinguish well between heat and temperature when they explain thermal phenomena (Kesidou & Duit, 1993; Tiberghien, 1983; Wiser, 1988). Their belief that temperature is the measure of heat is particularly resistant to change. Long-term teaching interventions are required for upper middle-school students to start differentiating between heat and temperature (Linn & Songer, 1991).

Middle-school students do not always explain the process of heating and cooling in terms of heat being transferred (Tiberghien, 1983; Tomasini & Balandi, 1987). Some students think that "cold" is being transferred from a colder to a warmer object, others that both "heat" and "cold" are transferred at the same time. Middle- and high-school students do not always explain heat-exchange phenomena as interactions. For example, students often think objects cool down or release heat spontaneously—that is without being in contact with a cooler object (Kesidou, 1999; Wiser, 1986). Even after instruction, students don't always give up their naïve notion that some substances (for example, flour, sugar, or air) cannot heat up (Tiberghien, 1985) or that metals get hot quickly because "they attract heat," "suck heat in," or "hold heat well" (Erickson, 1985). Middle-school student believe different materials in the same surroundings have different temperatures if they feel different (for example, metal feels colder than wood). As a result, they do not recognize the universal tendency to temperature equalization (Tomasini & Balandi, 1987).

Water Cycle & Changes in States of Matter

Students' ideas about conservation of matter, phase changes, clouds, and rain are interrelated and contribute to understanding the water cycle. Students seem to transit a series of stages to understand evaporation. Before they understand that water is converted to an invisible form, they may initially believe that when water evaporates it ceases to exist, or that it changes location but remains a liquid, or that it is transformed into some other perceptible form (fog, steam, droplets, etc.) (Bar, 1989; Russell, Harlen, & Watt, 1989; Russell & Watt, 1990). With special instruction, some students in 5th grade can identify the air as the final location of evaporating water (Russel & Watt, 1990), but they must first accept air as a permanent substance (Bar, 1989). This appears to be a challenging concept for upper elementary students (Sere, 1985). Students can understand rainfall in terms of gravity in middle school but not the mechanism of condensation, which is not understood until early high school (Bar, 1989). (AAAS, 1993, p. 336)

Four stages in children's progression of understanding of evaporation and condensation:

1. Water disappears, prevalent with younger students;
2. Water is absorbed into surfaces, a view that appears at about age 7. This represents a move from a descriptive to a reasoning view in which children reconcile their adoption of a conservation view with the contradictory fact of water no longer being perceptible;
3. Water is transferred ('evaporates') to another (upward) location such as the sky, clouds, ceiling or 'air'. The transition to this view occurs at about age 9, with children's developing views about air, but appears earlier with the boiling phenomenon because of the readily apparent agency of heat providing the upward move; and
4. Water disperses into air, associated with a phase change. This view becomes predominant by age 13. (Tyler, 2000, p. 450)

Misconceptions about Constancy and Change (AAAS, 1993, p. 357)

Lower elementary-school students fail to conserve weight and volume of objects that change shape. When an object's appearance changes in several dimensions, they focus on only one. They cannot imagine a reversed or restored condition and focus mostly on the object's present appearance (Gega, 1986). The ability to conserve develops gradually. Students typically understand conservation of number between the ages of 6 and 7, of length and amount (solid and liquid) between 7 and 8, of area between 8 and 10, of weight between 9 and 11, and of displaced volume between 13 and 14. These ages will vary when different children are tested or the same children are tested in different contexts (Donaldson, 1978).

Sources:

American Association for the Advancement of Science (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

Tyler, R. (2000). A comparison of year 1 and year 6 students' conceptions of evaporation and condensation: Dimensions of conceptual progression. *International Journal of Science Education, 22(*5), 447-467.