Engaging Students in Phenomena Related to Matter Transformation in Plants

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Abstract

Much of science involves finding patterns in observations and explaining them in terms of a small number of principles or ideas. For students to appreciate how science works, they need to have a sense of the range of observations (phenomena) that are used to form the patterns and the helpfulness of the principles or ideas in explaining them. Project 2061's evaluations of science textbooks revealed that textbooks rarely engaged students with phenomena relevant to important science ideas, rarely included phenomena that directly address the often incorrect ideas that students may already have, and rarely guided students in reconciling phenomena with scientifically accepted ideas (Kesidou & Roseman, 2002; Stern & Roseman, 2004; American Association for the Advancement of Science [AAAS], 2002; 2005). In response to these deficiencies, Project 2061 and other CCMS researchers are identifying phenomena that could be used to support the teaching and learning of ideas recommended in *Benchmarks for Science Literacy* (AAAS, 1993) and in *National Science Education Standards* (National Research Council, 1996).

This poster provides examples of phenomena aligned to middle school key ideas about the transformation of matter in living systems, specifically focusing on examples from plants. By their nature, living systems exhibit a degree of complexity that often requires students to utilize multiple key ideas in order to develop an understanding of any particular phenomenon. While this may pose a challenge to students and teachers alike, it also presents an opportunity for students to develop connections between key ideas and begin to recognize the importance of this set of interconnected ideas in explaining the growth and development of living organisms.

Selected Key Ideas

Idea A: Plants make their own food in the form of sugar molecules from carbon dioxide molecules and water molecules.

Idea B: Plants use sugar molecules to make more complex molecules that become part of their body structures.

Idea C: If not used immediately as a source of chemical energy or as building material, molecules from food are stored for later use.

What Students are Expected to Know

- Plants make their own food in the form of sugar molecules by means of a chemical reaction between carbon dioxide molecules and water molecules.
- Molecules from food (in the form of sugars that a plant makes) are reassembled into more complex molecules that make up a plant's body structures--such as stems, trunk, leaves, roots, fruit, and seeds.
- Molecules from food are stored and available for later use as a source of energy and building material if they are not used immediately. These molecules from food are chemically changed into new molecules (such as starch or fats) before they are stored.

Ideas Students Have

- Students think that plants have multiple food sources rather than that their only source of food is the food that they make from water and carbon dioxide (Anderson, Sheldon, & Dubay, 1990; Roth & Anderson, 1987).
- Students see food as any material (water, air, minerals, etc.) that organisms take in from their environment (Anderson, Sheldon, & Dubay, 1990; Roth & Anderson, 1987; Simpson & Arnold, 1982).
- Students think that food enters the plant through the roots, or that the roots are used for feeding (Anderson, Sheldon, & Dubay, 1990; Roth & Anderson, 1987; Simpson & Arnold, 1982; Vaz, Carola, & Neto, 1997; Wandersee, 1983).
- Students view food as merely a necessary condition for growth, rather than a source of materials for growth (Smith & Anderson, 1986).

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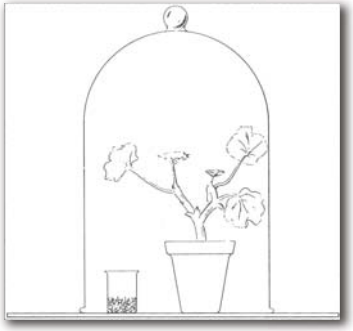
Students are expected to know that matter transformations involve chemical reactions in which carbon atoms are rearranged, but at the 6-8 grade level, students are not expected to know the structures or formulas for any of the reactants or products of the chemical reactions. The phenomena described on this poster address matter transformation in plants at the substance level. Corresponding representations that illustrate the rearrangement of atoms —from simpler molecules to more complex molecules and body structures—are needed to relate matter transformation at the substance and molecular levels.

Phenomenon 1: Comparing starch production by plants grown with and without carbon dioxide

Source: Morholt & Brandwein (1986)

Students observe that when a geranium plant is grown under a bell jar with plenty of light, water, and air, Lugol's solution will stain the leaves an intense dark blue. If a beaker of potassium hydroxide is placed under the jar with the plant and kept there for several days, Lugol's solution will no longer stain the leaves.



- To interpret these observations, students need to know that Lugol's solution turns dark blue in the presence of starch but not in its absence. Students also need to know that potassium hydroxide removes carbon dioxide from the air.
- With this understanding of the methods used to test for the presence of starch, students can infer from their observations that plants grown in the presence of carbon dioxide produce starch whereas plants grown in the absence of carbon dioxide do not produce starch.
- To explain the observation that the plant grown in the presence of carbon dioxide makes starch, students will need to know that plants make food in the form of sugar from carbon dioxide (Idea A) and that plants store molecules from food as starch (Idea C).
- To explain the observation that less starch is present when carbon dioxide was removed from the air, students will need to know that plants do not make sugar in the absence of carbon dioxide (Idea A) and that the starch originally in the leaves has been used (Idea C) during the time that the plant could not make sugar from carbon dioxide.

Phenomenon 2: Food storage in bulbs

Students observe that tulip and daffodil bulbs that had their leaves removed the previous year—before the leaves had died on their own—are smaller and produce fewer flowers than bulbs that did not have their leaves removed.

Photo: http://www.julieleung.com/archives/2003_12.html

- To explain these observations, students need to know that plants make food in their leaves in the form of sugar (Idea A). They also need to know that, if not used immediately, these sugars are converted to storage molecules such as starch and fats (Idea C), some of which are stored in the bulb for later use, and that some of these stored molecules from food are used as a source of building material to make body structures (Idea B) such as leaves and flowers the following year.
- To address incorrect ideas that plants obtain their food from the soil or have other sources of food (besides the sugars that they make), students could observe the growth of plants on a gravel substrate or other non-soil medium.

References

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press. ■ American Association for the Advancement of Science. (2002). *Middle grades science textbooks: A benchmarks-based evaluation*. Retrieved June 19, 2007, from http://www.project2061.org/publications/textbook/mgsci/report/index.htm. ■ American Association for the Advancement of Science. (2005). *High school biology textbooks: A benchmarks-based evaluation*. Retrieved June 19, 2007, from http://www.project2061.org/publications/textbook/mgsci/report/index.htm. ■ Anderson, C.W., Sheldon, T.H., & Dubay, J. (1990). The effects of instruction on college nonmajors' conceptions of respiration and photosynthesis. *Journal of Research in Science Teaching*, *27*(8), 761-776. ■ Kesidou, S., & Roseman, J.E. (2002). How well do middle school science programs measure up? Findings from Project 2061's curriculum review. *Journal of Research in Science Teaching*, *39*(6), 522-549. ■ Morholt, E., & Brandwein, P.F. (1986). *A sourcebook for the biological sciences* (3rd ed.). Fort Worth, TX: Saunders College Publishing. ■ National Research Council. (1996). *National science education standards*. Washington, D.C.: National Academy Press. ■ Roth, K.J., & Anderson, C.W. (1987). *The power plant teacher's guide*. (Occasional Paper No. 112). East Lansing, MI: Institute for Research on Teaching, Michigan State University. ■ Simpson, M., & Arnold, B. (1982). The inappropriate use of subsumers in biology learning. *European Journal of Science Education*, *4*, 173-182. ■ Smith, E. L., & Anderson, C. W. (1986). *Alternative student conceptions of matter cycling in ecosystems*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco, CA. ■ Stern, L., & Roseman, J.E. (2004). Can middle-school science textbooks help students learn important ideas? Findings from Project 2061's curriculum evaluation study: life science. *Journal of Research in Science Teaching*, *41*(6), 538-568. ■ Vaz, A. N., Carola, M. H., & Neto, A. J. (1997). *Some contributions for a pedagogical treatment of alternative conceptions in biology: An example from plant nutrition*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Oak Brook, IL. ■ Wandersee, J. H. (1983). Students' misconceptions about photosynthesis: A cross-age study. *Proceedings of the International Seminar on Misconceptions in Science and Mathematics*, 441-466.