Linking textbooks to science learning

Science textbooks are a major source of information in science classrooms, but the quality of this instructional support is often poor. Jo Ellen Roseman examines the evidence

CURRENT EFFORTS to improve K–12 science education are based on the premise that high school graduates need an understanding of the natural world that is richly interconnected. Rather than knowing isolated pieces of information, students should appreciate how the most important ideas fit together and how to apply them in a variety of contexts. The way in which these ideas are presented in textbooks is crucial. In many classrooms, textbooks are the principal source of science content, so what they cover is what gets taught. If there are gaps in the textbooks, there are likely to be gaps in students' learning as well.

To find out what students do and do not know, Project 2061 has been gathering data to help clarify how gaps in textbooks relate to what students know. Founded in 1985, Project 2061 is a long-term initiative of the AAAS (American Association for the Advancement of Science) which aims to help all Americans become literate in science, mathematics, and technology. We have been assessing elements of national and state science curricula through tests that are carefully aligned to each idea. Findings of these studies have implications for the design and use of curriculum materials, and for the preparation and practice of science teachers.

Gaps in the science story

Studies have shown that textbooks play a central role in teaching and learning. With this in mind, we conducted a series of evaluation studies on middle and high school textbooks that were in use from 1997 through 2000 to see how effective they might be in helping students achieve national and state science benchmarks and standards.

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For the nine high school biology textbooks included in our evaluation, we looked at how the textbooks treated several topics – from cell structure and function to heredity, natural selection and evolution, and matter and energy transformations in living systems. We considered whether each textbook presented the relevant ideas coherently and provided adequate support for teaching and learning.

We began our evaluation by first defining ideas that would be essential to understanding each topic. We expected to see those ideas presented as a coherent "story" in the textbooks and at a level of detail and sophistication that would be appropriate for early high school students. For example, in presenting the story of matter transformations in living systems, we expected textbooks to go beyond verbal

descriptions of the general principles, giving examples of observable phenomena involving transformations of substances made from carbon-containing molecules.

We also expected textbooks to engage students using models to relate their observations about the disappearance of the starting substances and the appearance of new substances to the underlying molecular changes. We were not looking for the details of biochemical reactions of photosynthesis or cellular respiration, but we did expect to see ideas presented so that students could develop a LEGO-like mental model for visualizing the conservation of carbon, hydrogen, and oxygen atoms even though the molecules built from those atoms were different. We also looked to see whether textbooks made important connections between the ideas – linking prerequisite

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ideas to key ideas, for example – and the degree to which the textbooks were explicit in describing how one idea related to another.

Our findings showed that, overall, the biology textbooks being used at the time of the evaluation failed to provide a coherent account of the set of ideas or to provide students with opportunities to make sense of them. Nonetheless, there was considerable variation across the nine textbooks in how many and which of the ideas were treated. With this data in hand, we then wanted to find out whether there was a relationship between the number of textbooks that treated an idea and what students who were likely to have used those books had learned.

Measuring students' knowledge

Because of the central importance of ideas about matter and energy transformations to an understanding of the relationship between living things and their environment, Project 2061 has also been collecting data on what students do and do not know about them. As part of an NSF-funded research and development effort focused on science assessment, we have used a rigorous process to develop, test, revise, and retest items that are closely aligned with important ideas found in national and state benchmarks and standards. Each of our items has been administered to approximately 2,000 students, including, in some cases, high school graduates and college undergraduates as well as middle and early high school students.

To examine our textbook evaluation findings in light of our data on students' science knowledge, we used the results from a set of 11 items we designed to test whether students could use a molecular model to make sense of ideas about matter transformation in living systems. We were not surprised to find that fewer than half of the 2,000 or so middle school students who took the items were able to answer correctly; most students are not taught to think in terms of a molecular model until high school.

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We then used the same items to measure the knowledge of 200 college freshmen enrolled in an introductory biology course. All of these students had taken both biology and chemistry courses in high school and so were expected to have learned about the molecular model for matter transformations.

We found that the high school graduates who were tested were knowledgeable about some of the ideas – that plants make sugar molecules from CO_2 and H_2O molecules and that animals and plants store food molecules for later use – but much less so about other ideas. By comparing the findings from our biology textbook evaluation with these assessment findings, we see in Table 1 the relationship between the number of biology textbooks presenting an idea and the percentage of students that appear to have learned it. The greater the number of textbooks covering an idea, the better students performed on the relevant assessment items.

Some implications

Our results suggest what many science educators have argued – that mere presentation of ideas, even if the presentation is coherent – is not sufficient to promote deep understanding. Even when all of the textbooks treated an idea – for example, plants make their own food – only 74% of students who had already taken chemistry and biology courses responded correctly. Students need to be actively engaged in sense-making, which depends on the quality of curriculum and teaching.

Idea	No. of textbooks (out of 9)	Students getting item correct
Idea A (What food is)	5	50% (2)
Idea B (Plant food making)	9	74% (1)
Idea D (Converting food into body structure of plants)	2	21% (1)
Idea E (Converting food into body structures of animals)	2	25% (3)
Idea G (Storing food for later use)	7	63% (4)

Table 1: Relating textbooks' inclusion of ideas to students' learning of them

While we were not able to examine the quality of teaching students encountered, we did have a good sense of the quality of instructional support provided by the textbooks for teaching and learning. Not surprisingly, Project 2061's biology textbook evaluations showed the quality of instructional support to be poor across books. Given the picture that emerges from our work, there is a need for more detailed and systematic study to determine the precise nature of the relationship between textbooks' treatment of particular ideas and students' learning of them. It is also clear that the poor quality of textbooks places a large burden on teachers to fill in the gaps. This requires preparation and ongoing professional development that can help teachers themselves develop a coherent understanding of the science ideas their students are expected to learn, to evaluate the strengths and weaknesses of the materials they are using, and to select and carry out instructional strategies that are most likely to be effective.

About the author

Jo Ellen Roseman is Director of Project 2061. In this capacity she is responsible for overseeing all of the project's programs and activities in the areas of curriculum, instruction, and assessment. She also serves as Director of the Center for Curriculum Materials in Science (CCMS), a collaboration of Project 2061, Michigan State University, Northwestern University, and the University of Michigan.

Further reading

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Matter and Energy Transformations

What the reviewers looked for

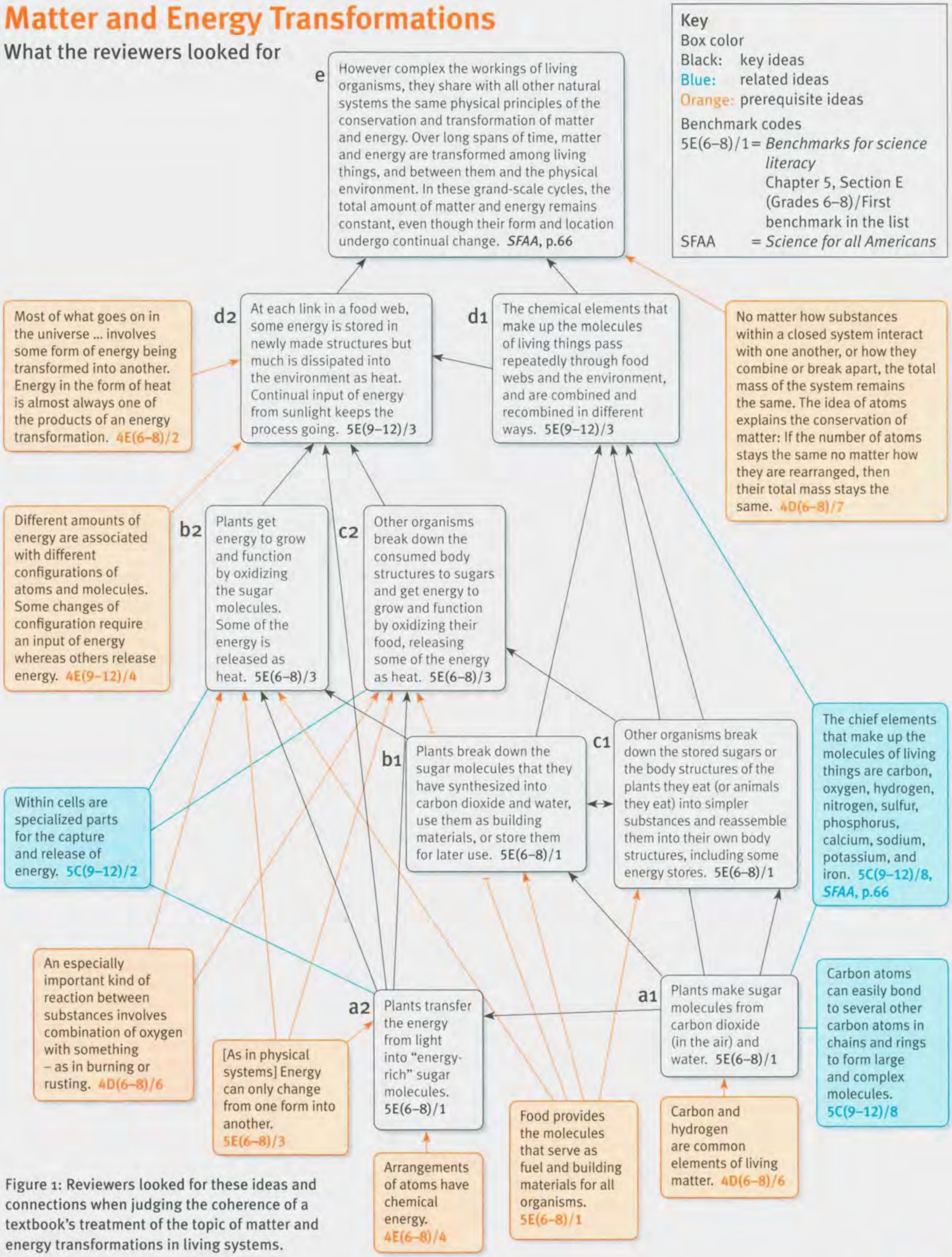

Figure 1: Reviewers looked for these ideas and connections when judging the coherence of a textbook's treatment of the topic of matter and energy transformations in living systems.