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Essay

Meeting the Challenge of Science Literacy: Project 2061 Efforts To Improve Science Education

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A modern understanding of the cell and its functions has been translated into learning goals for K-12 students by Project 2061's *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993) and by the National Research Council's *National Science Education Standards* (*NSES*) (National Research Council [NRC], 1996). Nearly every state has used these national documents to develop their own science standards, so that there is now a fairly broad consensus on what it is that students need to know and be able to do in science generally and in biology more specifically. While this consensus represents an important first step toward improving science education, without curriculum, instruction, and assessments that are well aligned with these goals, teachers will find it extremely difficult to help their students achieve them.

Here, we first highlight a few of the key findings regarding cell biology from Project 2061's study of high school textbooks and their alignment with standards. We then describe Project 2061's current efforts to develop new knowledge and tools that educators, researchers, and practitioners can use to help all students become literate in science, mathematics, and technology. Project 2061 is a long-term K–12 education initiative of the American Association for the Advancement of Science.

WHY WORRY ABOUT TEXTBOOKS?

Often cited as the nation's de facto curriculum, textbooks define what most U.S. students are taught, particularly in science and mathematics (Tyson, 1997). A recent study of K–12 science and mathematics education in U.S. classrooms confirms that teachers depend on textbooks for instructional guidance as well, finding that "textbooks are second only to teachers' knowledge, experiences, and beliefs in the frequency of influence on instruction" (Weiss et al., 2003). Imagine the power, then, of textbooks that are well-aligned with the content recommended in both *Benchmarks* and *NSES* and are designed to provide support for the instructional strategies that research has shown to be most effective.

WHAT AND HOW STUDENTS LEARN

Readers of *Cell Biology Education* will recall that Kimberly Tanner and Deborah Allen (2002) described the high-school learning goals in *Benchmarks* and *NSES* in the following way:

> Both documents emphasize that students in grades 9–12 (ages 14–18 yr) should understand that cells have specialized subcellular structures that underlie their many functions. These older students learn about the molecules of the cell and the role that these molecules play in cell functions—the gatekeeper role of the cell membrane, the storage of genetic information by DNA, and the many facets of proteins.

Tanner and Allen (2002) go on to characterize—quite accurately—a pedagogical approach found in both documents that emphasizes deep conceptual understanding rather than mere factual recall:

> The overarching functional approach to understanding cells found in the *NSES* and the *Benchmarks* moves away from the more traditional anatomic introduction to cells that is rooted in memorizing names of organelles followed by the requisite building of a cell model from clay or other materials. In fact, this functional view taken in the standards is intimately linked to a strong vision of how students should be learning science.

This new emphasis requires textbooks that incorporate a wide repertoire of content-specific instructional supports that will effectively promote understanding among students from diverse backgrounds and with diverse interests, abilities, and needs. How well are today's textbooks meeting this challenge? How well are they helping students to grasp even the most fundamental ideas about cells and how they work?

Not very well, we discovered, based on Project 2061's study of both traditional and more innovative biology textbooks that are being used in most U.S. high schools. Funded by the Carnegie Corporation of New York, the study was designed to investigate the extent to which textbooks were likely to help students learn some of the key biology ideas that are found in both national and state standards documents. Our study selected a few of these ideas to see how they were treated in the nine textbooks that were examined. (For a summary of the study, visit www.project2061.org/research/textbook/hsbio/default.htm.) As detailed below, an overemphasis on technical terminology, the lack of a meaningful narrative to weave the key ideas into a coherent story that students can make sense of, and the absence of support for teaching these ideas all serve to undermine the best intentions of authors, publishers, and teachers. Most textbooks end up promoting an outdated paradigm, presenting the cell as a static "bag of parts" rather than the active and dynamic entity that modern molecular biology has revealed.

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MISSED OPPORTUNITIES

While most of the textbooks "cover" the key ideas that our study looked for, the ideas are usually presented as isolated fragments of information. As a result, the textbooks rarely provide opportunities for students to draw connections between ideas—a significant cognitive step toward forming the kind of coherent understanding of a concept that characterizes expertise (National Research Council, 2000, p. 139).

Another problem is the sheer volume of detail that is included in most textbooks, usually at the expense of more in-depth coverage of the most important ideas. The typical textbook presents students with beautifully rendered, full-color diagrams of cells with every part carefully labeled—centriole, endoplasmic reticulum, Gogli apparatus, and so on—but rarely devotes as much care to explaining the central idea that these parts have specific functions that serve the cell and ultimately the organism. Instead, the texts expound on relatively trivial aspects of cell structure, using one technical term to define another until the text becomes a logjam of obscurity that keeps even the most capable students from understanding anything useful.

Here is a particularly egregious example of how the introduction of new vocabulary can become a poor substitute for the kinds of carefully constructed explanations, examples of phenomena, and other instructional supports that can help students develop a deep understanding of important concepts:

> Two major components of the *cytoskeleton* are *microfilaments* and *microtubules*. *Microfilaments* are threads made of a *protein* called *actin*. Each *microfilament* consists of many *actin* molecules that are linked together to form a *polymer chain*. (italics added)

The passage above is followed by nearly two more paragraphs on the structure of microfilaments but only a single sentence on the idea that the cytoskeleton is essential to cell movement and no mention of how structure and function are related concepts that would help students understand the cell as a dynamic functioning system. Our study also found that most biology textbooks rarely take into account what students may already know about cells (or any other idea) so that teachers can build on that prior knowledge or help students to clarify their thinking or correct their misconceptions. Using textbooks that don't provide adequate and appropriate instructional supports places an enormous burden on teachers, many of whom may be teaching outside of their discipline or with limited too little experience in today's diverse classrooms. What is more, given the limited time available for science learning, it becomes even more important to focus classroom instruction on the concepts and skills that have the greatest payoff for students.

NEXT STEPS

Addressing these and other concerns identified by our textbook evaluation studies will require both short- and long-term solutions. As an interim approach, educators, textbook developers and publishers, and others can turn to Project 2061 tools for advice on how to streamline the science curriculum and focus it on a coherent set of the most important concepts and skills. To draw attention to important connections across the curriculum, for example, the *Atlas of Science Literacy* (AAAS, 2001a) provides a collection of linked conceptual strand maps displaying the sequence of ideas that contribute to a sophisticated understanding of some key science and mathematics topics. By illustrating connections over time and across topic areas, *Atlas* maps can help guide the development of a more coherent and focused curriculum. In addition, *Designs for Science Literacy* (AAAS, 2001b) offers suggestions for restructuring time, instructional strategies, and content that can lead to very different kinds of curricula serving a common set of learning goals. (More details about these and other Project 2061 tools are available at www.project2061.org.)

To tackle some of the long-term systemic issues that affect science education, Project 2061 hosted a series of conferences where a dialogue could begin on textbook quality and how to improve it. Funded by the National Science Foundation, the conferences attracted a wide-ranging spectrum of attendees, including classroom teachers, education researchers and policymakers, and science and mathematics textbook developers and publishers. That dialogue continues through a recently established and also NSF-funded Center for Curriculum Materials in Science, which is in partnership with Michigan State University, Northwestern University, and the University of Michigan. Over the next 5–10 yr, it is expected that this Center will conduct significant new research on issues related to the design, analysis, and use of science materials, while also preparing a new generation of leadership through innovative graduate and postdoctoral programs.

Other collaborations are active. Project 2061 is leading an Interagency Education Research Initiative study, working with the University of Delaware and Texas A&M University, to examine how to coordinate curriculum materials, teaching practices, and professional development to improve student learning in mathematics. In related NSF-funded efforts, Project 2061 is studying the role of assessment as a tool for promoting science literacy, developing conceptual strand maps, and collecting examples of natural phenomena, representations, sets of questions, and research summaries that are well aligned to specific learning goals and can be incorporated into curriculum materials or classroom lessons. To engage parents and families as allies in promoting science literacy, Project 2061 has created a public service announcement campaign, a special Web site for parents (www.ScienceEverywhere.org), and a *Family Guide to Science* brochure.

In 1989, *Science for All Americans* (AAAS) challenged the nation to reform its education system: "There are no valid reasons—intellectual, social, or economic—why the United States cannot transform its schools to make scientific literacy possible for all students." By focusing its efforts on areas such as curriculum materials, teaching, assessment, higher education, and families and communities—all key levers in the education system—Project 2061's goal is to foster the kinds of changes that can help the nation meet this challenge.

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