Standards for Teaching and Learning

Developing scientific literacy for all students requires a special kind of teaching, as described in the vision statement on pages 1–2. In this kind of teaching, students are exploring the natural world and developing their explanations of it, by experimenting, observing and describing, designing and building, debating with each other, doing projects and research, taking field trips, reading journals and non-fiction works, asking questions, offering explanations, and citing evidence. This kind of teaching has much in common with teaching mathematics, social studies, and English language arts. The following Standards for Teaching have been adopted by science as well as the other subject areas, as focal points for discussions about the nature of effective teaching.*

Standard 1: Higher-order thinking.

Students should routinely use their powers of observation and their abilities to reason and solve problems as they learn and communicate important scientific ideas. They should have many opportunities to critically assess arguments and the fit of evidence, to draw conclusions and consider implications, to break things apart into their component pieces (analyze) as well as to see connections in diverse ideas (synthesize), to foresee difficulties and plan accordingly. They should routinely make and test predictions, gather, represent and use data, consider problems and alternative solutions, figure out how things work, design and build, imagine, and ask probing questions.

Higher order thinking of this kind is critical to deep and connected understanding. It challenges students to go beyond rote memorization, to actively engage themselves with the questions, problems and issues of science, and the ways in which scientists deal with those questions. Whenever students write, discuss, explain, inquire, and produce things, they should be challenged to use their entire repertoire of thinking abilities.

This is critical because the essential "activities" of scientific literacy are those that students will be expected to do outside of school: diagnosing, explaining and describing phenomena, applying knowledge, predicting and testing predictions, designing and constructing, reflecting on the merits of arguments, questioning, communicating, making connections, making decisions based on limited information, etc. These are all "higher order" ways in which we think and reason about the world around us.

Standard 2: Deep knowledge.

The goal of teaching should be for students to understand scientific ideas deeply enough so they can talk about them in their own words, apply them to show how things work, use them to find answers to new questions, and see connections within them. Scientific ideas may be expressed in simple language, especially for younger learners, but the content of science—to be worth learning—must be important, fruitful, enlightening. Every scientific idea is highly embedded in a conceptual ecology of other ideas,

Developing this kind of understanding takes time. It does not happen for most students if teachers short-cut the learning process by simply telling the definitions of key concepts, or the algorithms for solving problems, or the facts associated with the phenomena being studied. Instead, students need to spend time looking closely at evidence, figuring out what it means, and arguing about various explanations. As they do this, they come to understand deeply the ideas behind the concepts, often before they have terms and definitions to apply to them. Then when they are given the terms and definitions, the meaning makes immediate sense to them because they have developed a deep conceptual understanding of the phenomena and systems they are studying.

It is understandable why many teachers tend to jump to the "punchline" of a topic—skipping over its applications and deep connections to simply list its terms and definitions: Often, that is all there is in textbooks, a shallow examination of a topic with few examples, just the facts and definitions. If the goal is simply to get through the entire textbook, and "cover" every topic, then students can't do much more than simply read each page and go on to the next chapter, memorizing (if they can) the terms and definitions. But this is a false, surface-level punchline. When the goal is to "uncover" the ideas, connections, and applications in the content, textbooks become only guides to the basic storyline. "The rest of the story" is presented by teachers (in discussions and activities as well as lectures) to develop a deep understanding of ideas and how they are used to explain the natural world.

Unfortunately, teaching for understanding is difficult. It demands more of students—more mental effort than listening to traditional lectures. And because teaching for understanding often reveals the ways in which science is not commonsense, it demands an openness to new ideas.

Standard 3: Connections to the world beyond the classroom.

Learning should be related to young students' everyday lives, their neighborhoods and communities. As they get older, what students learn should be usable as they enter the larger world beyond their communities.

There are two good reasons for this. The first is science literacy, which requires that students learn how to understand and operate within the world around them. Because science literacy is essential, the problems and examples used in teaching should be about real events, real places, and real phenomena.

The second reason relates to motivation. Students must be interested in the ideas of science and see their relevance if they are to care enough to spend the time needed to understand scientific ideas and their applications.

Making connections to the world outside the classroom does not mean that instruction should be parochial, limited only to one's local community. Quite the opposite: Teaching should expand opportunities, open up new horizons, and acquaint students with the wider world beyond their own homes and experiences. Students should be immersed in the world as they learn all of their subjects, even though they usually spend most of their time in a classroom.

Standard 4: Substantive conversation.

Students need to talk about the ideas we want them to learn, to debate what evidence means, and to ask probing questions. This is both a mark of their mental engagement with the subject and a necessary teaching strategy for learning deep knowledge and how to use, construct, and reflect on it. When teachers ask questions, they should ask ones that draw out students' thinking, that make them refer to observations and other evidence, that make them take a stand and support it. They should ask "Why do you think that?" and "How do you know?"

While substantive discussion is becoming more the norm in science classes (as opposed to lecture and note-taking), it is important to recognize that teachers have a critical role to play in helping students develop scientific ideas. While teachers are often facilitators of students' exploration and cognitive coaches during students' construction of ideas, their role of introducing and explaining new concepts, showing how those new concepts can be used, and demonstrating how to perform new activities is central to the learning process. Only when new concepts are introduced and explained clearly by teachers can students practice how to use them effectively. But only when students are allowed to discuss and use new ideas, can they attain challenging standards of content.

* These four standards, taken from the work of Newmann, Secada, and Whelage at the Wisconsin Center for Educational Research, are described in the Center's more generic terms in *Michigan Curriculum Framework,* available from Michigan Department of Education Curriculum Development Program website. This description of the Teaching and Learning Standards is taken from the Michigan *Science Education Guidebook*.