CELLS Through the Lens of *Benchmarks*: Reflections While Using a New Tool

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I am a science educator. For 14 years I taught elementary and middle school science. Now I am responsible for developing curriculum in all subject areas, including science, in a large urban school district. I also teach graduate courses, helping prospective science teachers learn how to teach science effectively, and I teach fourth and fifth graders in a special Saturday school that focuses on helping students develop more effective thinking skills.

I have encountered widespread science illiteracy at all levels, and I am very troubled by its effects. So I welcomed Project 2061's first publication, *Science for All Americans (SFAA)*, as a document that established what all Americans need to know to be science literate. And I welcomed Project 2061's second publication, *Benchmarks for Science Literacy (Benchmarks)*. I need these tools. How, I asked myself, should I use them?

I am writing now to share with other teachers and curriculum developers the way I thought and things I did as I began to use *SFAA* and *Benchmarks* as tools to approach science education in a new way. I decided to select a commonly taught topic to which I would apply the recommendations of *SFAA* and *Benchmarks*. I selected the cell as the topic of my instruction.

I have taught students about cells many times. However, I did not go first to my files or to current textbooks. Instead, I began by rereading *SFAA* on cells. As I read, I noticed the strong focus on the work done by cells. Some of what I had always taught about cells wasn't there at all. For example, I had always asked students to diagram a "typical" cell and label its parts. But in *SFAA* such parts as the endoplasmic reticulum weren't even mentioned! I remembered a key recommendation of *SFAA*: less is better!

"Does this apply to cells?" I asked myself. "And, if so, how?"

Next, I read the essay on cells in *Benchmarks* 5C (Chapter 5, Section C) Cells. The essay points out some common misconceptions about cells and some concepts that students might find hard to understand. I recalled another common misconception, that cells are two-dimensional. Many teachers have students draw diagrams of the parts of a cell without making it clear to students that the cell is, in actuality, three-dimensional. This practice may lead students to believe cells are two-dimensional.

The introductory essay also suggests a way of getting started: focusing on the needs of macroscopic organisms. I remembered teaching needs of living things, not in connection with cells, but as a separate unit at the middle school level. Smiling, I thought of a lesson in which I had asked students to illustrate one life process. One student drew a colorful picture of a ponderous and not-very-lively-looking rhinoceros standing in a grassy area.

"Tell me about your picture," I said to the student. "What life process are you illustrating?"

"He's breathing," she said.

I will probably still teach the needs of living things. But, until now, I hadn't thought of focusing this topic on helping students understand cells as well as helping them understand macroscopic organisms.

I moved on to read the short essay and benchmarks for the K-2 level. I liked the idea of asking young children to "wonder what they might see with more powerful lenses."

As I read the other benchmarks for this level, I asked myself what experiences students should have if they are to know and understand particular benchmarks. For example, when I read, “Magnifiers help people see things they could not see without them,” I realized that, even at the kindergarten level, we should give students many experiences in which they examine a great variety of objects and materials with hand lenses. “Do we already do this?” I asked myself. “I think we do, to some extent,” I thought. “Do we also help students articulate the fact that, when using the hand lenses, they see more than they do when not using them?” I wondered. I made a note about this point. We cannot assume understanding; we must constantly verify it.

John Dewey, I recalled, said, “We learn by doing IF we reflect on what we do.” This is quoted in the current reform document, *Dimensions of Learning*. Providing ample time for reflection is also a central point of Project 2061’s tools for reform. How interesting it is for a practitioner like myself to relate one expert’s recommendations to those of others. This thought stayed near the surface of my thinking.

I moved on to the 3-5 essay and benchmarks. Here was something different, I realized. Students are to use microscopes extensively in these grades. But in my school district microscopes are not widely used until middle school. A change is indicated. I made another of what would be many notes. The essay says prepared transparencies and films are OK, and the image of a catalog of many prepared transparencies flitted through my mind. But I also want these young students to see live organisms. One of my favorite middle school activities, the hay infusion, came to mind. Should this be done earlier, in the 3-5 band? *Benchmarks* suggests that it should.

I moved on through the essays and benchmarks. At the 9-12 level I found, “Every cell is covered by a membrane that controls what can enter and leave the cell.” Two activities came to mind to help students understand this concept: first, using a dialysis membrane to model a cell membrane and show that substances can pass through seemingly impervious materials; and, second, observing plasmolysis of elodea cells in salt water. More notes.

My earlier thought about commonalties among current reform movements surfaced again. I needed to review what *SFAA* says about changing science education. I reread two chapters: Effective Learning and Teaching and Reforming Education. “BUT,” I thought, “Habits of mind are relevant here, too,” and so I read that chapter again, also. What a wealth of ideas, almost a checklist for me to use as I planned the details of activities.

Back to *Benchmarks*. I skimmed the benchmarks again. How clearly later levels build on earlier levels! I remembered the first workshop in our district where we had elementary, middle, and senior high school teachers work together. For most, it was the first time they had had this opportunity. For all involved, it was a significant experience. Kindergarten teachers learned how what they taught laid the foundation for later learning. High school physics teachers learned how they built on conceptions and misconceptions learned in the early grades. Teachers at all levels wanted more of this kind of communication.

Benchmarks and cross-grade-level experience suggests to me that, as you plan lessons and curriculum units, you need to keep in mind where your students have been and where they are going. On any topic the benchmarks can help you see how understanding is constructed from early levels to later levels. Again, I make connections between *Benchmarks* and what I had read in other places and what I knew from experience about how students construct knowledge.

Here was a factor to be kept in mind as I constructed lessons and units: be aware of the vertical construction of learning. Is *my awareness* all that is needed? I think not. I should *plan* to ask questions in the course of a lesson that will help students construct new knowledge on old (a point also made in Dimension 2 of *Dimensions of Learning*). For example, I will need to ask fourth graders, as they use the microscope for the first time, what experiences they have had with hand lenses and what they learned from those experiences. Maybe I will ask them what would happen if they looked through a microscope even more powerful than the one they are now using. Would they expect to see more details? Here I remembered Bronowski's chapter in *Ascent of Man* where he writes about how there are limits to how much detail we can perceive; as he puts it, we will never see with God's eye.

Thinking there were, probably, other rich connections to be made among the benchmarks, I looked next at other sections within Chapter 5. *Benchmarks* 5A Diversity of Life reminded me to "take the study of diversity and similarity to the molecular level." 5E Flow of Matter and Energy refers to many processes that occur within cells, and 5B Heredity and 5F Evolution of Life introduce the study of genetic traits and the fact that DNA provides for both continuity and variation within a species. Next I went to the Also See box at the beginning of the section on cells. There I was referred first to 3A Technology and Science (instruments), where I found a related benchmark: "Technology enables scientists and others to observe things that are too small or too far away to be seen without them." Another point to be made explicitly as I teach, again in the form of a question: "How is the microscope (or hand lens) helpful to us as scientists?" I need to ask the children.

I continued through the Also See references, gaining lots of ideas. A benchmark in the 6-8 grade band says, "All living things are composed of cells, from just one to many millions, whose details usually are visible only through a microscope." In 11A Systems I found two benchmarks with which I need to connect as I teach about cells: "Most things are made of parts" and "When parts are put together, they can do things that they couldn't do by themselves."

One connection led to another. I checked out the Habits of Mind chapter. In 12A Values and Attitudes, I found this benchmark: "Students should raise questions about the world around them and be willing to seek answers to some of them by making careful observations and trying things out." And in 12B Communication Skills I find: "Students should be able to draw pictures that correctly portray at least some features of the thing being described." As I read, an activity formed in my mind. I could give young children (K-2 band) some experiences with things having parts. As I mulled this activity over, I realized this experience will relate directly to the children's later learning about cells. Young students could identify things in the classroom which have parts. Then I might ask the question, "Do you suppose things outdoors also have parts? How could we find out?" The right answer, of course, is we can go outdoors and look around. (At this point I remembered having read a related benchmark about the nature of evidence.)

As the activity formed in my mind, so did the significant questions:

- What did we find out in our investigation?
- Would we find out the same thing if we did the investigation tomorrow?
- How do you know something is a part of the whole and not a separate thing?

So I was on my way to crafting an activity about cells. I reflected on how powerful are the connections among the various related benchmarks! And I realized, more than I did before, how important it is to make these connections explicitly with students.

I also realized that I had largely been instructing in isolated topics. After reading *Benchmarks* I knew that I must, in my instruction, be mindful of the vertical progression of understanding. Equally important, I must be mindful of the connections angling from one part of science to another, and to related subjects, mathematics, social studies, and language arts, among others. I must *plan* to make these connections in instruction, as I had not done previously.

Now I had read what *Benchmarks* has to say about cells. I had read connected sections, and I had even found additional connections. When I developed the 9-12 activity on the nature of the cell membrane, I might use dialysis tubing as a model. I would plan my lesson to help students learn about the nature of models and their use in science.

Again I reread the chapter in *SFAA* on Effective Learning and Teaching. This chapter suggested some other qualities for the lessons and unit I was planning. One quality is that my plans have to provide for students to be active learners. My telling them about cells will not mean necessarily that they will have learned what I have said. They need to have concrete experiences insofar as possible. Their learning should be collaborative, to model the nature of scientific inquiry. I need to be sure the girls and minority students, as well as the boys, are comfortable with the experiences.

At this point I realized I had a checklist, a way of judging the quality of the instruction I plan. My instruction on cells (and other instruction I will plan hereafter) will have to meet four criteria:

- Lessons should explore topics in depth, focusing on the content listed in *SFAA*, rather than skimming the surface by teaching only terms and definitions.
- Lessons must relate to the vertical flow of understanding described in *Benchmarks*.
- My instruction must help the student establish rich connections with other subject areas.
- I must employ effective pedagogy.

Finally, I explored Chapter 15: The Research Base. I know that *Benchmarks* is the work of many, many experts and that it was subjected to rigorous review in draft form by thousands more experts. I trust these people. Still, it was interesting to read about the research foundation for *Benchmarks*. Reading the section on Cells in Chapter 15, I found that children are probably more likely to understand cells as structural units of larger things than as functional units. I am pleased that this confirms the usefulness of my lesson on parts and wholes for the K-2 grade band.

So what was left to do? I needed to use the same process to finish developing my unit: getting saturated with *SFAA* and *Benchmarks*, making vertical connections and cross-connections among topics, and applying principles of effective pedagogy, all the while drawing on activities I now use as well as devising new ones.

The starting point, I think, is important. I did not begin with my old unit on cells and ask myself, “Which benchmarks support the use of this or that activity?” Rather, I began with the reform documents and asked myself, “Which activities and parts of activities support the benchmarks?”

Clearly, much has to be changed, not only with regard to teaching about cells, but in science education as a whole. I look forward to being involved in this exciting challenge and to using Project 2061 tools to help me do so.

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