incentive of my Carnegie project I gave it more thought and came to realize that though I thought this objective was important, I wasn’t doing much to fulfill it.

Assignments

As I mentioned in the March 2001 article, last fall I had wonderful results from my class when, for their first essay assignment of the semester, I asked them to describe the place where they felt most comfortable. When I returned the essays I explained that I had given them this rather odd assignment because I wanted them to have a greater appreciation for how I feel about the cell: I am at home in the cell just as they are when they’re in the place in which they are most comfortable. I think this assignment set a tone for the semester. It sent the message that I wanted students to reflect on their own feelings and attitudes about biology.

For their portfolios, due at the end of the semester, I asked students to collect 20 items related to a sensory experience. Again, I was trying to get them to think about biology in relation to something close to themselves. We had several discussions on what a sensory experience was, focusing on the visual, but I ended up broadening the assignment to include other kinds of experiences; emotional experiences like crying, for example, as long as they took a biological approach. They had to label the portfolio items, indicating how each related to the theme. These items could include newspaper and magazine articles, web sites, photographs, and advertisements, but had to include at least one art work, one piece of music [vocal or instrumental], and one poem. Original artwork or writing was encouraged but not mandatory.

Some of the portfolios were wonderful. Two students did theirs on crying, obviously a subject of interest to them. One began with a photo of her father who had died of lung cancer; her second item was a picture of a cigarette, which can also make her cry. Another student did a portfolio on death and had as his work of art a powerful drawing he had done himself. A hockey and a lacrosse player did their portfolios on their respective sports and came to realize something of the biology of what they experienced as they play—and I got to experience what a cross-section of a hockey glove looks, and smells, like. Several included items that were important to them. One student, whose theme was the experience of friendship, included a bracelet that his girlfriend had given him on their first date. A Taiwanese girl who also used friendship as her theme enclosed calling cards her friends in high school had given her; these were especially precious because she’s so far from home. I was awed that these students had entrusted me with such precious possessions and was relieved when I’d safely returned these items to their owners.

After correcting all the portfolios, it struck me that a great deal of sentiment had gone into them. While they were hardly scientific masterpieces, they were indications that students had related biology to things that were important to them, and they had realized that there could be an emotional side to biology. I see this as a real breakthrough in my teaching. While for years I’ve been interested in the relationship of the objective and subjective in science, it was only with this semester that I finally managed to help my students make the link. Also, these portfolios are evidence that I have made some headway toward my objective of having students demonstrate a more positive view of science when they leave my course.

In the past, I saw the essays and portfolios I assign just as ways to get students to think about biology in relation to their lives; now I realize they can also tell me a lot about student attitudes toward science. The portfolio is more than just a way to get students to realize that there is biological information in the magazines, newspapers, and web sites they see everyday; it is also a rich way to push students in creating these

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relationships between content and personal life, and to assess just how deep these relationships have become.

I was excited about all this when I met with my Carnegie project group in January. There are 40 of us in all, but we meet in groups of eight, and for further support, each of us is paired with one group member, a "critical friend," who has to read and comment on our project. My critical friend is Roberto Corrada, a professor of labor law at the University of Denver. Perhaps because he is a lawyer, Roberto was able to cut to the heart of my project and see the significance of the fact that I put improving students' attitudes first in my course objectives, and that when I talked about my project, what I was most excited about was not the visual but the affective. This didn't mean that in the spring semester I abandoned interest in the visual, but it did mean that I also continued to pay attention to the subjective side of teaching biology. One of my group's members, Patti Owens-Smith, a professor of psychology at Oxford College of Emory University, suggested that I look at some of the literature on feminist pedagogy and gave me a reading list. That's how I found bell hooks's (1994) Teaching to Transgress.

Objective & Subjective

As a scholar of African American and women's studies, hooks argues that the academic tradition requires students and teachers alike to bring their minds but not their bodies to the classroom. The focus across most disciplines is on objective, rational study; emotions and passions are to be left at the door. Though I think hooks paints an extreme picture to make her point, this idea rang true with me. Especially in teaching science, the emphasis is on what Joseph Axelrod (1973) calls the "principles-and-facts" approach to teaching: it is not important how the student feels about protein synthesis, what is important is that the student understands the process and knows the elements involved. But is it that clear-cut? This is what I am beginning to seriously question. Even though I am still committed to the principles and facts involved in protein synthesis, I now realize that this is a tough topic for nonmajors to absorb, and if they don't have some emotional engagement with the topic, it's going to be hard going for them to learn it.

This makes sense to me, but at the emotional level it is difficult for me to accept. I am coming to appreciate that even though I am interested in the aesthetic, the emotional, the subjective side of science, I have managed to keep that interest very objective. I think about these things and verbalize about them, rather than feel them, or least rather than focusing on those feelings. I have been so trained in a positivist tradition in science, it is so much a part of me, that it is second nature for me to focus on thought rather than feeling and to value thought rather than feeling. I would like to improve my students' attitudes, but I just don't think in terms of attitude when I am teaching; I think in terms of content, of ideas. I may say that an idea thrills me, but I don't take the time to think up an assignment or take the time to lead students through an activity that might help them to share in this thrill. In the back of my mind, my inner scientist is saying to me that any digression from the content is not "real" science.

Yet I have spent years studying the private side of science, so I am well aware that thrills, enthusiasms, intuitions, and even emotional aversions are very much a part of how science is done. One of my favorite examples of such emotions is Arthur Kornberg's declaration that he found the level of the enzyme especially congenial; small molecules seemed too simple and cells too complicated for his tastes. His attraction to the macromolecular level led him to the discovery of DNA polymerase, work for which he was awarded the Nobel Prize and about which he wrote in For the Love of Enzymes (1989)—the cognitive and affective are so interwoven here as to be impossible to tease apart.

But it is one thing to talk about and write about such examples, and another to experience them, and it is only with experience that students will come to appreciate what is involved here. This makes a lot of sense, but it is not something that comes naturally to me, because I am so imbued with the ideas that teaching science is about teaching the objective side of science and that getting involved with the subjective is somehow suspect. hooks is right; we have been socialized to see education, particularly higher education, as a serious business, and not to let emotions in, and I think this is particularly true in science. Scientists take themselves very seriously and see any talk of emotions as somehow "unscientific" and dangerous because it may lead nonscientists to think less of the scientific enterprise. Despite the fact that I disagree with this view, I am coming to realize how much influenced I am by it, to the point where I actually feel guilty about my students' portfolios! There was just too much emotion there. It was only when I realized that getting students to feel about science was quite an accomplishment that my guilt eased, but I can't say that it has disappeared.

Views of Science

For feminist writers on science, the standard view of science as an objective enterprise is a masculine
view that developed out of the ideas of Francis Bacon and other theorists in the early days of modern science (Keller 1985). Writers like Hilary Rose have described alternative views of science, views that are more in line with women’s approaches. Rose (1983) sees the union of the physical, intellectual and emotional—what she calls “hand, brain and heart”—as characteristic of women’s approach to science. The linking of hand, brain and heart is very different from the distanced objectivity that is a major characteristic of more positivist views of science. This linkage means that the emotions are valued rather than suppressed in doing science.

But it is not just feminist writers who have accepted such linkages. C.F.A. Pantin (1954) describes “aesthetic” identification of species in the field, by which he means an intuitive sense that comes with deep knowledge of a group of organisms, a knowledge rich enough to make correction identification relatively easy, but the thought processes involved cannot easily be put into words. Michael Polanyi (1962) writes of “tacit knowledge,” the kind of intuitive discernment that comes with experience in any field; again, it is not something that can be put into words or taught in a textbook, but can only be learned by doing. It was Polanyi who originally got me thinking about the other side of the objective/subjective divide, who got me to realize how much richer science is than just a mass of theories and concepts. Now, I don’t want to go too far here, I don’t want to give the idea that I don’t think theories and concepts are interesting and important. It was fascination with ideas that brought me to science, but fascination has an emotional component whether we pay attention to it or not. And while we are nurturing students’ understanding of science content, we should be giving some attention to nurturing the emotional side as well.

There is now a great deal of evidence for a biological basis to the linkage of the cognitive and the affective. In Descartes’ Error, Antonio Damasio (1994) argues that Descartes was wrong to see the mind and the body as separate entities, that the body very much influences what goes on in the mind and vice versa. He cites evidence that the link of mind and body is through the emotions: that thinking elicits feelings—bodily responses—and that feelings actually influence thought. The cognitive and affective interact for a great deal, because in many cases the same areas of the brain are involved in both (Damasio 1999). Robert Leamson (2000), a biologist, has written an article on “Learning as Biological Brain Change.” He contends that what we now know about the way the brain is organized should be influencing the way we teach. For example, because individuals’ brains are organized dif-

ferently, students learn differently, and so it is important to take learning styles into account. Using more parts of the brain in learning means better learning, which is why hands-on activities are so effective—and also why emotional engagement is important. Leamson cites work pointing to links between cognition and affect, and discusses how he tries to link the two in his own teaching:

“The really difficult part of teaching is not organizing and presenting the content but rather in doing something that inspires students to focus on that content … to have some level of emotional involvement with it” (p. 39).

Teaching to Objectives

Despite the validity of hooks’s view that subjectivity is usually banished from the classroom, discussions of teaching often mention that the most important characteristic of a good teacher is enthusiasm for the subject. But now I think there is more to it than that: this enthusiasm has to be transmitted to students. I had always assumed that if I were interested in a topic and explained it well, explained why it was interesting, students would somehow get excited about it too.
Even though I had years of experience indicating that this was not the case, I stuck with the idea, because, quite frankly, I didn’t know what else to do. My Carnegie year helped to change that by giving me time and tools to reflect on my teaching.

The tools included a book called _Understanding by Design_ (Wiggins & McTighe 1998) which stresses the importance of having clear objectives and then designing assessments that measure whether or not the objectives have been achieved. I am one of those college professors who started teaching without a single education course, so writing objectives and reflecting seriously about them is not second nature to me. As for assessment, I saw quizzes and tests as the primary ways to measure student performance. So I was shocked when I read in _Understanding by Design_ that tests and quizzes are not the way to test for enduring understanding, that “performance tasks and projects” are better tools for measuring the kind of learning I am looking for. I now see that it’s through portfolios, essays and projects that I am much more likely to discover this kind of change.

This semester I gave an assignment that I’ve heard other teachers use, but I had never tried it myself. I asked students to take one of three topics we had covered (protein synthesis, genetic mutations, or genetic diseases), explain it to someone else, and then describe the experience. I wanted to know how each one “taught” the material and what the response of the “student” had been. The papers were great; this was one time when they forgot that I had asked for only two pages. Usually they can, at best, eke out what they were asked for, but this time, they just couldn’t stop themselves. They obviously had fun with the assignment and so, seemingly, had their test subjects, who were friends, romantic attachments, siblings, and parents. Students wrote of having to prepare for the “lesson” of being forced to find another way of saying the same thing in order to get a point across and of needing visual aids to clarify an explanation. In a couple of cases this meant going to the web, something I’ve done more than once in class. This assignment turned out to be a great way to test their knowledge of a subject and also deepen that knowledge because as we all know, you really learn something when you have to teach it. Also, getting ideas across became a challenge for students and provided emotional commitment to the project.

**Pretests & Posttests**

The original plan for my Carnegie project focused on how students come to understand images of cells and molecules; I ended up straying far from that original idea, but I didn’t give it up completely. One part of that plan that I did follow through on was a pretest I gave on the first day of class and again as a posttest on the last day. Both semesters, the test included questions about attitudes toward cells and molecules and questions on knowledge about these subjects. Looking at the pretest results told me something about students’ knowledge coming into the course. I had never done pretesting in a systematic way, and I can see that it is beneficial, at the very least as a reminder of the information gaps and misinformation students bring to a course.

The posttests were disappointing. Student attitudes improved a little, but not significantly. Their knowledge was better but not great, though there was more improvement in knowledge than in attitude. I had asked them to draw a cell and a protein. The cell images improved dramatically, and they sprouted labels, which almost none of them had had in the pretest. The protein images, which were almost nonexistent on the pretest, were hardly wonderful on the posttest and not nearly as good as the cell images. Instead of looking like twisted robes, which is how I would have drawn a protein if asked, these molecules looked like long strings or strings of pearls. This disappointed me until I thought about it; I had described the amino acid chain as a string of pearls and had actually brought in a necklace for illustration. So something had stuck. This experience made me realize that science teachers can easily create misconceptions as well as dispel them, and a posttest can be a way of ferreting them out.

The most interesting, and encouraging, finding involved the question: If you could visit the inside of a cell, what would this experience feel like? On the pretest, the answers were short and not very imaginative; in many cases there was no response. On the posttest almost everyone responded, and the answers were on average about three times longer than on the pretest. So I may have achieved, at least in part, my primary goal of getting students to feel at home in the cell or at least to consider what it would be like to be inside a cell.

**The Future**

In one sense, it is good that I strayed from my interest in cellular and molecular images in the world of affect because I am not going to be able to get back to the cellular world for awhile. The University has approved a new core curriculum with a new science course called Scientific Inquiry. The course looks at the history and present-day significance of a major scientific concept, the particular concept depends
upon the instructor: chemists will teach about atomic theory, physicists about nuclear energy, and biologists about evolution. Goodbye mitochondria, hello natural selection.

But as I start to plan this course, I can see that my Carnegie experience will prove useful. I am much more careful in framing my objectives, and even more so in planning activities and assessments that will link the cognitive with the affective. I am now aware that I have to work at it if I want students to become really involved in the course material. This may seem like an obvious thing, but I was trained in a very content-laden tradition and the idea that there are ways to present content that also serve other objectives, like improving student attitudes, is still novel enough for me that I have to work at it.

My Carnegie experience taught me things that are second-nature to most teachers, that, for example, objectives have to be tied to approaches used in the classroom. The Kansas State Idea Center (www.idea.ksu.edu) has done a study on the match between objectives and approaches. One of the findings was that active learning strategies produced more effective learning. To me, active learning involves “hand, brain and heart” and leads to better attitudes as well as better learning. So I am working on ways to make evolution real for my students: classification and “natural” selection activities, drawing phylogenetic trees, and examining representations of dinosaurs. As the last two indicate, I haven’t abandoned my interest in the visual. And I know from past experience, that just mentioning the word dinosaur creates a flurry of interest; now I have to devise ways to sustain it. I am finding that dealing with the subjective does not have to mean abandoning the objective. bell hooks is right, they are inextricably linked. The trick is to reflect sufficiently on my goals to be able to find ways to keep the two effectively coupled in the classroom.

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