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CHAPTER 5

Meaningful and Mindful Learning

Real Life Can Promote Meaningful Learning!

Susan's mother, her two sisters, her aunt, and her aunt's daughters had contracted breast or ovarian cancer and three of them, all less than 45 years old, had succumbed to their diseases. For these reasons, Susan decided to have her breasts removed prophylactically. However, cancer researchers had just identified a molecular marker associated with the gene for breast cancer in Susan's family, known to them as "Family 15." The researchers hadn't thought about sharing their findings with the family until they heard about Susan's plans for surgery.

Members of Susan's family had come to believe that a breast cancer gene was being passed from mothers to daughters. Susan thus assumed she would follow in her sisters' footsteps. However, the researchers informed Susan that she didn't require surgery because she did not have the breast cancer gene. Without realizing the bomb they were dropping, they explained that 50% of all family members, males and females alike, would have this autosomally linked gene.

The many family members who had thought they were exempt from the cancer plague went into shock. Anna and Adrienne, two daughters of Susan's Uncle Doug, had assumed their father did not have the gene and thus neither did they. However, they learned within a period of less than 3 intense weeks that a) they may have the breast cancer gene, b) in fact, they did have the breast cancer gene, and c) they not only had the gene, but mammographs revealed that they also had breast cancer! Their previously secure worlds turned topsy-turvy. At the same time, they realized that their newfound scientific knowledge probably saved their lives. (Waldholz, 1997)

This vignette illustrates a mother to daughter theory of inheritance invented by a family under duress. The theory adequately accounted for the cancer cases they observed in their own family during a relatively short period of time, but the data were limited and insufficient. Under dramatic circumstances, family members were informed that the scientific theory was quite different from their own. Compelling evidence (in the form of the unexpected presence of breast cancer in two young women who thought they were safe from the scourge) supported the scientific theory. All 39 family members not only had to discard their "naïve conceptions" (described in Chapter 4) and assimilate the new scientific ideas, but they also had to generate new inferences about appropriate ways of managing their lives.

Real life has a way of imposing meaningful learning on us in a highly persuasive manner. Learning and retention are generally increased when adrenaline levels are

higher, as in these life and death situations. The classroom is a bit different, however. This chapter looks at the problems of achieving meaningful learning in biology classrooms.

WHAT IS LEARNING?

Learning can be a lot harder than simply absorbing new knowledge. Learners' prior knowledge and background assumptions can present major obstacles. Carefully selected hands-on experiences can serve to challenge such background assumptions and bring new understandings. Such science activities are not an end in themselves, but rather a means to an end – to develop understanding of scientific ideas. In this chapter I aim to clarify and make explicit what we mean by “understanding of scientific ideas,” “meaningful learning,” and “mindful learning.”

Much has been discovered about how people learn in the past few decades, due in part to a convergence of theory and empirical research from many different fields. These findings seem strong because different researchers in different fields using different methodologies have come to similar conclusions. The reform movements currently sweeping educational communities at all levels, especially precollege (briefly described in Chapter 1), are attempting to bring some of this knowledge into the classroom. The goal is to generate the mirror image of how to learn – namely, how to teach.

MINDFUL LEARNING

The *processes* of mindful learning lead to meaningful understanding (Langer, 1989, 1997; Murray, 1997; Gagne, 1977). Mindful learning refers to the ways in which we function during the learning process.

The basic idea is that fluid, flexible thinking boosts our learning ability. Langer encourages us to experiment and to play with information, looking at it from different perspectives, making use of multiple examples, and exploring how the meanings of a given set of information change in different contexts. She identifies seven myths or false attitudes (Langer, 1997, p. 2) that are embedded in the educational system and that stunt students' growth and interest in learning. They are reviewed below.

First, many in education believe that the basics should be so well learned that they become second nature. This is incorrect, says Langer. Drilling in the basics leads to overlearning or learning without thinking – the automaticity described above. Does it make sense, she asks, to freeze our understanding of a skill before we try it out in different contexts and adjust it to our own strengths and experiences? One of the studies performed by Langer and her colleagues found that pianists who learned by varying their playing style performed more competently and creatively than those who learned to play strictly through repetition.

Second, educators think that paying attention means staying focused on one thing. This myth, according to Langer, fails to recognize the value of novelty in holding our attention. Her studies show that varying the target of our attention, whether it is a visual object or an idea, improves our memory of it. In one study performed with

Martha Bayliss, groups were instructed to read short stories. The “mindful” groups were instructed to vary aspects of the story such as to read from different perspectives, consider different endings, etc. The “focus” groups were told to focus their attention on certain fixed aspects of the stories. The control groups read without any specific instructions. When participants were asked to list all they could remember from the story they just read, the mindful groups remembered significantly more details than the others, even though they had the most to think about.

Third, conventional education buys into the idea of “work (learn) now and play later.” Langer claims, however, that learning itself can and should be fun. She feels the fun is lost when ideas are removed from their contexts and when learning is evaluated and graded. This shifts the reward from the innate pleasure of learning to the pleasure of getting a desired grade (or the fear or disappointment of not getting the desired grade). The innate pleasure of learning, she says, comes from making finer and finer distinctions between things.

Fourth, rote memorization is prevalent in education, but Langer sees memorizing as a way of taking in information that is personally irrelevant. Rote learning is usually undertaken for the purpose of performing on an evaluation, not to achieve understanding. It is analogous to the twist that occurs in the courts as lawyers set out to win a case, not necessarily to find justice. Langer feels that one way to reduce rote learning is to encourage students to make information personally meaningful.

Fifth, memory is essential to living in the world. It provides the basis for our expectations, actions and safety precautions (e.g., don’t put your hand on a hot stove). But, says Langer, forgetting can have its benefits, especially in the opportunities it provides for rethinking ideas in a new context.

Sixth, teachers often act as if intelligence consists of knowing facts. This is not the case, says Langer. Intelligence consists of thinking flexibly and looking at the world from multiple perspectives. This theme, so relevant to biology, has been elaborated by Spiro and colleagues in their cognitive flexibility theory, a theory of knowledge acquisition in ill-structured domains (e. g., Spiro, Coulson, Feltovich, & Anderson, 1988). Although Spiro developed cognitive flexibility theory to describe biology learning by students in medical school, I find it provides an excellent model for teaching nonmajor biology as well (Fisher & Gomes, 1996a).

I believe that when teaching nonmajors or majors who will be working in other fields, emphases on the “big picture” are important. Details can be obtained on an as-needed basis in the future. At the same time, detailed facts are important for those who will be working in the domain. As mentioned in Chapter 3, content knowledge about a domain is a *major determinant* of problem-solving performance in that domain. In studies of two disparate domains (mathematical vectors and using a video tape recorder), Gordon and Gill (1989) found that subjects’ interconnected content knowledge, mapped in conceptual graphs, predicted 85 to 93% of an individual’s ability to solve problems in those domains. Missing concepts or missing links caused problems with performance. These studies and related research indicate that teaching isolated facts is largely useless, while prompting learners to construct a coherent and interconnected set of ideas about a domain is productive and worthwhile.

Langer's seventh point is that many teachers believe there are right and wrong answers. Langer disagrees with this belief, as do most constructivists. Science aims to produce the best model of the world at any given time; it is not necessarily the "right model," the "only possible model," or the "truth." There is awareness among scientists that any theory or observation may change or be replaced in the future, either by generation of new empirical data or by conceptualization of an even more satisfactory and powerful theory. Thinking that we have the "right" model leads to rigidity and fixedness, whereas thinking that what we have is currently the "best" model can lead to flexibility, openness, and continued willingness to question.

A key message that runs throughout Langer's discussions is that students must become motivated to learn (learning can be fun) and that students must take responsibility for their learning. Given its important role in learning, it seems that increasing student motivation to learn should be our number one priority.

MOTIVATION

In studying learning, Rumelhart and Norman (1978) observed that motivation outweighed any cognitive variables they were able to measure. Likewise, Dubin and Taveggia (1969) found that student motivation was a more powerful determinant of learning than any change in teaching strategy. Some steps which are known to increase motivation are:

- giving each student a voice in the class,
- respecting each student's input;
- allowing students to pursue their own questions;
- encouraging students to work in groups and discuss their ideas among themselves;
- creating opportunities for students to create and test their own explanatory models;
- giving students an opportunity to demonstrate their knowledge to others through publication or presentation; and
- providing tools which can sustain student analysis and discussion. *Enhancing student motivation often entails reducing emphasis on learning the facts and increasing emphasis on learning scientific processes.*

MEANINGFUL LEARNING

Ausubel (1968, pp. 37–38), a psychologist who spent his lifetime thinking about learning, describes meaningful learning in this way. The essence of the meaningful learning process is that ideas are related in a substantive (nonverbatim) fashion to what the learner already knows. Each new idea is connected to some existing relevant aspect of an individual's mental structure of knowledge (for example, an image, a meaningful symbol, a concept, or a proposition). Meaningful learning requires two conditions. First, the learner must be motivated to learn in a meaningful way, and second, the material being learned must be inherently meaningful and accessible to

the learner. A third condition is that there be sufficient time for meaningful learning to occur, since learning is an effort- and time-demanding process.

Basically, learning involves a number of steps including *perceiving* the world and information in the world, *interpreting* that information, *encoding* it somehow in the mind, *retrieving* it as needed, and then *applying* the information in various contexts. Each of these steps is briefly discussed below.

1) Perception

Our perceptions are limited by our particular perceptual hardware. We cannot “see” like a satellite camera, measuring color or density differentials, nor like an eagle, spotting a small animal on the ground from high in the air, nor like a bee, taking in the ultraviolet spectrum. The world we are able to know directly is constrained and molded by our perceptual hardware.

Since our perceptual limitations filter and define our world, we can never “know” the world absolutely and totally. “Right answers” are elusive. Yet science as a “search for truth” has been a popular conception among science teachers for years. As Langer says, science is often taught as if there is a “right” answer to each question, and the students’ job is to memorize those facts or truths about the world.

But this is not how science is actually conducted. Scientists strive to construct the best possible *model* of the world at any given time. They constantly evaluate their models and assess which one is best in terms of its ability to explain, to predict, and to account for many different observations. “Facts” are not necessarily truths but rather well established records of objects or events that are widely accepted to be correct, at least for the time being. In science, a prevailing model can be replaced with another at any time, if the newer model is more powerful and satisfactory. The replacement process can be painful for individual scientists in the “out” group, those who are still attached to the old ideas, especially where large conceptual revolutions are involved (Kuhn, 1970).

Teaching science as if it consists of facts alone is self-defeating, in part because the facts keep changing. Students need to understand that the scientific way of knowing is based upon systematic study of objects and events combined with the construction of models to explain and predict (although prediction is not often possible in the retrospective sciences). Models are tested under a variety of circumstances and by many different scientists. Creation of scientific knowledge is thus a collaborative venture. The public is often confused when they hear conflicting beliefs and claims by different scientists, but such disparate viewpoints are a natural part of a group knowledge-building effort that relies on individual ingenuity, collaboration, and competition. When a particular knowledge claim is challenged, its supporters are prompted to find even more convincing evidence to support their point of view, and so science advances.

A surprisingly effective way for students to learn about the scientific process *and* to develop a fairly deep understanding of science content is to read a good popular book on a subject. In my experience, biology nonmajors who read and discuss *The Beak of the Finch* (Weiner, 1995) while also completing a series of related lessons in



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