Cell Biology Education
Vol. 3, 197–201, Winter 2004

Feature

Approaches to Biology Teaching and Learning: Learning Styles and the Problem of Instructional Selection—Engaging All Students in Science Courses

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THE PROBLEM OF INSTRUCTIONAL SELECTION

Teachers aspire to have all of their students learn. This aspiration of reaching all students spans disciplines, age levels, and all varieties of institutions. Most teachers do so out of a genuine love for their discipline and a desire to share the wonder of their chosen field with others. Science teaching is no different than other disciplines in this respect. However, try as we may in science, the lack of diversity apparent in the statistics of who chooses to pursue scientific disciplines professionally suggests that we still have much to learn about how to reach all students.

In their book, *Talking About Leaving: Why Undergraduates Leave the Sciences*, Elaine Seymour and Nancy Hewitt (1997) provide ample evidence from analysis of previous studies and their own research that two major factors contribute to choices students make about pursuing science majors and their satisfaction with science as a choice of major—classroom climate and faculty pedagogy. These factors underlie many of the reasons "switchers" leave science majors and many of the complaints "nonswitchers" have about their education in science (Seymour, 1997). Competitive class climate, strict grading, overpacked curricula, and the overt "weed-out" attitude of some faculty are cited most often as criticisms and reasons for abandoning a science major. However, Seymour and Hewitt (1994) emphasize that "switchers" and "nonswitchers" are not identifiably different populations of students, in that academic ability is not a reliable predictor of who stays and who leaves. This leads to the conclusion that science classroom environments, instructor teaching styles, and the process of instructional selection is unintentionally causing the loss of able, interested students from the profession of science. If we lose students precisely because they learn differently and think differently than those who currently dominate the profession and teach them, we lose a potential source of future creativity in our discipline. Sheila Tobias (1990), author of *They're Not Dumb, They're Different*, writes that "not every student who doesn't do science can't do science; many simply choose not to." Tobias identifies the selection process of introductory science courses as a driving force against diversifying participation, and thus diversifying intellectual approaches within the profession.

Consider the environment that characterizes most science classrooms, particularly in the late 1980s when Sheila Tobias conducted her research in these classrooms. It is usually organized by an individual—faculty or a teacher of grades 6 through 12—who survived, if not thrived, in the fairly traditional pedagogical settings of teacher-centered direct instruction, mostly dominated by lecture-based approaches to teaching. The dominance of lectures and direct instruction, especially at the high school and undergraduate level, in an attempt to transmit the large body of accrued scientific knowledge efficiently, has created a relative monoculture of teaching styles in these settings. Although a variety of strategies have been developed to broaden access for students through more varied instructional strategies (see, e.g., Allen and Tanner, 2003; Tanner *et al.*, 2003), these approaches are not widely used for a variety of reasons. This is not to say that lectures have no place in the pedagogical toolbox of a science instructor, but rather that this tool tends to be overused (Powell, 2003). As such, teaching strategies used in science classrooms have created a situation that we'll refer to here as *Instructional Selection*, in which by our very choice of pedagogy, we are constructing environments in which only a subset of learners can succeed. Understanding the variety of learning styles that students bring to a science classroom will not only help some students learn more science, but also help more students learn any science.

LEARNING STYLES: RAISING AWARENESS OF THE DIVERSITY AMONG LEARNERS

> Do not then train youths to learning by force and harshness, but direct them to it by what amuses their minds so that you may be better able to discover with accuracy the peculiar bent of the genius of each.
>
> — Plato

To provide open access to science learning and encourage a broader spectrum of students to pursue studies in the sciences, we—as teachers, instructors, and faculty—must begin to address the diversity of learning styles among the students in our classrooms. So, what is a learning style? An individual's learning style can be defined in many ways,

DOI: 10.1187/cbe.04-07-0050
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including, "the complex manner in which, and conditions under which, learners most efficiently and most effectively perceive, process, store, and recall what they are attempting to learn" (James, 1995) or, alternatively, "the preference or predisposition of an individual to perceive and process information in a particular way or combination of ways" (Sarasin, 1998). From a biological perspective, the brain is the organ of learning, and as such, a learning style is likely to be a complex, emergent interaction of the neurophysiology of an individual's brain and the unique developmental process that has shaped it through experience and interaction with the environment. Learning style, thus, is a phenotypic characteristic of an organism like any other. Given the plasticity of the human brain and its propensity to learn and likely change synaptically over time, learning styles should be considered to be flexible, not immutable—an individual's learning style could be actively adapted, to a certain extent, to different learning environments.

The study of human learning styles is a well-established field within the discipline of cognitive psychology. Shelves of books and hundreds of papers by leading researchers in the field are beyond the scope of this short introduction to learning style theory. To provide entry into the core ideas for interested science faculty, we have chosen to briefly explore three accessible frameworks for characterizing differences in the way learners prefer to learn: the VARK, Multiple Intelligences, and Dimensions of Learning Styles in Science. No one school of thought is superior or inferior to the others, and those presented here are but a sampling of the ideas in this field of cognitive psychology research. There are many common strands and themes among these examples. Other approaches to describing and categorizing learning styles have been proposed that are not dissimilar to the ideas presented here (Honey and Mumford, 1982; Kolb, 1984, 1994). In particular, Isabel Briggs Meyers and her mother, Katherine Briggs, adapted the theories of Carl Jung to produce the Meyers-Briggs Type Indicator assessment, which explores the connection between personality, temperament, learning style, and career choices and is commonly used in both corporate and academic environments (Meyers and McCaulley, 1986; Meyers-Briggs, 1980). It is important to keep in mind that all of these frameworks and research literature on understanding learning styles are attempts to simplify what is fundamentally a complex issue; namely, who we are and how we learn.

Sensory Modalities of Learning: The VAK Framework

Perhaps everyone has heard the refrain, "But I'm a visual learner" or "I'm an auditory learner." One of the oldest characterizations of learning styles has been to define a learner's preferred mode of learning in terms of the sensory modality by which they prefer to take in new information. VAK is an acronym that stands for three major sensory modes of learning: visual, aural, and kinesthetic, depending on the neural system with which a learner prefers to receive information. More recently, this sensory framework has been expanded to VARK to include reading/writing as an additional type of mixed-sensory learning modality (http://www.vark-learn.com/english/index.asp). Although all learners can use all of these sensory modes in learning, one mode is often dominant and preferred. Visual learners learn through seeing and prefer to learn through drawings, pictures, and other image-rich teaching tools. Auditory learners learn preferentially through hearing and are adept at listening to lectures and exploring material through discussions and might need to talk through ideas. Reading/writing learners learn preferentially through interaction with textual materials, whereas kinesthetic learners learn through touching and prefer learning experiences that emphasize doing, physical involvement, and manipulation of objects. In fact, as we progress through schooling in the United States, pedagogy often emphasizes kinesthetic learning with young children through the use of models and manipulatives, moves on to more visual learning as language develops in the elementary school years, and culminates in primarily aural learning in the form of lectures, accompanied by increased reading and writing, in the high school and college years. An exception is often the college laboratory setting, which continues to offer opportunities for mature learners to use manipulatives in building science knowledge. Most instructors organizing introductory science courses will find that the material can be organized to include all of the above types of learning modalities, but the reality of large class enrollments and limited budgets can make this a challenge.

Developed in 1987 by Neil Fleming, the VARK Inventory is a tool for assessing where an individual's preferences for learning lie within these sensory domains (see http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/vark.htm).

Deconstructing Intelligence: Howard Gardner's Theory of Multiple Intelligences

In contrast to other characterizations of learning styles, Howard Gardner's approach to defining learning styles stems from the notion that the concept of intelligence has been too narrowly defined. Gardner argues that psychologists, in defining intelligence and designing instruments to measure and compare intelligence across individuals, have focused on a singular, unitary notion of intelligence. In Gardner's view, the dominant formal IQ test only measures one type of intelligence, yet humans can excel in multiple areas of intelligence. In his 1983 book *Frames of Mind*, Gardner introduced his now widely discussed Theory of Multiple Intelligences. In addition to linguistic-verbal intelligence and

Table 1. Howard Gardner's (1983) Multiple Intelligences Theory

The Eight Intelligences	
Intelligence	is characterized by facility with . . .
Linguistic-verbal	Words, language, reading, and writing
Logical-mathematical	Mathematics, calculations, and quantification
Visual-spatial	Three dimensions, imagery, and graphic information
Bodily-kinesthetic	Manipulation of objects, physical interaction with materials
Musical-rhythmic	Rhythm, pitch, melody, and tone
Interpersonal	Understanding of others, ability to work effectively in groups
Intrapersonal	Metacognitive ability to understand oneself, self-awareness
Naturalistic	Observation of patterns, identification, and classification

mathematical-logical intelligence, the two major cognitive skill sets tested by IQ instruments, Gardner proposed another initial six domains of intelligence (see Table 1). Gardner points out that although these categories of intelligences might only represent a subset of the range of human abilities, they are likely to be a more accurate representation than a singular notion of intelligence. In exploring the multiple intelligence framework of Gardner, one will find vestiges of the sensory modality approach to learning styles described above. Visual-spatial intelligence is characterized by facility with images and graphic information and bodily-kinesthetic intelligence involves facility with physical manipulation of objects, the body, and other modes of physical interactions (Gardner, 1983). In addition, Gardner proposes two intelligences that are characterized either by particular talents in understanding and interacting with others (interpersonal intelligence) or by a talent for self-perception and metacognition about oneself (intrapersonal intelligence). To define a category of intelligence, Gardner's theory requires that several criteria be met, including distinction of intelligences through psychological tests, the potential for localization in the brain, the existence of savants who excel within the realm of a single intelligence, and a potential evolutionary history. This last aspect of defining intelligences is particularly intriguing biologically, given the existence of acute spatial skills in reptiles and insects and the evidence of adept musical skills in birds important for marking territory and attracting mates (Gardner, 1999). Again, an introductory science course can readily be organized to draw on most of these diverse intelligences by including a variety of learning activities throughout a course, such as lectures rich with visual information, discussions that promote student–student interactions, group projects and presentations that allow for creative elements, and laboratory investigations that engage learners in the physical doing of science.

Dimensions of Learning Styles in Science: Felder and Silverman

The VARK sensory modality model and Gardner's Multiple Intelligences schema, along with other theoretical frameworks not presented here, provide approaches for thinking about diverse learning styles in a classroom. However, they do not specifically address aspects of learning styles that could be particularly relevant to science education and the issues of inclusion and exclusion of learners in science classrooms. Inspired by Sheila Tobias' study of why some capable students are self-selecting out of introductory science classes, Richard Felder and Linda Silverman attempted to construct a framework for learning styles to highlight the disconnect between diverse learning styles and the traditional teaching styles in science courses. Their Dimensions of Learning Styles in Science was originally proposed as a framework for analyzing teaching and learning in engineering fields; however, its usefulness extends throughout the scientific disciplines.

Table 2. Felder and Silverman's (Felder, 1993; Felder and Silverman, 1988) Dimensions of Learning in science

Dimensions of Learning		
Sensory	⟷	Intuitive
Visual	⟷	Verbal
Active	⟷	Reflective
Sequential	⟷	Global

Felder and Silverman (Felder, 1993; Felder and Silverman, 1988) propose four dimensions of student learning styles, each of which relates to students' preferred modes for receiving information, including 1) the type of information they receive (sensory or intuitive), 2) the modality in which they receive it (visual or verbal), 3) the process by which they receive it (actively or reflectively), and 4) the order in which they receive it (sequentially or globally). These dimensions are useful in considering the diversity of learning styles and how teaching strategies in science classrooms do or do not regularly provide access to learning for these different types of students.

Science coursework, regardless of the pedagogical style of the instructor, is generally rich in the amount of information being presented. In their model, Felder and Silverman propose that students can differ substantially in the types of information they prefer to receive during learning. At one extreme are sensory students—those who prefer to receive facts, are adept at memorization and details, and prefer clear expectations and well-established routines in learning. Dichotomous to them are intuitive learners, who prefer to receive concepts, see relationships among ideas, explore complexities and exceptions, and welcome innovative and varied approaches to problems. Felder and Silverman emphasize that there is certainly a continuum of preferences between the extremes of sensory and intuitive learners as described above but argue that the distinction is helpful in considering the match or mismatch between these two learning style dimensions and an instructor's pedagogy in a science course. Both types of learning are essential if a student is to acquire both the needed knowledge base and the desired skills to apply that knowledge in thinking creatively about scientific problems.

The second dimension of learning styles proposed by Felder and Silverman relates to the actual sensory modality through which learners get information, similar to the VARK framework described above. Visual learners are characterized by a preference for learning from demonstrations, pictures, diagrams, and graphs, whereas verbal learners prefer opportunities to explore new material through language-based processes such as talking, writing, explaining, and discussing. Felder points out that much of college-level science teaching relies heavily on the use of the lecture as a pedagogical tool, often bereft of more visual materials, a practice that consistently would hamper access to learning by a preferentially visual learner. In the life sciences, visual resources are becoming increasingly available, ranging from illustrations provided in several formats by textbook publishers, to libraries of electronic resources including animations and videos (see the archives of *Cell Biology Education* features such as "Video Views and Reviews," as well as "WWW.Cell Biology Education").

Also relevant to the dominant pedagogy of science classrooms, Felder and Silverman's third dimension of learning styles draws a distinction between active learners and reflective learners. They proffer that active learners prefer to learn while doing and being actively engaged in investigations, group work, discussions, and other opportunities for student–student and student–instructor interactions. Reflective learners, on the other hand, are more likely to prefer opportunities for reflection, individual work, and a chance to digest information in the absence of a social context. Harkening back to Gardner's framework, the active learners in Felder and Silverman's framework might possess high interpersonal intelligence, whereas reflective learners might excel in the domain of intrapersonal intelligence. Ideally, opportunities for both individual and group work should be part of any introductory science course.

Finally, Felder and Silverman propose a dimension of learning based on the preferred manner in which a learner builds new knowledge for themselves, describing the dichotomy between a sequential learner and a global learner. Sequential learners are described as individuals who prefer a well-ordered, linear pathway to new knowledge, which is presented as a series of smaller pieces that fit together. Global learners, in contrast, prefer to establish an overview of the larger concepts and then proceed to undergird these ideas will smaller details. In traditional science courses, sequential learners might likely excel, and might be able to do so in the absence of understanding the systems and interconnectedness of major concepts. In these same environments, however, global learners could get lost amid the facts and fail to grasp the larger picture which is essential to them in knowledge building.

In summary, Richard Felder (1993) argues:

> Students whose learning styles fall in any of the given categories have the potential to be excellent scientists. The observant and methodical sensors, for example make good experimentalists, and the insightful and imaginative intuitors make good theoreticians. Active learners are adept at administration and team-oriented project work; reflective learners do well at individual research and design. Sequential learners are often good analysts, skilled at solving convergent (single answer) problems; global learners are often good synthesizers, able to draw material from several disciplines to solve problems that could not have been solved with conventional single-discipline approaches.

To assess where your own preferences lie on these four dimensions of learning, access the Felder's Index of Learning Styles tool at http://www.ncsu.edu/felder-public/ILSpage.html. Felder also emphasizes that shifts in instruction to increase access to science learning need not be major shifts. The use of both pedagogical strategies that provide time for students to think and reflect in class and strategies that structure student–student interaction during a course will vary instruction and allow for experiences that are optimal at different times for both reflective and active learners. Simply introducing the larger concept of harvesting energy from food prior to the detailed presentation of the process of cellular respiration could provide the necessary conceptual overview to engage the global learner and aid the sequential learner in connecting these chemical processes to the macroscale functions of living things.

LINKING LEARNING STYLE THEORIES TO THE CLASSROOM

> The teaching of math and science suffers from being all scales and not enough music.
>
> — Sheila Tobias

Differentiating Science Instruction

Combining the research on why students abandon science courses and the frameworks for categorizing learning styles, the challenge seems clear. To reach diverse audiences of learners, science teachers must differentiate and diversify their own teaching styles and the pedagogical approaches used in science courses. In most cases it is neither possible nor desirable to tailor coursework to the individual learning styles of each student. How students characterize their learning style and with which framework they characterize it might not even be so critically important, although it could contribute to their academic success by promoting self-awareness and the use of learning strategies that work for their learning style. What is essential, however, is that an instructor's teaching style provide access for students with different learning styles during the experiences of a science course. The key to avoiding *Instructional Selection* and retaining a broader swath of students interested in science is differentiated instruction, a teaching style that derives from multiple pedagogical approaches and not a singular approach.

Reflecting on Your Own Teaching Style

Although less well developed than the many theoretical frameworks for considering learning styles, tools are emerging to characterize and examine the variety of teaching styles of instructors. In his 1996 book, *Teaching with Style: A Practical Guide to Enhancing Learning by Understanding Teaching and Learning Styles*, Anthony Grasha (1996) proposes five teaching style clusters and evaluates how flexible each can be in addressing the needs of multiple, divergent learning styles in one classroom: Expert, Formal Authority, Personal Model, Facilitator, and Delegator. Each style varies mostly in the extent to which instruction is teacher-centered or student-centered. Rarely is any one instructor adequately represented by a single teaching style, just as no student is characterized by a single learning style. However, Grasha's proposed categories provide a framework for exploring and assessing one's own teaching style. In your own teaching style, to what extent do learners have access to material not only through auditory-based lectures, but also through visual means such as graphs, charts, and opportunities for students to draw their own diagrams? When do predominantly kinesthetic learners get to explore materials, participate in simple demonstrations, or develop creative presentations? To characterize their teaching style further, readers can take Grasha's Teaching Style Inventory and peruse his analysis of the relationship between different teaching styles and different learning styles (http://longleaf.net/teachingstyle.html). The teaching style of an effective instructor need not always match a student's preferred learning style; an additional goal for students is to help them in expanding their own repertoire of learning skills.

Being Explicit About Diverse Learning Styles

Finally, perhaps the simplest step toward reconciling diverse learning styles and more singular pedagogical styles is to explicitly acknowledge the issue and the existence of different learning styles. Many resources now exist on most college and university campuses to aid students in understanding their own learning style. Beginning a course by directing students to tools that can assist them in becoming metacognitive about their own learning processes and preferences can go a long way. Once a student understands that they are a more visual learner, they can work toward translating information into pictures, diagrams, and charts, even if the information is not initially presented to them in that mode. The self-assessment tools referenced above can be a good place for students to start.

So, we return to where we began. Teachers aspire to have all of their students learn. The thing is, we just might not know how best to teach each of them, especially in one classroom. To engage students of diverse learning styles in our classrooms, we likely must reach beyond the ways of teaching that worked well for us as learners and find new approaches that open the door to science learning for a broader variety of students. And expanding the repertoire of one's teaching style is not an immediate, major shift, but rather an incremental process that can be approached in small steps, trying new methods one at a time and perhaps for just a class period. Drawing a more diverse group of students into science will enrich our own experiences and bring a new strength and diversity to our scientific enterprise.

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