Counterpoint of View: Can Nonmajors Courses Lead to Biological Literacy? Do Majors Courses Do Any Better?

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?1 There has been a long, evolving, and often politically charged debate as to what the nonmajor student should know about science (Ravitch, 2000; Shamos, 1995). A recent view, presented by Robin Wright in the accompanying article, is that "No knowledge exists in any field, including biology, that is so vital or essential that every literate person must know it" and that "literacy implies that an individual has the potential for deeper learning in that field." This position raises some interesting issues, but before they can be addressed, it is essential that we define our terms, so that we are actually talking about the same things. First and most importantly, we must agree what we mean by scientific literacy. According to the Merriam-Webster Dictionary, literacy is "the quality of being literate," and literate means "1a: educated, cultured; b: able to read and write; 2a: versed in literature or creative writing; b: lucid, polished <a literate essay> c: having knowledge or competence <computer-literate> <politically literate>." Basically, to be literate means to be able to read a language with understanding and, in turn, be able to converse with some sophistication in that language.

If we bring this same approach to scientific literacy, we presumably mean the ability to read and converse in the language of science. So, is the language science simply English or any other "common language," or is it more? The answer is clearly "it is more": it involves its own, often discipline-specific, vocabulary as well as common understanding of the nature of scientific experiment, argument, and proof. Basic concepts, such as "positive" and "negative controls," "allele" versus "gene," or how natural selection can act on random mutation to generate complex traits, are not commonly understood by students or the general public; in fact, they are the focus of deeply held misconceptions that actively block effective learning and clear understanding (K. Garvin-Doxas & M.W. Klymkowsky, unpublished observation).

The vocabulary required for biological literacy consists of terms whose meaning must be robustly and unambiguously understood. When we talk about biological literacy, we must also define the "reading level" that we expect students to achieve. That is a question that is rarely addressed, much less answered in a realistic way. While there are a number of suggestions of what basic science/biology literacy should entail, such as the American Association for the Advancement of Science's (AAAS) *Project 2061: Benchmarks for Science Literacy* (AAAS, 1993) or the *Bio2010* report (National Research Council, 2003), there is generally little thought given to whether these goals can be achieved given the resources available (a product of available student credit hours × learning per credit hour), nor has there been much of an effort to develop objective measures of student understanding. Such assessment instruments are not afterthoughts that can be hobbled together, but require a directed research and validation effort; their construction and testing require adequate resources and expertise, which few instructors have (or have access to). No competent biologist would start an experiment whose outcome relies on a specific instrument without having extensive data that the instrument measures what it purports to measure; in the same light, few biologists would have the expertise to construct even a simple instrument, such as a pH meter—and so it is with educational "experiments" and instruments as well.

The next question to be addressed is equally important: what is the best way to bring students to the desired level of biological literacy? If we follow the example of standard literacy, this can be accomplished only through having students read and converse in the language they are expected to master; they must be actively engaged in the learning process. Most courses in the biological sciences are divided

Table 1. Differences in major and nonmajor courses

Course type	Course goals and characteristics
Majors	High level of "scientific/discipline-specific literacy"
	One of a sequence of courses
	Weed out "unsuitable" students
Nonmajors	Basic level of "general/biological scientific literacy"
	Stand-alone course
	Inspire students to take up the major
	Increase departmental student contact hours
	Appealing to the consumer

into two general types, "majors" versus "nonmajors." How do these courses differ? (Table 1). While there are clearly differences related to instructor, design, and teaching philosophy, there is a more fundamental difference—nonmajors courses normally stand alone, whereas the typical majors course is part of an extended sequence or group of courses that are expected to be taken by the student. How does this extended sequence of courses impact course and curriculum design and learning outcomes? Consider how much language fluency students might be expected to achieve in a single course in their nonnative language and you get the picture—it is almost impossible to imagine that they could converse above the most rudimentary level. Is this what we mean by scientific/biological literacy?

There are a number of secondary, but nevertheless important, differences between majors and nonmajors courses. Majors courses are commonly viewed as harder, more rigorous, and more comprehensive—unfortunately, there is little objective data that they actually produce better or more extensive learning gains compared to nonmajors courses. In a set of studies, Sundberg and colleagues (Sundberg and Dini, 1993; Sundberg *et al.,* 1994) found "an
?4 *inverse* [my emphasis] relationship between the amount and rigor of content presented and 1) positive change in student attitude and 2) increased conceptual understanding! Students developed more sophisticated conceptual understanding, and a more positive regard for science, when fewer specifics were taught" (Sundberg, n.d.); and "majors, who received a much more rigorous treatment of the material, come through the semester with the same degree of understanding as the
?2 nonmajors!" (Sundberg and Dini, 1993).

At the same time there is a common perception among students, and at least some faculty, that an important goal of introductory majors courses is to "weed out" those who are not appropriate (whatever that may mean) for the major. On the other hand, nonmajors courses are often (but not always) whirlwind, and necessarily superficial, tours through a subject. This is a design feature that often leads to the perception that such courses trivialize difficult subjects, although it is also possible that they can inspire students to study specific topics further. There are also the real institutional factors at work; a primary raison d'etre for many nonmajors courses is to capture student contact hours rather than to bring students to literacy in the subject. Because departments compete with one another for a limited number of student science requirement credit hours, there is a pervasive temptation to make these courses more appealing to the consumer, rather than designing them to optimize learning.

ARE EITHER MAJORS OR NONMAJORS COURSES ADEQUATE?

Most surveys of public attitudes indicate that ~50 percent of the general public are confused or misinformed about the nature of science. These surveys, which rarely query more subtle, but nevertheless critical, aspects of scientific methods or concepts, do not attempt to identify underlying misconceptions. It is therefore quite likely that the level of scientific literacy is actually much lower than is commonly recognized. The question then is, what level of scientific literacy is adequate for our society? This is a very difficult question to answer. Shamos (2000) argues that market forces will, over ?3
the long term, drive the production or the importation of all of the scientific expertise needed by the economy. But what about general biological literacy—isn't that important? Probably, but again the question is, what level of literacy are we seeking to achieve, and how much in the way of resources are we prepared to devote to its attainment? Presumably most would agree that a suitable goal is a level of fluency that enables one to make informed choices about health care issues, to judge in a reasonable way how to interpret the news, and to appreciate the beauty of our growing understanding of our living world.

At present there are few objective and validated assessment tools for measuring student comprehension of key biological concepts; it is therefore quite difficult, and often impossible, to determine which type of course, majors or nonmajors, will attain our learning goals. More importantly, the goals for both majors and nonmajors courses need to be clarified and made explicit, tested to see whether they are attainable; and if not, either these goals must be revised (i.e., made more realistic), or more resources (e.g., student credit hours, alternative teaching strategies) need to be assigned toward their accomplishment. While it is possible to believe that biological vignettes presented in many nonmajors courses can be understood in a meaningful way without the rigor of a learned vocabulary and syntax, there is little or no objective evidence to support the claim. Anecdotes of inspired students can distract us from the majority of students who pass through such courses with their misconceptions intact (if not actually strengthened) and little understanding acquired. At the same time, the structure of majors courses is too often based on the belief that the breakneck pace of progress in the biological sciences demands an equally frenetic pace through the material. Unfortunately this type of class structure often leaves fundamental concepts poorly grasped and ignores the fact that many of the basics in the biological sciences are as well established and essentially static as those in basic physics and chemistry. The failings of both majors and nonmajors courses can, I conclude, be recognized and eventually corrected only through the development and deployment of objective and validated instruments designed to measure whether course learning goals are actually achieved.

If biologists had assessment instruments analogous to the Force Concept Inventory for basic Newtonian mechanics (Hestenes *et al.,* 1992; Klymkowsky *et al.,* 2003) , introductory majors and nonmajors courses would converge toward a common focus on fundamental concepts, critical to communicating in the language of biology. Introductory majors courses will spend more time ensuring that students actually understand the material presented (which is likely to drastically reduce the quantity of material "covered" per credit hour), while nonmajors courses will be forced to cover basic concepts needed to understand biological processes.

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