A Proactive Strategy for TEACHING EVOLUTION

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The teacher of biology has an opportunity – and an obligation – to point out some of the practical implications of Darwinian theory for human conduct. A thoughtful biologist cannot fail to find (in Shakespeare's words) "tongues in trees, books in the running brooks, sermons in stones. ..." If he is interested in people as well as in things – and a teacher should be, even if a researcher is not – he will want to help students hear the sermons.

– Hardin, 1973, p. 15

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Getting Prepared

Biology teachers are fortunate when topics to be addressed possess inherent qualities that interest students. Classical genetics rarely fails to interest secondary school students because it is introduced at a time when they are self-absorbed with their nascent physical characteristics, emerging sexuality, and/or future athletic potential. A topic like genetics is always an easier sell than would be taxonomy, for instance. How should one treat topics that traditionally are tougher to teach?

A simple but effective method for self-assessing readiness to teach a particular topic is to be prepared to respond to the questions, "Why do I have to know this stuff?" and "What's in it for me?" Faced with these questions, real or implied, instructional decisions will be made to better address the needs of target learners. If the teacher's response does not have sufficient perceived relevance to the target learner, students find it quite easy to dismiss the "stuff" as unimportant – something to be memorized for a test and forgotten.

Preparation to teach evolution often carries with it an implicit additional question, "Why should I *believe* this stuff?" An inadequate response to this question can undermine a teacher's credibility and compromise his/her rapport with students and parents alike. How then should one reply? One place to start is to examine position statements on the teaching of evolution issued by professional organizations like the National Association of Biology Teachers (http://nabt.org/sup/resources/position_statements.asp) and National Science Teachers Association (http://www.nsta.org/position). Understanding how professional associations use the terms "truth," "belief," "theory," etc. can make an important contribution to the clarity of a teacher's communication.

It is not important, for instance, whether people *believe* in evolutionary theory. Indeed, the word "believe" is not appropriate to use in a scientific context. Our goal as biology teachers should be that students *understand* evolutionary theory to be the most powerful contemporary problem-solving tool at the disposal of the biologist. In disease control evolutionary theory is employed daily. What would happen to our ability to develop new antibiotics and vaccines if health researchers fail to assume common ancestry? When asked where we would be in our fight against deadly viruses and other pathogens without the evolution tool, a past director for the Centers for Disease Control once flatly remarked, "Potentially dead!" Without using common ancestry to our advantage, we would start from scratch to attack each and every "new" organism.

Generally, therefore, in responding to the question of "Why do I have to know this stuff?" it is crucial to have students recognize the idea that evolution seems capable of explaining a great deal. Evolution is a powerful idea that has changed the way we approach each and every biological problem. The semantics are subtle but profound–we should not be interested in whether a theory is "true," only whether the theory works. If a theory continues to solve problems, make accurate predictions, and explain phenomena that were formerly considered "unsolved" puzzles we are likely to continue its use.

Becoming Proactive

Teachers need to become proactive in the way they teach evolutionary theory by representing theories as tools that biologists use, much in the same way as doctors use diagnostic tools. Diagnostic tools help to identify logical solutions to medical problems with more reliability than either simple guesswork or an appeal to the supernatural. The most difficult dilemma for teachers is to convince students that in providing a theory as a new type of tool, they are not rejecting religious beliefs as a condition for accepting this new tool. Is it possible for teachers to provide explicit instruction on evolution in a scientifically accurate and psychologically responsible manner? The answer to this question depends greatly on a teacher's willingness to adopt instructional strategies that are more student-centered than many teachers are accustomed to using (Duschl & Gitomer, 1991; Nelson, 2000; Scharmann, 1993).

This shift in instructional approach is especially crucial when teaching evolution and other issues where science and society intersect (e.g., stem cell research, cloning, etc.). When students have difficulty with a topic they perceive to be in conflict with personal/family values, they may simply not be ready to adopt a position on it that is consistent with the one held by a biology teacher. Instead of posing an explicit threat (teaching in a scientistic manner) or avoiding the issue (sidestepping), teachers need to provide students with opportunities to "get part of the way there" by understanding the tools of science (i.e., theories) the way a biologist does. Echoing the sentiments expressed so eloquently by Garrett Hardin, it is far more important to have students realize that although they may find aspects of evolution personally questionable, the vast majority of the public welcomes the practical implications and beneficial consequences of evolutionary thinking (e.g., antibiotics, herbicides, vaccines, etc.). Evolution, like any theory, is an extraordinarily powerful explanation that can be used as a tool to solve problems. It doesn't need to be true in any absolute sense; it just needs to work as a problem-solving heuristic. Such a reference to the functional quality of a theory such as evolution is consistent with an "Instrumentalist" philosophy (Audi, 1999, pp. 438-439).

A Successful Proactive Instructional Strategy

A successful strategy one might employ in introducing evolution is the use of a small group, peer discussion. Foreshadowing current reform efforts, as exemplified in the "Teaching" section of the *National Science Education Standards* (National Research Council, 1996), Schwab (1962) cited three reasons for the effectiveness of small group discussions:

- Students are most active and individually engaged in learning when working in small groups.
- Discussions evoke, as reinforcers of learning, a host of more desirable affective outcomes (e.g., working, belonging, and identifying with a peer group).

- Teachers can establish greater instances of interpersonal relations (i.e., both student-student and student-teacher) during a given instructional period compared with most other teaching methods.

The time to consider the use of a peer discussion with respect to evolution is when students begin to exhibit anxiety, confusion, anger, withdrawal, or negative nonverbal expressions (Scharmann, 1990).

The following lesson provides a synthesis of the use of cooperative learning (Johnson & Johnson, 1991), an application of the learning cycle in teaching biology (BSCS, 1997; Lawson, Abraham, & Renner, 1989), and enhances the potential for conceptual change (Posner, Strike, Hewson, & Gertzog, 1982). It also integrates suggestions for dealing with student resistance to biological evolution (Clough, 1994; Scott, 1999) through the use of more active forms of teaching and learning (National Research Council, 1996; Nelson, 2000). It further emphasizes reflective analysis of what science is/is not (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick & Lederman, 2000). Finally, it gives students a voice in their own learning with an opportunity to express their concerns with respect to evolutionary theory (Dagher & BouJaoude, 1997; Smith & Scharmann, 1999).

Engagement

(Note: the engagement can be used as either an in-class or out-of-class activity)

Request students to respond individually, in writing, to the following:

1. Consider what you have read or been taught about evolution and summarize your understanding.
2. Are you personally aware of any explanation(s) that may differ with evolution theory in interpreting the present diversity that we see in nature?
3. Is there anything about evolution theory that causes you personal concern?

Exploration

Assign students to small discussion groups of three to five individuals. Have them share with classmates their responses to the Engagement Activity. Once completed, have groups work together to:

- Develop a set of reasons **for** learning evolution.
- Develop a set of reasons for **not** learning evolution.
- Examine the merits (i.e., strengths and weaknesses) of each set of reasons. Is one set of reasons more compelling? If so, which set? Why?

The teacher's role during discussion is to monitor group progress. It is neither to lead groups nor provide limitations on the direction of discussion; instead, it is to maintain on-task behavior and mutual respect. In monitoring groups, teachers should note obvious instances of misinformation and sources of student disagreements. The only exception (regarding direct teacher intervention) is to remind students that the intent of discussion is to listen to and respect the opinions of other group members. Ultimately discussions, unlike debates, do not require winners and losers – a well-constructed discussion produces only winners. Each group should select a spokesperson to share his/her group's consensus concerning merits for and against learning evolution. This phase of the learning cycle compels students to perform a risk/benefit analysis, determine criteria for making decisions and, at least for some students, note that issues related to "theories" are not simply right or wrong. Strict dualism (Perry, 1970) doesn't serve us very well in understanding the nature of science.

Explanation

Upon completion of student reports and any final inter-group clarification, teachers should bring the class together for an interactive, large group discussion. The teacher should plan to address any misinformation, especially related to competing knowledge claims resulting from different "ways of knowing" (i.e., religion vs. science). It is very important for teachers and students to be aware when they are using science and when they are using religion as their basis for explanation. The compatibility of these "ways of knowing" is strictly left as an individual choice, consistent with a position statement endorsed by the National Science Teachers Association (Skoog et al., 1998). It is at this point, nonetheless, that teachers might find it useful to introduce some critical products/benefits of evolutionary thinking:

- Antibiotics – Why are we instructed by physicians to take them over seven days even when we feel better after five days? Shouldn't we save the last two days worth of the medicine for the next time we get sick?
- Herbicides/Pesticides – Why should we use a rotation of different products? What happens if we keep using the same product over time?
- New Strains of Grain (e.g., wheat) – What might happen if we grew only one wheat variety? How

do we ensure that wheat crops remain viable?

- Identification of "New" Diseases – How do the Centers for Disease Control in Atlanta, Georgia identify organisms never previously classified?
- Vaccines – Why do we develop a serum in another animal for use in humans? Why do such vaccines work?
- Wise Consumerism – Should we purchase products labeled as "anti-bacterial?" Are they better and/or worth the extra money?

Thus, even if students don't wish to "believe" some implications of evolutionary theory (e.g., common ancestry/descent), they might begin to recognize that we all readily accept products derived from applications of this powerful theory. Finally, students should be given time to reflect upon (e.g., by writing a journal entry) what they individually gained as a result of participation in the small group discussion. Explicit reflection should also be initiated concerning student views of the nature of science and scientific theories; research continues to indicate the crucial nature of such reflection (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick & Lederman, 2000).

Elaboration

This phase of the learning cycle provides students with planned opportunities to "add greater depth to their conceptual understanding by probing in more detail the same concepts covered during the explanation phase" (Dougherty, 1997, p. 31). Problem-based scenarios might, for example, serve to initiate both critical thinking and an application of key evolutionary concepts. Scenarios such as the following might be used:

- In a national survey of high school-aged teens, suppose it was noted that there are more students today diagnosed with some form of visual problem that required correction (i.e., glasses, contact lenses, and surgery) than ever previously recorded in human history. Further suppose that the percentage difference is statistically significant compared with surveys from 50 years ago. What factor(s) might account for this difference? (Hint: How might natural selection be used to explain this difference?)
- Suppose that medical records indicate a three-fold increase in childhood asthma reported by elementary school nurses in the United States during the past decade. The percentage increase cannot be attributed to air quality, types of insulation used in the building trade, or other common environmental factors usually associated with childhood asthma (e.g., allergic response to airborne irritants such as ragweed, tree pollen, etc.). What factor(s) might account for this phenomenal increase? (Hint: How might natural selection be used to explain this difference?)
- Few vaccines were developed prior to the publication of Darwin's theories regarding evolution. Edward Jenner in 1798 was so convinced of a connection between cowpox and smallpox that he "immunized" his son with an injection of material from live cowpox lesions in order to provide convincing evidence to parents of other children. What assumption does evolutionary theory make that permits researchers to develop vaccines more quickly than if each had to be exclusively tested on humans? (Hint: How might common ancestry be used to explain a more rapid pace in the development of vaccines?)

The number of additional learning opportunities varies from one to several depending upon the degrees of depth and time allocated to the evolution unit of study. Irrespective of the number of activities, however, teachers should plan to further engage students in additional reflection concerning the differences inherent to science as a way of knowing in comparison to other ways (e.g., theology, aesthetics, etc.). Some other suggested activities can be found in the following:

- *Teaching About Evolution and the Nature of Science* (National Academy of Sciences, 1998)
- *Teaching Evolution: Designing Successful Instruction* (Scharmann, 1993)
- *Investigating Evolutionary Biology in the Laboratory* (McComas, 1994).

Summary

Garrett Hardin, in the opening quote of this paper, made a strong appeal to the inherent practical quality possessed by evolutionary theory. Hardin further argued that we would, as practicing biologists, continue to lose battles with our students and the general public if we maintain our case for evolutionary theory devoid of aesthetic and practical considerations.

Helping students to see the practical implications of evolutionary theory is no easy task. It requires overcoming apprehension, misunderstanding, and incorrect assertions. For a secondary student, however, to realize that the Darwinian view can be used to solve a host of practical problems (e.g., the creation of antibiotics, vaccines, herbicides, etc.) without necessarily threatening personal values and/or religious assumptions is a task worth undertaking.

The bottom line for teachers should be to best address the needs of the students they do (or will) teach. Perhaps Smith sums this sentiment up best when he wrote:

> *If we are to be successful in teaching evolution, we must take into account our students' worldviews as well as their individual understandings and misconceptions. ... It is important to know our students – their cultures, personal histories, cognitive abilities, religious beliefs, [and] scientific misconceptions. [It is also important] ... to address directly the likely cultural/religious concerns with evolution and to do so early on so as to break down the barriers that keep students from hearing what you say.*
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> – Smith, 1994, p. 591

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