Switching from Teaching to Learning in Biological Education

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SUMMARY

In biological education the “challenge of the next century” is to switch from the outmoded teaching paradigm to the more effective learning paradigm. The emphasis on learning is based on constructivist principles. It is student-centered and aims to promote deep understanding. This transition will not be easy. It requires new skills on behalf of students and instructors. Of particular importance is providing students with structures to promote processing of biological information. Suggestions are provided from genetics. Student-centered approaches will be met with resistance from students, teaching assistants, faculty colleagues and university administrators. Finally, without a strong context for biology, no matter what paradigm is in effect, the students can not learn deeply. We propose that community-based instruction, starting as early as possible in the curriculum, is an effective way to develop a strong context for biology. Community-based exercises allow students to record the diversity and observe or measure the properties of plant, animals and microbes in the community environment around the school or home.

KEY WORDS: teaching, learning, constructivism, understanding, biological education, community-based science

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The teaching paradigm

Nobody knows when in history teaching began, but it is likely that teaching as we now know it, i.e. a professor lecturing to a large assembly of students, is of medieval origin. In an age when books were scarce, it made sense for the learned professor to broadcast his or her knowledge in a lecture. However, it was probably true then, and it is certainly true today, that telling alone is not an efficient pedagogical method. There are several reasons. First, the general set-up promotes student passivity; the students represent empty mugs to be filled up with knowledge from the professorial jug. Second, in biology particularly, lecturing leads to a view of biology as a "fact mountain". Research in biology is proceeding faster than in any other science, and the teacher is inclined to profess all the latest results without removing earlier material, leading to the daunting mountain that students perceive they must climb or otherwise internally digest. The fact mountain produces the third main problem, shallow understanding, at best a smattering of facts. The modern student response to the fact mountain is that instead of trying to understand, they engage in a process of credentialling: in their minds the goal becomes not wisdom but to pass the course. Their burning question becomes "What does the professor want me to know?"

In this teaching paradigm the schools and centers of higher education ("universities" for short) are locked in a vicious cycle. School science teachers learn not only their science in universities but they also learn the way that science is taught. Their students then arrive at university with an expectation of mug and jug education and so it continues.

The learning paradigm

Student-centered learning approaches to instruction are finding widespread adoption today. This learning paradigm seems to be inherently more able to produce deep understanding because it is based on constructivism, the educational principle that states that learning must be personally constructed by engaging with some kind of data processing. We define "understanding" in the way used by David Perkins, that is "flexible performance capacity". In other words understanding does not exist inside the brain. but is an outward expression of some kind of performance, usually writing, verbalizing or problem-solving. This view of understanding sharpens and changes the pedagogical methodology because it must be aimed at the very specific goal of flexible performance rather than regurgitation of facts.

Implementing learning.

Although the learning paradigm is elegant and convincing, switching from teaching to learning is fraught with difficulties. This then might be viewed as the "Challenge of the next century". We will consider just three of these difficulties.

1. Facilitating student processing.

Some students find self-directed learning easy, but these are the exceptions and most need structures to help them learn in the constructivist mode. Partly it is the switch from passivity to activity, which requires more energy, but partly it is a question of not knowing where to begin.

We have developed processing tasks specifically for genetics, as it is the most challenging area of biology for students to learn deeply, but in principle these can be applied to any area of biology or science. Genetics is quantitative and analytical by nature, which sets it off somewhat from other areas of biology. Furthermore it has its own language and vocabulary, also different from other parts of biology. Additionally the subject is fraught with multiple representations. For example a drawing of a single line can be used to represent a single polynucleotide strand, a DNA double helix, a chromosome. a chromatid, a pair of sister chromatids at mitosis or a pair of sister chromatids at meiosis. In another example, the letter X is used in numerous different ways in genetics, which do not match common usage. Professionals can switch between these representations easily but for students they can be conceptual roadblocks.

Some examples follow of processing tasks that we have found useful.
a) Problem-solving by triads. Triads are groups of three students in which each has an assigned role. Two are problem-solvers, whose task is to try to solve the problem by discussing it out loud, and the third is a scribe whose job is to record the unsuccessful and successful paths followed by the problem-solvers. After 4-5 minutes the scribes report to the class publicly and the general methods tried are compared and discussed.
b) Mimicking problem solutions. The instructor shows his/her way of solving a problem. Students are then selected randomly to duplicate the approach publicly. (No note-making allowed.)
c) Concept maps. A tried-and-true approach but very effective at pinpointing underlying weaknesses in understanding. One way is for students to make their maps on OHT sheets which are then discussed in the general class.
d) Commentaries. Students are asked to provide a substantial commentary on a figure from the text, or on a paragraph. In one modification the student speaks for 1 minute without pause or hesitation on a some topic such as “the origin of aneuploidy” or “detecting a transloction”.
e) Problem expansion. A problem is the above-surface tip of a conceptual iceberg on which the student ship can founder. Problem expansion invites the student to break up the problem into all its component words and phrases and examine them, and question their significance. Once the bulk of the underwater knowledge is identified, the way to solve the problem becomes more obvious.

These are merely suggestions, but it should be clear how they are all ways of promoting active engagement with the course material.

2. Resistance.

Anyone who has tried a new pedagogical technique has felt the pull of resistance that impedes progress. People generally shy away from things that do not conform to their perception of the way education should be. Students are particularly resistant because the university seems to be set up to promote teaching; a great deal of money has obviously been spent on providing lecture halls, so that surely is the way things should be. Students expect to be taught, “I have paid a lot of money to come to the university to be taught by an expert”. In truth they have little confidence that the learning paradigm will be successful. Certainly this type of resistance is especially difficult to overcome over the span of one course, but at the beginning any new approach must be explained to the students carefully and some sense of the availability of a support system conveyed.

Teaching assistants (generally graduate students) also show resistance because they too have generally come through the teaching paradigm. Somehow they must be given a sense of ownership of any new methodology they have to implement.

Faculty colleagues are often resistant. They are secure in their lecturing mode, have developed a good style and a good set of notes that all make their educational duties easy. they are apt to balk at new methods that are unfamiliar and which inevitably take more preparation time.

Lastly, administrators resist. Anxious to promote the institution as an effective educational unit, they encourage displays of professional knowledge and competence. Evaluations of student-centered classes are often inferior to those of straight lecturers. No administrator wants to deal with a lot of complaining students or parents.

As with student resistance, the best solution is to explain beforehand what is being tried. Discussion groups and support groups can achieve this.

3. The problem of context

The switch from teaching to learning can only be accomplished when a meaningful context for learning biology is presented. Despite the adoption of student-centered approaches, learning can only be superficial if the student does not have a biological context to stimulate learning. We propose that all biology pedagogy should be grounded in the study of the natural world. Real biology (plants, animals and microbes) are outdoors, not in labs, textbooks or on television. Nature must be the starting point for learning biology at all levels of the educational system. When students are exposed to the natural world in their school and university classes the material they learn in classrooms is integrated, relevant, and immediate.

Unfortunately biology is usually taught as separate units of knowledge in courses that are isolated from each other and from the real world outside. This tendency is encountered more frequently the higher a student rises in the educational system. When students graduate with a degree in biology it is not uncommon for them to have acquired isolated packages of knowledge that they cannot integrate - such students see no connection between ecology, genetics and biochemistry. We contend that when a connection is made to the world outside in biology classes, nature provides an integrating focus for this knowledge and an authentic context for their understanding.

Disconnection from nature can lead to alienation and indifference to the fate of natural ecosystems. We believe that the connection to nature should be established early and based in the community in which the students live. Children are attracted to plants and animals and are innately curious about the world around them. This love of nature can provide a “hook” to give students a will to learn more about biology and develop investigative skills to study the natural world. A connection to nature can develop into a caring attitude from which springs not only the desire to know more but moreover a sense of responsibility and stewardship to the place where one lives.

Many simple but powerful learning experiences can be made on the life in the schoolyard or in the 1 km radius around the school. Plant and animal identification is a beginning. Studies on bird and other animal behavior (fish, insects, snails, etc.) encourage careful observation. Similar exercises can be based on plant growth, distribution and dispersal. Species counts provide an appreciation of biodiversity. Although biology provides a strong hook for most children, similar exercises can be constructed in astronomy, geology, geography, meteorology and architecture, all of which provide a sense of unity with the community and yet show the general principles at work globally.

Biology education grounded in a study of the natural world will provide students with the tools to investigate the crucial issues that face them now and in the future. Most of the major problems that we face in the world today, whether economic or ecological, are rooted in biology. This fact requires biologists, teachers and the general public to be able to deal knowledgeably with issues based on a wide variety of data input and opinions.

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