The Use of Research Data in Classrooms :

Application of Research Data on *Caenorhabditis elegans* to Enhance the Teaching of Introductory Biology

In the past 15 years there have been two landmark documents that have addressed the need for reform in undergraduate science education. They are: *Undergraduate Science, Mathematics and Engineering Education*, or, "the Neal Report" (National Science Board, 1986), and *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering and Technology* (National Science Foundation, 1996). These two reports signified an increasing awareness of an ongoing crisis in our undergraduate science education and the need to solve it. They addressed issues regarding what went wrong in the traditional teaching process and what needs to be done in the future, such as stressing "science for all students," providing all students a supportive learning environment, and having students undertake inquiry-based learning. Below I will examine the basis for this reform, including problems the reform was trying to address. I will also evaluate the need for new approaches to science education, in particular the use of science research data, including research image data, as possible additions to a modified reform movement.

Problems and Calls for Changes

Focusing on Research Instead of Teaching

The need for reform of undergraduate Science, Mathematics, Engineering and Technology (SME&T) education can be explored by examining the SME&T curriculum and the university environment that gave rise to it. In the university setting, the reward structure for faculty is more heavily tipped towards the conduct of research than it is toward teaching. Because universities compete for research money to supplement their endowments and to fund their education missions, faculty who attract research money are rewarded far more than faculty who concentrate only on teaching. As Alberts said:

> At major research universities, the most prestigious faculty appointments are those with no teaching responsibilities. The reward structure is especially problematic for junior faculty, for whom earning tenure often depends primarily or exclusively on the number and quality of their research publications. Although many professional organizations and disciplinary societies have published guidelines for recognizing and rewarding scholarly work in education, these guidelines are not widely accepted. [Y]ounger faculty … are often advised by their more senior colleagues to delay [developing innovative courses and experimenting with new teaching methods] until after they receive tenure. (National Science Foundation (NSF), 1996)

This lack of emphasis on undergraduate curriculum and the corresponding focus on research by the university administrations has resulted in decreased faculty enthusiasm to improve teaching (Atkinson & Ruzin, 1992; Bess, 1990; Joseph, 1998). This situation not only discourages teachers but ultimately causes students to suffer as well. Research and teaching are not separate enterprises. They are part of the same effort to help us understand our environment. To help students learn science is as important as the discovery of new knowledge. The faculty reward system is a problem that needs to be addressed in order for undergraduate education to be improved. How to allocate available resources to improve both research and education is a challenge for higher education (Atkinson & Ruzin, 1992; Bess, 1990; Coalition for Education in the Life Sciences (CELS), 1998; Joseph, 1998; NSF, 1996; Tobias, 1992). However, the solution to giving education an equal standing is not the only obstacle to improving science education.

Students' Lack of Interest

There is an increasing trend among college students to become disinterested or frustrated by their required introductory science courses. One consequence of this is a decline in the number of undergraduates who enroll in advanced science courses. An increasing majority of students are turning away from science during the first two years of their undergraduate studies (Bodner, 1990; CELS, 1998; McNeal & Avanzo, 1997; Tobias, 1990). This is due to a science education system that by design weeds out students in the introductory classes (Atkinson & Ruzin, 1992; NSF, 1996; Tobias, 1990). The phenomenon has been described as the "champagne glass" approach (Fig.1) (McNeal & Avanzo, 1997).

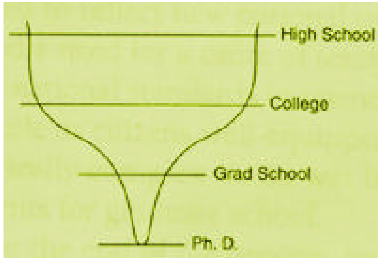


Fig.1 Champagne glass approach reflects the weeding out of students as they advance through the science curricula

A major reason why students are not interested in science is due to the science curriculum. Science curricula are designed for science major students and not for the non-majors (Atkinson & Ruzin, 1992; McNeal & Avanzo, 1997; Tobias, 1990). Mauldin and Lonney (1999) support this thesis, by stating,

> Introductory science courses designed for science majors fail to foster scientific understanding among the non-science majors. Without a broad context, many students

> neither understand the distinctive process of science, nor do they retain the abstract content of what they have been taught. Ultimately, this needlessly narrow approach to science education alienates most non-majors, who graduate with the perception that science is difficult, boring, and irrelevant to their everyday interest.

We live in a dynamic society where the use of technology in our daily lives is increasing exponentially. Universities not only have to educate future scientists, they must also educate students to become involved citizens in this era of technology. For example, we encounter engineering manipulated (EM) food, such as certain breeds of potato, corn, and soybeans, everyday. To understand the pros and cons regarding EM food is needed for us to decide whether it is worth our spending more money on organic foods. A well-taught science curriculum should not be for the few talented students who choose to become scientists but for all students to prepare them for the increasing demands of a high technology society. However, the inclusion of science education as part of a broad general curriculum does raise a difficult challenge: How to convey science in an approachable, yet informative manner (NSF, 1996)? Another issue concerns where we can start to improve our science education while keeping in mind a goal for enhancing science education for all students.

The Focus in Undergraduate Curriculum Reform

The reasons for focusing on undergraduate education are because

1. K-12 teachers who are taught in the undergraduate science curriculum will pass on their learned methods/understanding to their students. If they are poorly trained, they'll teach poorly.

2. Undergraduate science education is the place where most of our future technical workforce is prepared.
3. It is the place where our future scientists are introduced to the broad sciences and where they learn to integrate concepts from one discipline to another.
4. It can be a place to teach science literacy to all citizens.

While we target science education reform at the undergraduate level, the next question to ask is "what we are trying to accomplish?"

The Goal

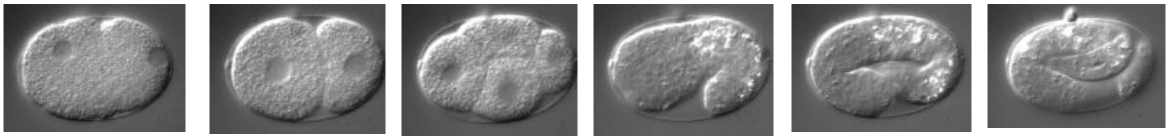
The goal of curriculum reform in the sciences is that:

> All students have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology, and all students learn these subjects by direct experience with the methods and processes of inquiry (NSF, 1996).

This goal focuses on students and learning. It stresses that "all" students learn science in a "supportive" environment and gain an "excellent" undergraduate education that involves scientific "inquiry". This means that all undergraduates, regardless of their major, will be trained equally well in the sciences. To meet this goal will require everyone's effort. For instance, the federal funding system needs to support both research and teaching in a way that will benefit both (Raines, 1998). For university faculty, the reward policy needs to increase the recognition of teaching as important to professional advancement. For science curricula, there needs to be a shift from the dull and boring textbook and straight lecture to methods that engage all students in active scientific inquiry as a way of learning. As science is an active, not passive, endeavor, students should be engaged in the process of doing science. Using research data to teach science not only actively integrates research and teaching, but actually involves students in the creative process of scientific methodology and practice.

Making Use of Research Data in Education

As discussed by several authors, including Atkinson & Ruzin (1992), Bess (1990), Joseph (1998), and Tobias (1992), more resources and funding need to be invested into college teaching . The resources are necessary to provide students with modern instructional facilities and to support faculty in efforts to improve teaching. One challenge is to set a national priority in order to allocate the available and necessary resources to both research and teaching (Atkinson & Ruzin, 1992; CELS, 1998; Joseph, 1998). A second challenge is to find a way to make use of research resources, such as using science research data in science education. The case can be made that if all undergraduate students have opportunities to engage with existing research data, they may develop insights into how research is done, thus leading to science 'literacy' for all students (Abraham & Hoagland, 1999). Therefore, we can help the undergraduate science curriculum reform if we can develop ways to disseminate available research data for educational purposes. One controversial viewpoint is that because researchers receive public support, they have an obligation to release their research data in an usable form for educational use (CELS, 1998; McNeal & Avanzo, 1997). Because this issue has not been implemented formally, and due to intense competition among scientists to publish their findings before anyone else, some researchers are reluctant to open their databases to the public.



Research data on *C. elegans*: from a zygote to a worm

About This Project

As part of the science reform movement, there are demands for educational dissemination of research data. This turns one of the problems facing college professors, the increased importance of research over education, into one of the solutions for a new breed of undergraduate scientific curricula. Embattled professors who are often torn between duties of teaching and research, have already attempted this on a small scale, by bringing their own research into the classroom. However, the vast majority of the top researchers at universities still remain uninvolved in undergraduate science education. This is sometimes due to a lack of interest on their part, but in many cases due to the lack of a framework that would encourage their participation. There is evidence that such a framework could go a long ways towards reforming undergraduate science education (Fortenberry, 1998).

Research into human learning indicates that students learn best when they actively construct their own knowledge. One indicator of this is that there is evidence that students who are exposed to research examples either directly in the laboratory or in the classroom tend to remain more interested in science (Lanza, 1988; McNeal & Avanzo, 1997). In this project, I will establish a basic framework for the involvement of researchers in undergraduate education by using *Caenorhabditis elegans* (*C. elegans*) as an educational model. *C. elegans* is a widely studied research organism because of its inherent simplicity and yet has the ability to reveal the mechanisms behind important biological concepts in much more complex organisms.

As you might note in the "Overview" page, the Laboratory of Optical and Computational Instrumentation (LOCI) is a research center located at the University of Wisconsin-Madison. In studying the function of genes in *C. elegans*, researchers at LOCI have produced various research data sets on *C. elegans*. My purpose in this project, which is posted on the world wide web, is to use research data on *C. elegans* to help students gain a better understanding in introductory biology.

C. elegans is used as a model research organism. I intend to show it will also serve as a model organism for teaching. In the first section of my project, I will explore what model organisms are and why people use model organisms in research. In the second part, I will review the characteristics of *C. elegans*. What properties make it a good model organism both in the lab and the classroom? In the third part, I will provide a survey on currently used *C. elegans* curricula. In the fourth part, I will review the project web site and provide some possible ways on how this project can be used in classrooms. Then, in the last part, I will propose the ways to disseminate the research data in the classroom. This section will cover several topics, including developmental biology and embryogenesis, which will use available *C. elegans* resources to help students learn biology. It is my intent that the development of curricula using *C. elegans* research data will serve as a model for the future development of curricula integrating other research data sets.

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