Sort by: Author

Learning Through Technology (LT^2)

LT^2 Home

- Search
- Site map
- Who we are
- CL-1 Home

introduction | quick looks | conversations | cases | resources

Mining the Databases and Solving Problems: Modeling Biology Learning on Biology Research

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Why use technology?

I want my students to get experience in what biologists actually do. To do that, I've worked at taking the tools that biologists use in the real world and finding ways to bring them into the classroom. It seems unrealistic to expect students to develop any appreciation for what science is if we only present them what is already known and have them do labs that are designed to confirm expected outcomes. At some point in each of my courses I want students to pursue a problem that they have had some role in shaping, using methods that reflect realistic scientific inquiry.

Computers play a variety of roles in biological research (e.g., data acquisition and analysis, modeling and simulation) and I try to take advantage of those different functions when I am providing investigative opportunities for students. **I am concerned about finding a balance between wet lab experiences and computer based experiences.** You can't rely exclusively on either approach-they complement one another in very important ways. The challenge for me involves trying to find a balance between different types of research, trying to find ways to integrate them so that the simulations the students are running complement what they're doing in a wet lab, and making sure that both complement lecture and discussion.

BioQUEST.

BioQUEST Library.

3P's

Genetics Construction Kit (GCK)

BIRDD

Biology Workbench

Biology Workbench Investigative Portal

Biology Workbench-Bioinformatics

BioQUEST ordering information

Beloit College is a small liberal arts college in Southern Wisconsin that emphasizes innovative teaching and student-faculty collaboration. The academic culture here at Beloit is such that students expect to do research projects in all their science courses, and technology is highly integrated across the curriculum. Besides being a supportive environment for trying new things in the classroom, Beloit is also the home (since 1986) of the BioQUEST Curriculum Consortium, an international group of educators and institutions dedicated to the reform of undergraduate biology education. BioQUEST materials emphasize giving students the opportunity to learn science by identifying and solving problems using the same methods and tools that research scientists use. The teaching philosophy has been described as the 3Ps: **P**roblem Posing, **P**roblem Solving, and **P**eer Persuasion.

The strategy

It has been my experience that most students come to a science course expecting to be told what the facts are in that discipline. While there is certainly a great deal of accumulated knowledge in any field of scientific inquiry, I resist taking on a role as the dispenser of what is known, because it tends to reinforce several problematic misconceptions about the nature of science. Instead, **I try to put students into situations where they need to make sense of data and apply theoretical models to explain phenomena**. This helps them understand that doing science is actually a very dynamic, creative, and social process.

I suppose that another way to characterize the approach I take to teaching is to think of the factual information as the starting point for understanding the discipline, not the end product. Thinking about a course this way, one would learn about something like the central dogma (the flow of information from DNA to RNA to protein) as a means of addressing some interesting biological problems, such as how we can understand the genetic inheritance patterns for certain diseases. If you can make this shift away from an emphasis on rehearsed facts and toward using what we know to solve problems, it really opens up opportunities for students to apply what they know and see the relevance of the material beyond the scope of the course.

The difficult part, of course, is finding ways to create these "open-ended" learning environments for students. It is also tricky to get students used to defining their own problems and pursuing them without strict protocols to follow. I rely heavily on learning technologies (e.g., simulations, modeling tools, and electronic data sets) to provide rich problem spaces for students. I think the best way to help students learn how to work on problems is to give them lots of practice. In the Genetics course, for example, students prepared weekly poster presentations of their findings from computer-generated problems they had been assigned. As they worked each week to convince their peers that they had viable solutions to the problems, they became much more comfortable with their own ability to collect and analyze data in support of a particular hypothesis. Over the course of the semester students learned to take information from the textbook (such as a description of epistasis - the interaction of several genes to produce a phenotype) and apply it, as a researcher would, to develop tests that check to see if the inheritance of a character is following that model.

The courses

I've taught a variety of courses here at Beloit including Human Biology; Biological Issues: Understanding Evolutionary Explanations; Genetics; and Evolution. All of these courses have labs associated with them; they serve 20-30 students; and I've used learning technology in all of them.

The learning technology

The Genetics Construction Kit (GCK) is a simulation that provides students with populations of fruit flies they can cross in order to discover the patterns of inheritance for various characters. What I like about this program is that I have a great deal of flexibility in defining the genetics of the populations students will work with. However, because GCK is a "problem generator," each group of students can work on a unique problem though they all share the same underlying genetics. This means that there is no pre-determined right answer and we all are forced to look at the evidence they collect to support their hypotheses.

BIRDD: The Galapagos Finch Database is a big collection of raw research data on the Galapagos Islands and the finches that live there. The strength of this resource is that it brings together so many types of data (maps, habitats, weather, morphology, distribution, songs, molecular sequences, etc.) that students can do the kinds of integrative analyses that evolutionary biology demands. I have had success using BIRDD data as the basis for original research projects in both majors and non-majors courses. There was a real sense of scientific community established when we were all working on different aspects of the same system.

The Biology Student WorkBench (http://www.bioquest.org/bioinformatics/ and http://peptide.ncsa.uiuc.edu/index.html) is a set of resources for the analysis of molecular sequence and structure data. The Biology Workbench was designed as a research tool, but we have a National Science Foundation funded project to bring these powerful bioinformatics resources to an education audience. The use of bioinformatics tools to organize and analyze massive amounts of publicly available biological data is revolutionizing research in many disciplines. The Biology WorkBench provides students (and researchers) with web-based access to an integrated suite of bioinformatics resources. Within a common interface, students are able to do things like search databases, align sequences, predict restriction sites, build phylogenetic trees, and view 3-dimensional protein structures. Because the Biology WorkBench is Web-based, it can be accessed from a PC or a Macintosh and you can save your work within the Workbench, without having to download anything.

In my genetics course, students worked in groups to investigate a family of related proteins (such as the globins or the potassium channels) that have similar functions. In addition to doing the background research on the natural history of the gene family, they were able to compare different proteins to identify conserved functional domains and hypothesize about different mechanisms that may have lead to the changes in sequence and function of the different family members. In the evolution course we examined the phylogenetic relationships between the primates by analyzing a variety of gene sequences. In addition to considering how different genetic markers (such as restriction sites and microsatellites) can be used to build phylogenies, we were able to compare trees built from genes that have experienced very different selection pressures over evolutionary time. Each of these investigations required that students spend some time learning how to use the Biology WorkBench tools. However, because these are real research tools, understanding how to use them was a valuable part of what students took away from the experience.

The results

There are always a few students who have a negative initial reaction to the use of technology in my courses. I've found that by using the same tools several times for different assignments, students are able to work past their barriers to the technology and see the computers as ways to work on interesting biological problems. In general, I think we tend to overestimate the impact of the first exposure to a tool on students' learning. On the other hand, **I think we underestimate the impact that can be achieved by more in-depth use of a real research tool**. As students gain familiarity with the details of how to use a piece of software, they can begin to use it more effectively. We often get trapped jumping from one tool to another in our teaching and never letting students feel a sense of control over the technology they are using. There are aspects of biology that can only be done with the aid of computers, so we will need to continue to work on ways to help students effectively use these tools.

If you have any questions about BioQUEST, GCK, or the Biology Student Workbench, please contact me at:
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