

# "Crossing the Chasm" of Curricular Reform: BioQUEST Curriculum Consortium Invites CAL-laboration

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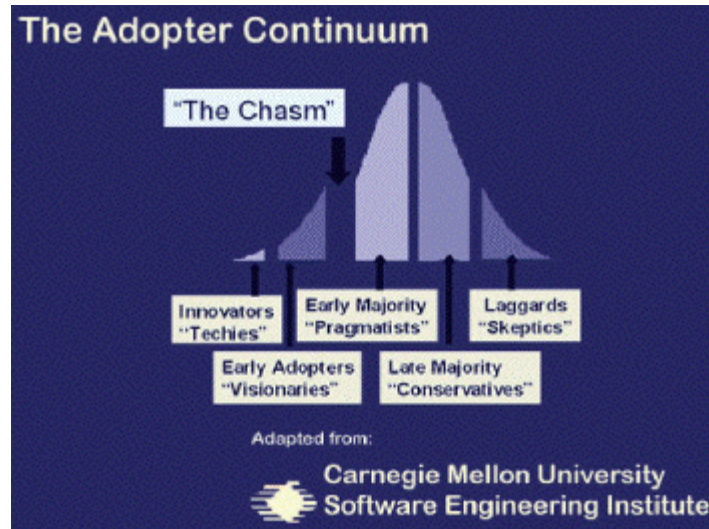
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The BioQUEST Curriculum Consortium supports and encourages innovation in bioscience education through the development, distribution, and field testing of computer based curricular materials that have been designed to help students learn long-term strategies of research. BioQUEST is an acronym for **Quality Undergraduate Educational Simulations and Tools in Biology**, reflecting its initial focus on the development of curricular resources for biology educators through *The BioQUEST Library*. The Curriculum Consortium emphasizes investigatory and collaborative learning strategies for problem solving in the biological sciences. To these ends, workshops for faculty development, multiple presentations, and publications by staff and collaborators are provided each year. A communication network for committed educators is maintained by the organization.

A major challenge to curricular reform efforts is to reach beyond early adopters and adapters in undergraduate biology education to a larger sector of biology educators. The BioQUEST Curriculum Consortium would like to collaborate internationally to address four foci: complex problem solving; collaborative learning; use of computer simulations, tools, and digital libraries in original research or research-like experiences; and networking innovators.

The BioQUEST Curriculum Consortium is in its fourteenth year. Our intellectual predecessor, CUEBS (Commission on Undergraduate Education in the Biological Sciences), one of the longest undergraduate reform efforts in the United States in this century, lasted from 1964-1973 (nine years). Persistence is critical to sustain reform in order to provide support for educators who take the risks of experimenting with their pedagogy, curricula and curricular materials.

During 1986-1993, most of the BioQUEST focus was on the development of innovative software designed to help students learn long-term strategies of research. This phase culminated in the publication of the first edition of *The BioQUEST Library* (1993). In a model of change popular in Silicon Valley (see Figure 1), our first seven years primarily involved working with 'innovators', both from pedagogical and technological perspectives.



**Figure 1. The Adopter Continuum (Myers)**

In our second seven year phase, 1993-2000, we have been successful in engaging 'early adopters', who have adopted and adapted materials published in *The BioQUEST Library* for their classroom, laboratory, and field curricula. This outreach was accomplished through publications, workshops, presentations, and continued development of software. *The BioQUEST Library*, now published by Academic Press, grew from 17 modules in Volume I to over 65 modules in Volume V. Over 140 colleges and universities purchased campus site licenses and many more have individual licenses. Our free newsletter, BioQUEST Notes, is distributed to between five and six thousand subscribers, mostly college and university biology educators. We share extensive information through our web site, <http://bioquest.org/>. In addition, a network of individual and group field testers participate in design and refinement of curricular materials and we host 24 to 40 professors per year for a nine-day summer curriculum development workshop at Beloit College. We encourage interested biology educators to join us!

Currently, BioQUEST has support for three initiatives: (1) to develop curricular materials and research bases in bioinformatics, ecology, evolution, and microbiology education and develop digital libraries for undergraduate research and education; (2) to develop on-line resources for and with two-year community college biology educators; and (3) to expand the BioQUEST community of users of technology in democratizing opportunities for greater participation in open-ended problem solving and research in undergraduate biology education. As we begin our next seven-year phase, our focus is to extend problem posing, problem solving, and peer persuasion resources for undergraduate biology curricula.

As shown in Figure 1, most innovators find crossing the chasm from early adopter to early majority difficult. *The BioQUEST Library* is our catalyst of curriculum reform. It allows us to demonstrate our philosophies in action. This diverse collection of modules (Figure 2) that have been systematically tested in classrooms and laboratories provides both resources and support for adopters/adapters who want to incorporate problem solving into their curricula. For faculty, the ability to instantiate our philosophy in software environments that support systematic problem

solving and realistic research-like strategizing has been critical to opening previously closed doors.

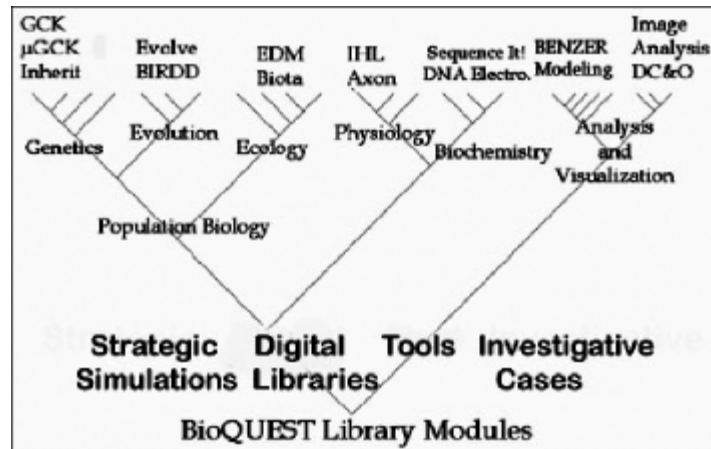


Figure 2. Modules in *The BioQUEST Library* represent multiple kinds of software and multiple areas within the life sciences

### *The BioQUEST Library*

We will discuss our experience with five different components of *The BioQUEST Library*: strategic simulations; tools; digital libraries; case studies; and decision-making.

#### **Strategic simulations**

Numerous simulations have been constructed which are designed to help students engage in the exploration of open-ended problems and offer complex data sets, opportunities to manipulate multiple variables, multidisciplinary tools for exploration, and numerous modes of data analysis and visualization. These 'microworlds' allow students to investigate contemporary research problems, to explore 'what if' questions, to pose new problems, and to examine fundamental concepts as well as classical experiments. In order to explore the potential of a rich simulation in considerable depth, students find these learning environments are content rich and process rich. Students are challenged to understand which tools are appropriate in which contexts and why one tool is more powerful than another. Surprises can arise if students have committed themselves to models or predictions of behavior that can be examined for contradictions, axioms, inadequacies, or the falseness of their own mental model for causation.

Strategic simulations encourage student ownership of the research/problem solving agendas, combine mathematics into scientific exploration, and lead to quantitative skill development and interpretation of multiple visualizations of data. Simulations offer flexibility of use in classroom contexts (e.g. case studies, investigative laboratories, homework, and distance education) as well as local contexts (e.g. experience and talents of students and teachers) which enhance conceptual integration and conceptual change. Simulations provide students with the opportunity to explore problems/experiments that would otherwise be considered:

1. too risky (safety issues);
2. unethical (destroy biodiversity, medically too intrusive, unnecessary use of animals);
3. too expensive (but note NOT in replacement of wet laboratories);
4. take too long (requiring multiple life cycles, multiple trials);
5. too difficult (requires special laboratory skills);
6. inaccessible (no link to research databases, enhanced data-mining and, in some cases, the opportunity for students to do original, open-ended research as opposed to research-like inquiries); and
7. out-dated (replicate aspects of historically important models/classical experiments).

Screen shots from simulations in *The BioQUEST Library* are provided in Figures 3 and 4.

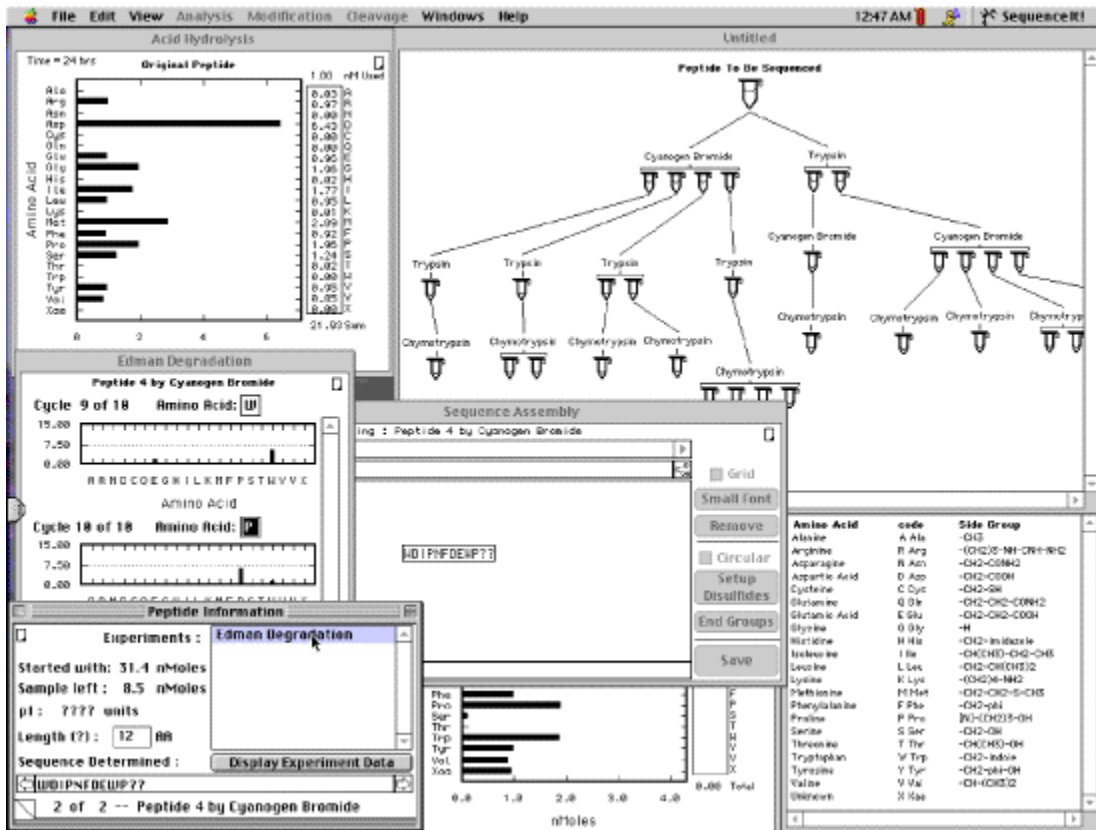
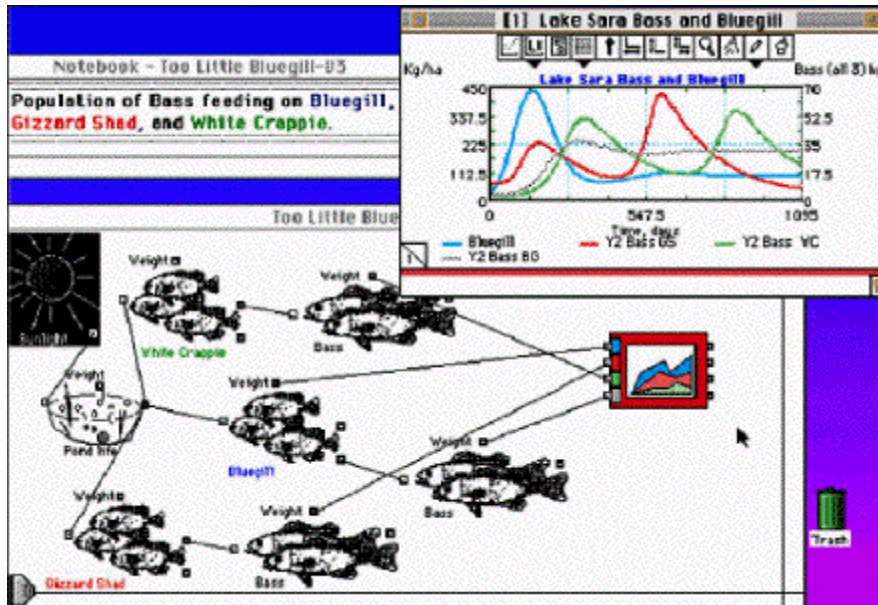


Figure 3. *SequenceIt!* (Place and Schmidt)



**Figure 4. Environmental Decision Making (Odum, Odum and Peterson)**

Strategic simulations make use of the ten characteristics shown in Table 1 (Jungck and Calley, 1986).

1.	Novelty of problems each time that a program is run
2.	Realistic outcomes for each experiment performed
3.	Infinite opportunities to perform experiments
4.	Computational power
5.	Speed in obtaining results
6.	Large, complex data sets
7.	Facilitates successive hypothesizing and logical and numerical testing
8.	Sequentially developed problem difficulty involving an increased quantity of natural phenomena
9.	Solutions as hypotheses
10.	Collaboration and peer review

**Table 1. Features of strategic simulations**

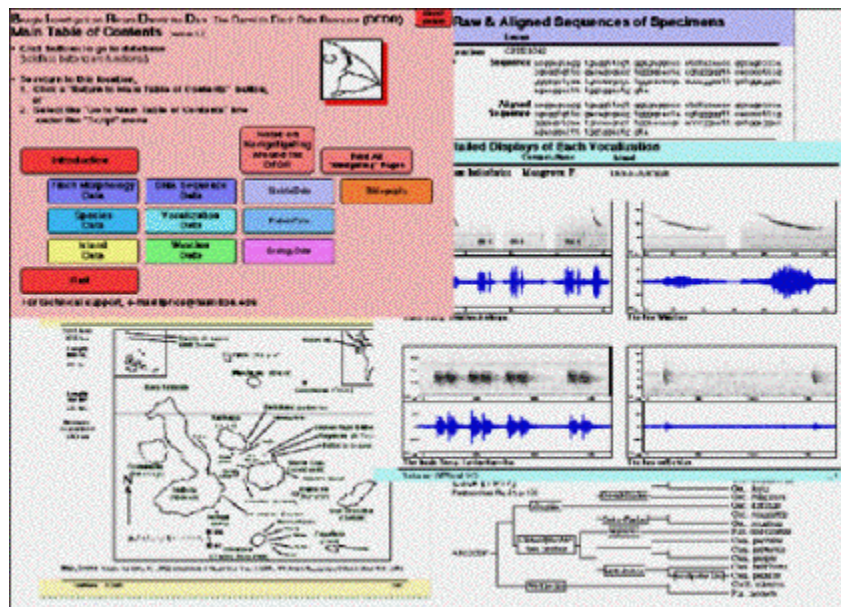
## Tools



Tools have fundamentally changed the nature of the science that can be done and by whom. For example, with the advent of computers, biological systematics has been dramatically transformed. Two such powerful tools in *The BioQUEST Library* are *MacClade 2.1* (Maddison and Maddison), and *Phylogenetic Investigator* (Brewer and Hafner). Mathematical tools for measuring *Fractal Dimension* (Boston University) and ascertaining if deterministic chaos is present in biological populations (Wimsatt and Schank) are also included. A widely used tool, *NIH Image*, is a freeware package that we make available. It allows users to transform any picture into quantitative data that can be used to test hypotheses quantitatively.

## Digital Libraries

Another variety of software that promises to be of broad interest to the biology education community involves rich, complex data sets focused on a particular phenomenon. *The BioQUEST Library* includes our digital library on Darwin's finches and the Galapagos Islands (Figure 5) and features a student interface with the *Biology WorkBench*, a bioinformatics environment for downloading and analyzing sequence data completely through the use of web-based tools, developed in collaboration with the University of Illinois Urbana Champaign and the University of California San Diego. (<http://bioquest.org/bioinformatics/>)



**Figure 5. Screen shots from *BIRDD* (Beagle Investigation Returns with Darwinian Data), a digital library (Price, Donovan, Stewart and Jungck)**

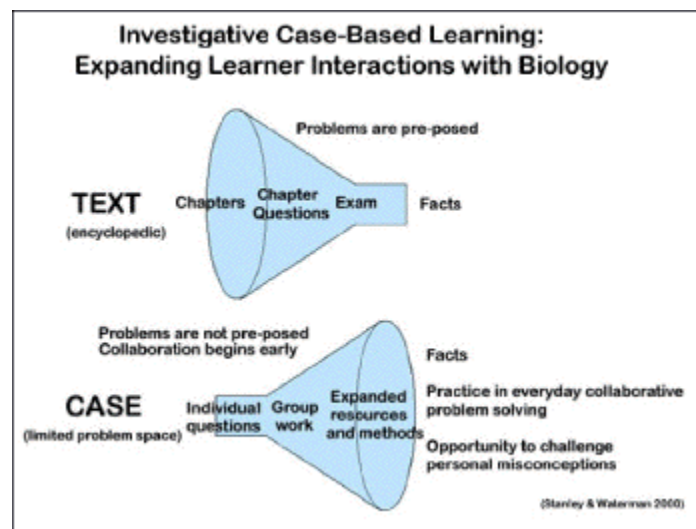
Data can be easily exported to spreadsheets and statistical analysis software so students can quantitatively test hypotheses.

## Case studies

Getting started with simulations, tools and digital libraries may be facilitated with the use of case studies. Ethel D. Stanley, Director, BioQUEST Curriculum Consortium, and Margaret A.

Waterman, Assistant Professor of Biology, Southeast Missouri State University, have developed case studies and are collaborating with two-year faculty on a web-based project: *LifeLines OnLine: Curriculum and Teaching Strategies for Adult Learners*. (See an example at <http://bioquest.org/lnsta/>)

BioQUEST cases for biology are open-ended and draw from a broad range of applications in biology. Students move beyond an initial searching for 'facts' related to the questions they are exploring to investigate biological phenomena. What sets this approach apart from other problem-based learning is an emphasis on a research-like environment for learning biology. This investigative case-based approach encourages problem posing, investigation and persuasion. Although the problem space is defined by the case, students are not only asked to learn relevant material, but also to pose a question, develop accountable approaches to investigate it and present methodology and conclusions to the class that support a reasonable answer.



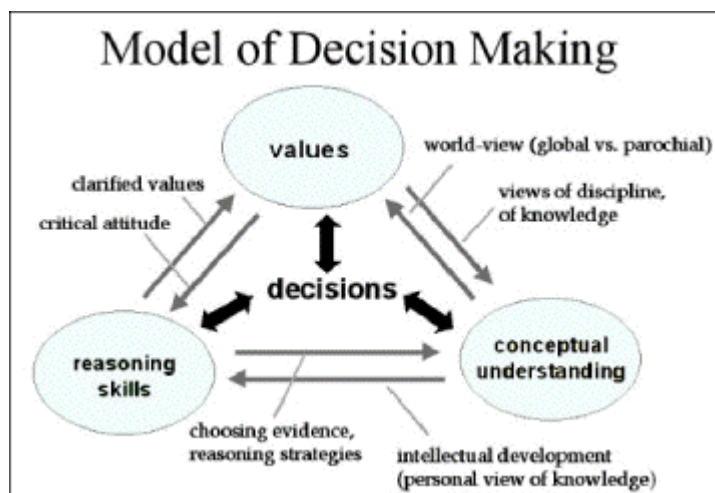
**Figure 6. As an alternative teaching/learning strategy, case studies facilitate student exploration of their own questions rather than what might be asked on an examination**

*LifeLines OnLine* materials integrate information technology with investigative case-based learning (ICBL) pedagogies. Students work to develop questions and reasonable investigative approaches, gather data and information, test their hypotheses, and work to persuade others of their findings. Using a variety of resources (including traditional laboratory and field techniques, software simulations and models, data sets, web-based tools and information retrieval methods), students develop problem solving strategies for lifelong learning in the context of investigating biological problems that they find meaningful.

### **Values and decision making**

The purpose of reform in biology education is to have biology students understand and apply the process of science, not just its products. Although current biology courses introduce life science concepts to undergraduates, the "curriculum and pedagogies often fail to prepare students to use what they have 'learned' to solve real problems" (Stover 1998). Students should connect the

biology they learn with the biological issues they face each day. While inquiry, or "asking a good question, as well as accessing, locating, evaluating and using information" is critical in scholarship, these skills are invaluable to an even greater degree in making daily decisions (Ercegovac and Yamasaki 1998). In order to develop lifelong strategies for problem solving, the biology curriculum must provide opportunities for students to direct their own learning as they explore the science underlying realistically complex situations. Students work collaboratively to identify issues, to frame questions of interest to them, and then to identify additional information in answer to their questions.



**Figure 7. Dan Udovic and colleagues at the University of Oregon developed this model to emphasize the integrative aspects of decision making.**

## Conclusion

The BioQUEST Curriculum Consortium is eager to learn about successful pedagogical and technological innovations in biology education from science educators in Australia, Sweden, and the U.K. We hope that by CAL-laborating with a larger community, we collectively can "cross the chasm" of biology education reform.

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