Improving UBC Biology Education using Evidence-Based Practice.

BACKGROUND

The Departments of Botany, Microbiology & Immunology and Zoology at UBC are strongly committed to the goals of the Carl Wieman Science Education Initiative (CWSEI). Faculty from the three departments have unanimously approved participation in this proposal.

The Biology Program, established in 1968, is a joint enterprise that coordinates life science teaching at UBC across three departments. This includes UBC life science teaching in lower (first and second year) and core upper-level biology courses in genetics, evolution, ecology, physiology and biometrics, and includes many elective courses in plant, animal and eukaryotic cell biology. Microbiology & Immunology oversees an upper-level program that builds on the base provided by the lower-level Biology Program and parallels those in Botany and Zoology.

We propose to develop a biological concept inventory (BCI); a course-independent assessment tool to measure the ability of students to apply key concepts in analytical and synthetic contexts. We will use the BCI to guide curriculum reform across the three departments, for example in developing curricula to better serve Life Science majors from all disciplines as well as nonmajors. The BCI will enable us to assess the effectiveness of curriculum changes on student learning and to ensure that all students, regardless of their specific paths, will achieve a well-grounded education in the biological sciences. In addition to development of BCI, we propose to develop repositories of teaching materials of demonstrated value for the development of core competencies and concepts within and across the programs.

We are dedicated to implementing results-based learning, and our history of cooperation in teaching courses with a wide range of enrollments, makes the Biology Program a flagship opportunity to implement the goals and approaches of the CWSEI.

Why Biology is well-placed to achieve CWSEI goals:

- *An opportunity to have a major impact on a large number of students*

Providing a successful model for outcome-based learning in biology will have wide-reaching impacts on undergraduate education within and beyond the Faculty of Science at UBC. First and second year biology courses are required by virtually all programs in Life Sciences at UBC. These courses have enrollments of ~1700 and 1200 students in first and second year respectively, representing two thirds of all Faculty of Science students and many students from other programs. There are currently ~600 Biology and Microbiology & Immunology majors in each of the third and fourth years, two thirds of all Life Science students.

- *Large, multi-section classes*

The core biology courses in first and second years and the foundational courses in third year have large enrollments and are offered in multiple sections. By applying replicated approaches across multiple sections, we can test the effectiveness of new pedagogical approaches or tools.

- *Faculty and administrative commitment to the redevelopment of an integrated curriculum*

The three departments are in the process of implementing major curricular changes in all years of their programs.

The first round of revisions will include:

- A new non-majors course that targets scientific literacy (~400 students, initial ceiling)
- A fully revised and coordinated two-course first year biology series (~1700 students each)
- Interactive mandatory tutorials in BIOL 201 (~900 students)
- A first year seminar and writing course, if additional resources become available (~900 students).

These proposed changes emerged from two extensive rounds of discussion and consultation in our community over the last four years. The first round (2002-2003) dealt broadly with education goals and

philosophy, and the second (2005-2006) focussed on developing and organizing the conceptual content of the first two years in the Life Sciences curriculum[1]. Many faculty members volunteered to participate in the committees that are now working to implement curriculum change, following a recent (Nov. 8th, 2006) mandate from the Council of Life Sciences. With the exception of the proposed seminar course, which is currently under discussion at the faculty level, the proposed changes are not likely to require continual or large funding increases. This work provides a conceptual framework for change at the program level, which will be facilitated by development of reusable materials for active learning strategies at the course level across and within the three departments.

The Dean of the Faculty of Science actively supports these revisions, demonstrated by his support for the Science Centre for Learning and Teaching (Skylight) and the provision of most of the salary for Dr. Gülnur Birol, the research associate coordinating these revisions.

As soon as feasible (probably in year 2 of the CWSEI), we will extend our analysis to upper-level courses to optimize fit to overall program objectives.

- *An on-going commitment to the scholarship of teaching and learning (SoTL)*

We are committed to testing the effectiveness of changes to our program. We have an assessment and evaluation committee working to develop tools and metrics to assess comprehension of those content and core competencies that we believe are fundamental to the learning objectives of the programs.

Presently, we have several on-going SoTL projects lead by faculty in the Biology Program (e.g., those involving BIOL 140, BIOL 200, BIOL 335). However, because of faculty time constraints, these studies currently suffer from a lack of in-depth data analysis. Fellows hired using CWSEI funds would be able to execute in-depth studies and assist and encourage interested faculty in assessing the effectiveness of their own pedagogical practices.

A current biology graduate course, BIOL 535 (Teaching and Learning in the Life Sciences), offered with the assistance of Skylight, has the goal of educating graduate students in theories of constructivism, active learning techniques, critical thinking and the practice of SoTL. The graduate students from this course constitute an excellent resource pool for future CWSEI fellows, as they already have some training in pedagogy and in interpreting higher education research. The existence of this course is an indicator of our continuing commitment to SoTL and is an on-going resource for support of teaching and learning in the Biology Program after CWSEI funding phases out.

GOALS OF THE BIOLOGY CWSEI PROPOSAL

We will develop program-level learning objectives, active learning strategies, and reusable instructional resources that stress core concepts and competencies, particularly in the context of large multi-section courses. We will use quantitative and qualitative methods, outlined below, to test the effectiveness of these resources for student learning.

A CWSEI award would be timely, as we have already been planning and implementing changes that focus on evidence-based pedagogical practices. We are excited by the opportunity that CWSEI provides for optimizing the development of active learning tools and to rigorously test their effectiveness.

1. Objective assessment of student achievement at the program level

We will track students' transition year by year from novice (lower-level) to expert-like (upper-level) thinking and understanding of biological concepts. This will be done by developing, adopting and adapting evaluation tools across upper-level courses (in Biology and in Microbiology & Immunology) and the lower-level courses that feed them. We will specifically assess learning and comprehension of key concepts and core competencies, and evaluate these against program-level learning objectives. We will inventory student beliefs and attitudes towards their own learning and towards science, and their understanding of how biological science relates to society. This work will likely build upon available

[1] Report is available at ftp://eshop.botany.ubc.ca; user name: ls; password: report

resources such as the biological concept list developed at the University of Colorado at Boulder[2], the biology concept framework from MIT[3], the Utah State University model[4], and current literature in science education. This information will be used in the development of a biological concept inventory. There is presently no such assessment tool available for the biological sciences. Such a tool would therefore be significant worldwide.

2. Iterative curriculum development

Figure 1 illustrates our proposal for an iterative curriculum design process at the course and program levels. We will build upon our strong base from four years of collective work (above) and our present strengths to focus on pedagogically sound educational delivery, by initially gathering baseline data on current learning levels for students in lower-level courses with respect to competence and concept application. The data analysis will guide course reorganization to align course objectives and outcomes more closely with program objectives and to assess the effectiveness of changes in pedagogy. We see evaluation as an ongoing and iterative process, to ensure that the revisions are successful, and to inform and re-phrase course objectives, where necessary. Once these tasks are well underway, we will expand this assessment plan to upper-level courses to develop a coherent framework for the program as a whole.

3. Development and implementation of teaching resources

The "how people learn" framework[5] will guide the development and adoption of reusable instructional resources; these will stress key concepts and core competencies throughout our programs, and will better enable students to make connections among and within courses. Candidate courses that we have identified as high-priority are noted in Figure 1.

In a trial experiment that lacked formal controls, we found that reusable resources, including interactive web sites and 'clickers' markedly improved student exam performance and student satisfaction with Cell Biology (BIOL 200). Web-based data interpretation exercises of classic experiments in cell biology give students practice in evaluating and analyzing data, and expose them to the scientific process in an interactive fashion. Cell Biology teaching faculty also developed a free, publicly available image database[6] for students to allow them to practice image interpretation using pictures of cells donated by researchers at UBC and around the world. We look forward to developing similar resources for other biology courses and to engaging in research that rigorously tests the effectiveness of these new teaching tools. Because faculty often lack time to develop and test these resources, CWSEI support will allow us to empirically identify successful approaches that can be then used to maximize student learning.

4. From UBC Biology to the world: Dissemination of materials, methods, and technology

CWSEI support will allow us develop globally available resources and pedagogical approaches for biology teaching that are currently lacking at the local, national, and international level.

The specific deliverables of our proposal are:

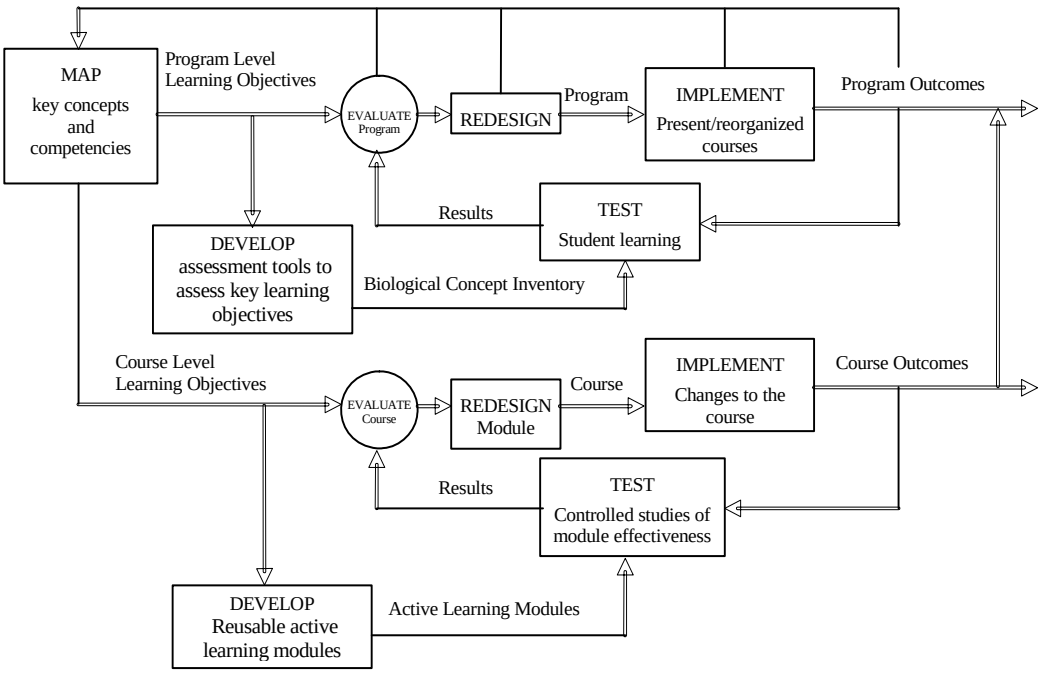
1. A biological concept inventory including a clear statement of key biological concepts across a range of biological sub-disciplines. This would be associated with assessment tools designed to measure application and evaluation of these concepts.
2. A database of teaching resources (e.g., online active learning exercises) to reinforce core concepts and competencies.
3. A body of scientific research providing evidence for the effectiveness of these tools.

We will share these specific deliverables with other institutions to maximize their impact and utility. Where appropriate, we will publish results in peer-reviewed journals, attend conferences to present the

[2] Bioliteracy project, 2006
[3] Khodor et al, Cell Biology Education, V3, 111-121, Summer 2004
[4] http//www.biology.usu.edu/assessment
[5] Bransford, J. D., Brown, A. L., and Cocking, R. R. (Eds.). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press, 1999
[6] www.biomedia.cellbiology.ubc.ca

results of our SoTL studies, and promote and disseminate our online resources, for example through online teaching resource repositories (such as the Multimedia Educational Resource for Learning and Online Teaching; MERLOT[7]).

Students deserve no less than to be partners in learning in biology courses that amaze, fascinate and empower them, and that inspire them to become lifelong learners as academics, biotechnologists, health-care providers, parents, voters, teachers, and global citizens. We strongly believe that a partnership between CWSEI and the UBC Biology Program will significantly enhance science education, both nationally and internationally, making UBC a world-leader in science education.



Focal courses for CWSEI Biology initiative:

- High-priority lower-level core courses in which fundamental concepts and competencies of biology (cell, organism and population) are developed.
  - a new non-majors biology course (~400 students)
  - two new first year biology courses (~1700 students each)
  - BIOL 140 (~1500 students)
  - BIOL 200 (~1200 students)
  - BIOL 201 (~ 900 students)
  - BIOL 204, 205, 209, 210 and MICB 202 (~1600 students in total)
- High-priority upper-level core courses: These courses were selected for analysis because they are the core upper-level courses taken by the majority of students in our programs, and also act as important core courses or electives in many other Life Sciences Programs.
  - BIOL 334, 335: Genetics (~1500 students in total)
  - BIOL 361: Physiology (~335 students)
  - BIOL 303: Ecology (~500 students)
  - MICB 302: Immunology (~300 students)
  - BIOL 336: Evolution (~200 students)

Figure 1: Iterative Curriculum Design Process and Focal Courses for CWSEI Biology Initiative

[7] http://portals.merlot.org/biology/