Carl Wieman Science Education Initiative (CWSEI)

Request for Proposals – 2nd Round – Summer 2007

You are invited to contribute a proposal for CWSEI funding. The deadline for submission is October 26, 2007, and funding decisions will be made by the end of the Term. Depending on the strength of the proposals, up to three departments in the Faculty of Science will receive funding. The level of the funding will depend somewhat on the size of the department and the needs, but anticipated levels are likely to be in the range of $1.5-1.75 M in total per department, to be expended over a period of 5-6 years. Some IT support will also be provided through CWSEI central staff (see supplementary material below).

The fundamental criterion for funding is the probability of achieving widespread sustained improvement in undergraduate education. It is expected that any efforts will be built on the three foundational elements of:

1) Reaching agreement within the department on measurable educational goals (i.e. what students should be able to *do*).
2) Rigorously evaluating what students are actually learning to determine how well they are achieving those goals.
3) Where necessary, making changes in materials, curriculum, and/or teaching practices to better achieve the desired goals.

Relative to the first round of proposals, second-round proposals need to contain a more extensive discussion of planning and implementation of the educational improvement efforts. The proposal page limit has been increased to 10 pages to accommodate this discussion.

The proposal should discuss:

- A plan for sequence -- how all mainstream courses are to be addressed, in what order and timeline.
- Plans for how to achieve coherence across the program and within course sequences.
- Plans and mechanisms to ensure sustainability of the educational improvements.
- How leadership and oversight of the effort will be provided within the department.
- What the scale of faculty member participation will be, how faculty member efforts will be recognized, and what the mechanisms will be for establishing faculty consensus on educational goals, practices, and assessments.
- A rough estimated budget, including breakdown by major categories of expense.

Departments interested in participating should submit a proposal by October 26, 2007 to the CWSEI Executive Coordinator, Grace Wood (gwood@exchange.ubc.ca). Proposals should be no longer than 10 single-spaced pages. Below are supplementary materials to help departments develop their proposals. Carl Wieman is happy to discuss and give feedback on proposal ideas with members of departments prior to their proposal submission. Copies of the successful first-round proposals can be downloaded at: http://www.cwsei.ubc.ca/proposals/.

SUPPLEMENTARY MATERIAL: CWSEI BACKGROUND AND RESOURCES

GOALS AND PHILOSOPHY OF THE INITIATIVE

- To achieve department-wide sustained educational improvement for all undergraduate students
- To improve the coherence of educational delivery within and across departments to ensure there is a well-organized progression of courses
- To obtain clear measures of student learning
- To achieve these goals in a sustainable manner (including not requiring substantial additional amounts of faculty time or money beyond the CWSEI funding)
- To make UBC a leader in science education

Fundamental philosophy: Science education is a science in itself, and a scientific approach can be applied to optimize its delivery and impact. The CWSEI will assist science departments with implementation of research based methods and technology to assess and optimize delivery of education.

CENTRALLY SUPPORTED CWSEI ACTIVITIES

In addition to the direct financial support to departments, the CWSEI will have a small central staff to provide ongoing assistance to departments in their efforts. This includes providing relevant references and information to faculty and staff, organizing workshops, coordinating efforts across departments, coordinating with activities at the University of Colorado (CU) SEI and ensuring UBC departments have ready access to relevant materials and software created at the CU-SEI. Also, the central CWSEI staff will take responsibility for tasks common to multiple departments and thus most efficiently handled centrally, such as:

- Training and support for departmental staff hired to work on CWSEI efforts.
- IT support for development, implementation, and maintenance of a web-based archival system for course and educational program materials.
- IT support for development of interactive simulations.
- Dealing with human research subjects approval for obtaining student data.
- Assisting in writing up and publishing science education research results in suitable scholarly journals.
- Assistance with development of interview protocols for collecting student data.
- Creating materials and technology that will save faculty time, particularly time connected with teaching that is not directly enhancing student learning.

BACKGROUND AND METHODOLOGY

- A scientific approach to optimization of science education needs to include the following elements
    - Specification of measurable learning goals
    - Rigorous objective assessment of student achievement of these goals
    - Implementation of teaching methods aimed at maximizing achievement with respect to the specified goals, that are consistent with empirically established results and principles
    - Means for easy dissemination and duplication of materials, methods, and technology
    - Sustainable and continued optimization based on results of assessment

The following descriptions are intended to be illustrative of how some of these ideas have been and/or might be implemented in a department, but are not intended to be a dictation of procedures that must be followed by any specific department.

- Definition of learning goals
    - This has been done by making an assessment of needs of students for various career goals combined with detailed discussions among the faculty in the department as to goals they perceive for the various courses and how these align from one course to the next. Discussions with other relevant departments are often included as well as employer feedback. Some departments have preferred to start from overall programmatic goals and work down to individual course goals. Most find it more manageable to start with individual course goals and eventually work up. Educational goals may be different for different student populations (honors, majors, other science, nonscience).

    - These goals consider all aspects of student education that the faculty members in the department feel are important. These typically include analytic and problem solving skills, critical thinking, communication, conceptual understanding, attitudes about science, mastery of technical terminology, knowledge of particular topics, etc. Most people find it helpful to start the process of establishing course level goals with a framework for delineating different levels of cognitive activity required, such as Bloom's taxonomy[1].

- Assessment methods
    - There are now a number of assessment tools for looking at particular aspects of learning that have been rigorously developed. Examples include the Force Concepts Inventory that tests students' mastery of the basic concepts of force and motion covered in first semester physics and is now widely used, the Basic Electricity and Magnetism Assessment that tests understanding of concepts in E&M as typically covered in second semester physics, and the Colorado Learning Attitudes about Science Survey (chemistry and physics versions) that measures students attitudes and beliefs about science and how to best learn it. Instruments

[1] Benjamin S. Bloom, *Taxonomy of educational objectives*, published by Allyn and Bacon,.

for testing conceptual understanding in chemistry, geological sciences, and biology have been developed and are currently at various stages of refinement.

  - These and similar assessment instruments suitable for machine grading, and hence large scale use, are created using what is now a fairly standard multi-step methodology. The essential aspects are to identify the desired goal to be tested, understand and characterize relevant student thinking, and create questions for which the responses accurately reflect the student thinking. In practice, the typical steps are as follows. 1) Obtain faculty consensus as to relevant concepts/beliefs/skills to be assessed, often with input as to manifestations indicating lack of mastery that they have observed. 2) Obtain data allowing one to characterize student thinking on the specific items to be assessed. This data is collected through examination of student work, observation of student discussions and problem solving, surveys, and interviews of students before, during, and after instruction on the item(s) of interest. 3) Open-ended questions are created and given to sample populations. From those responses, multiple choice questions are generated. 4) These are tested with experts to ensure there is a consensus as to the validity of the question, and then tested in student interviews to ensure there is consistency of interpretation and the reasons for choosing different possible answers are consistent. 5) Assessment is then administered on a large scale. Various standard statistical tests are done on the large scale data to check that the questions are testing what is intended and results are reproducible and not dependent on irrelevant variables. 6) Typically over the first one to two years of large-scale use, there are minor revisions as larger data samples reveal minor difficulties. In many cases, one or more of these development steps can be replaced by referring to the science education literature.

- Examples of researched teaching methods

There are a number of teaching methods that have been guided by and/or are consistent with cognitive science and educational research on important elements of developing long term learning. These all involve some aspects of concentrated mental engagement and targeted feedback. Some examples are:

  - “Peer instruction”- where there are regular short student-student debates during class. These are usually supported through some means by which students must submit answers to the questions that are the topic of debate.
  - Project-based or workshop style classes- students, often in small groups, engage in extended in-depth work on a specific problem or topic.
  - Published “Tutorials”- students work in small groups answering a carefully developed and sequenced set of questions on particularly challenging topics that confront common misconceptions and lead student to correct understanding and application of ideas on the topic. These are supported by TAs specifically trained in implementation of the tutorial.
  - Homework- Although there has not been extensive research on the precise forms of effective homework, there is extensive data indicating that the quantity and quality of study plays a major role in learning. Extensive "authentic" homework problems that require the use of the full range of desired expert skills and knowledge and allows for effective feedback to students on progress in their learning has clear beneficial impacts.

- "Just in time" teaching- using web or email based systems, various types of questions are posed to students and they answer shortly before class. The instructor then adapts coverage and discussion in subsequent class according to student responses.

- Existing educational technologies of proven value
  - Personal response systems ("clickers")- students are regularly asked questions during class, and the clicker allows them to provide a response. A receiver records their identity and their answer and stores them on computer. These have been used in conjunction with peer instruction to good effect.
  - Interactive computer simulations- These encourage students to explore physical phenomena and develop deep understanding through discovering relationships and connections. They also aid students in developing visual models and conceptual understanding.
  - Computer graded homework systems- these automate many of the aspects of administering and grading of homework. Systems come with widely different capabilities ranging from merely saving instructor and TA time to "intelligent tutoring" systems. Such "intelligent tutoring" systems provide immediate feedback to the student in the form of hints or follow up questions targeted to address specific student errors.
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Using resources more efficiently and effectively

-TA training and use.

Well developed TA training programs have been shown to produce TAs who are far more effective teachers and who can play a larger and more effective role in instruction. Developing standard marking rubrics has been shown to dramatically reduce the time necessary for TAs to mark lab reports and homework assignments, which providing clearer more consistent feedback to students.

<u>- Faculty division of labour in multi-section courses.</u>

There are examples where the tasks associated with teaching large multisection courses are divided up in novel ways so as to greatly reduce duplication of faculty effort. In a number of cases, this has been shown to achieve a more consistent higher quality educational experience for students, as well as using faculty members' time more efficiently.

Laboratory courses

- Existing research literature on lab courses.

  It is universally recognized that laboratory courses have the potential to fill a unique educational role, because they are the only classroom experience that can represent the full range of activities and thinking involved in actually doing science. However, the evidence is that, in the form they are often implemented, lab courses fall far short of reaching this goal. Research on the effectiveness of lab courses shows that the goals of the instructors are usually not understood or achieved by most students (especially those who are not likely to become professors). While the same sorts of problems have been seen in studies of other science courses, the discrepancies are exceptionally large for lab courses. One likely contributor to this is that the typical lab course is intended to address a mixture of different educational goals. These goals encompass mastering techniques and hardware, learning science content, and developing the understanding and skills of science as an experimental activity. In many lab courses conflicts between some of these goals often remain unresolved. For example, if one desires a student to learn the basics of how to pose scientific questions and develop experiments to answer those questions, it is counterproductive if the equipment they are to use for this exercise is highly complex and unfamiliar to them. Laboratory organization and scheduling, grading policies, and inadequately trained TAs are among other factors that can also prevent lab courses from living up to their potential.

- Alternative lab courses

  There are examples of alternative labs courses where there is good evidence that they are educationally effective. These courses usually have the lab activities fully integrated as part of a more general course, such as Workshop Physics[2]. They also have carefully defined goals for the lab activities, typically involve much simpler experimental hardware, and sometimes have much more time available for experimental design, redesign, reflection, and iteration than in many standard lab courses. The number and type of such proven-effective courses is limited however, and so it is likely that there are other models that would work but have yet to be widely tested. Because of the limited amount of research, the relatively high costs, and the intense emotions connected with lab courses, this is an area where it would be particularly appropriate to try a variety of approaches on an experimental basis and carefully assess the cost effectiveness of the results to guide creation of highly effective lab courses.

[2] E. Redish, *Teaching Physics with the Physics Suite*, Wiley, 2003