The Carl Wieman Science Education Initiative at the University of British Columbia: A Dean's Perspective

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1 Introduction

In 2007, the University of British Columbia launched a major science education initiative led by Prof. Carl Wieman with the goal of transforming undergraduate science and mathematics. Distinctive features of this initiative include the large scale ($11M over 8 years), systemic approach, the focus on department-centred proposals, and the critical role played by science teaching and learning fellows (see Wieman, this volume). Eight years later, 167 courses have been transformed resulting in improved learning for more than 15,000 individual students/year enrolled in Science, Applied Science, Arts, Commerce, and other programs. Key challenges that emerged include learning what compels individual instructors to embrace research-based teaching practices, determining who controls what students should learn in a course, and sustaining the transformations after the initiative finishes.

Over the past two decades, brain research, cognitive psychology, and university science classroom studies have advanced our understanding of how humans learn and how best to enable student learning. (e.g., Ambrose et al., 2010). For STEM disciplines, an important review by Hake (1998) involving 62 introductory physics courses demonstrated that students taught using active learning techniques exhibited more than twice the gains in conceptual learning compared to students taught using traditional methods. The recent U.S. National Academy of Sciences (Singer et al., 2012) review of ~1,000 STEM research studies clearly demonstrates "research-based instructional strategies are more effective than traditional lecture in improving conceptual knowledge and attitudes toward learning … Effective instruction involves a range of approaches, including making lectures more interactive, having students work in groups and incorporating authentic problems and activities." Many individual university faculty members across North America are adopting these methods, but few universities are attempting to do so on an institutional scale. We know how to dramatically improve student learning, but how do we individually and collectively change the way we teach? This is as much a question of institutional culture change as it is a question of how best to deploy limited financial and time resources. In this paper I briefly describe how a large-scale science education initiative at UBC has succeeded at improving student learning across all science departments, and my perspective as Dean on important keys to success and lessons learned.

2 The Carl Wieman Science Education Initiative at UBC

UBC's Carl Wieman Science Education Initiative (www.cwsei.edu.ca) is a research-based approach to improving undergraduate science education that has involved more than 100 instructors across the Faculty of Science. [Note, a *Faculty* in a Canadian university is equivalent to a *College* in the United States.] Launched in 2007, UBC and donors have invested approximately $11M to transform undergraduate science teaching at UBC. The UBC investment was made by the Provost and at $1.5M/yr is equivalent to roughly 1.5% of the Faculty of Science's annual operating budget. A key initial assumption was that one-time resources were needed to transform courses, but once transformed the courses would not require additional resources. We plan to continue to invest resources (at 25-50% of the CWSEI funding rate) to support transformation of additional courses, ongoing measurement and scholarship efforts, evidence-based refinement of our approach, and the training of new faculty.

The overall CWSEI approach involves three steps (Wieman et al., 2012):

1. Establish what students should learn. These learning outcomes or learning goals need to be explicitly stated and ideally most can be measured.

2. Scientifically measure what students are actually learning. Several scientific disciplines have developed measures of conceptual learning for specific topics, with the best example being the Force Concept Inventory developed to assess student learning in introductory physics (Hestenes et al., 1992).

3. Implement teaching methods aimed at maximizing learning. Such methods include effective use of personal response systems (clickers) into lectures, peer instruction, group work, interactive lectures, and computer simulations. This is an iterative process with teaching methods revised based on measuring the effect on student learning. These techniques increase feedback to students and instructors about student learning that is largely lacking in traditional large lectures.

The CSWEI focuses on the academic department as the cultural unit for teaching, with faculty experts and the department determining what students should learn in each course and program. Funding was based on department proposals that needed to demonstrate department-wide commitment and readiness to undertake sustained effort to improve science education, with a clear plan and timeline for transforming courses. Transforming a course is typically a multi-year project and requires three iterations – a planning term, an implementation term, and a revising and refining term. All proposals made extensive use of limited-term science teaching and learning fellows (STLFs). These science education specialists, commonly post-doctoral scholars, have disciplinary content expertise, and developed pedagogical expertise through central training and mentoring by the CWSEI team. STLFs work closely with faculty members to develop course learning goals, design learning approaches that promote learning, construct appropriate measurements of student conceptual thinking and learning, and publish results of implementation and measurement design.

UBC's Faculty of Science consists of nine departments spanning the life sciences, physical sciences, and the mathematical and computational sciences. The Departments of Botany and Zoology, with contributions from Microbiology and

Immunology, deliver a single undergraduate Biology program. The creation of an Associate Head, Biology, reporting to the Heads of Botany and Zoology, proved to be an important organizational change that enhanced success in this large undergraduate program delivered by multiple departments. The Department of Earth, Ocean and Atmospheric Sciences and the Department of Physics and Astronomy successfully undertook large transformation projects and their efforts are mature and largely complete. The Biology program and the Departments of Computer Science and Mathematics were funded for large projects; these efforts are maturing, but are not yet complete. The Departments of Chemistry and Statistics were funded for more limited transformation efforts.

As of Fall 2014, 167 undergraduate science and math courses, involving 150,000 student credit hours, have been fully or partially transformed by the CSWEI, resulting in improved student learning in 67% of the student credit hours delivered by the Faculty of Science. Most of these courses were large first- and second-year lecture courses, with 100 to 450 students per lecture section. In science departments, most of these transformations are "flipped" courses with information transfer moved outside the lecture and research-based active teaching and learning practices incorporated into the lecture. In mathematics, most of the CWSEI efforts involved incorporating online homework tools and tutorials into first and second-year classes with relatively few changes made to the lectures. Faculty surveys conducted in 2007 and 2012, validated by classroom observations, document that the CWSEI is successfully increasing the adoption of research-based teaching practices across the Faculty of Science (Wieman, 2015). Our data suggest that the changes made to improve student learning are being sustained. Based on the 2012 survey, only one out of 70 UBC faculty members who tried research-based teaching methods with CWSEI support had stopped using such methods more than one year after that support had ended. Even more encouraging, most of those instructors are transforming additional courses with little or no help from the CWSEI.

3 A Dean's perspective

In a separate paper in this volume, Prof. Carl Wieman describes the important results and lessons learned based his extensive experience leading major science education initiatives at the University of Colorado and the University of British Columbia. Here, I add my perspective as Dean of the Faculty of Science at UBC from 2006 to the present.

1. Success is more likely to be obtained (and sustained) when there is critical mass of educational leaders within a department who have the strong support of their department head. Critical mass may already exist in some departments, but will need to be built in others. Departments as a whole must own the challenge of improving student learning and rewarding educational transformation efforts. Departments have limited bandwidth for major initiatives. If a department is

already undertaking a major project, such as major curriculum reform or strategic planning, attempting also to transform the way they teach can prove overwhelming. I believe the overall leader of the initiative is also critical, and at UBC we have benefitted greatly from the leadership of Carl Wieman, winner of the Nobel Prize in Physics and numerous science education awards.

2. Success requires close collaboration between the science education transformation team and the Dean's office. Faculty need to hear a consistent message regarding the importance of improving student learning. At UBC, Carl Wieman, as Director of the CWSEI, reported directly to the Provost. CWSEI was focused exclusively on improving teaching practices within the Faculty of Science, so having this initiative reporting to the Provost rather than to the Dean created both opportunities and challenges. Department heads (and faculty members) report to the Dean, not the CWSEI Director, so departments and faculty could choose not to listen to CWSEI directives and advice (of course, the same could be said about the Dean's directives and advice). The substantial financial resources provided a major incentive for most, but not all, departments to engage fully with the CWSEI.

3. Organization change is hard, particularly in the absence of a crisis. Universities have been around for centuries and academic traditions are deeply ingrained. Groups, individuals, and the press have argued that STEM education is in "crisis", but it lacks the emergency and visibility of other crises faced by universities, like steep reductions in government funding. Changing the collective teaching culture of a university requires a sustained commitment from individual faculty members, department leaders, and administrators over a period of 5-10 years.

4. Each faculty member has a different view of what constitutes compelling "evidence" that would lead them to change the way they teach. Many faculty are not aware of research in science education and cognitive psychology, and can be quick to dismiss research studies from these disciplines as not relevant to their field or as being soft science. In some cases, discipline-specific education research data from their institution can prove more compelling. At UBC, Delauriers et al. (2011) showed that active engagement techniques increased student learning by a factor of two in a large, multi-section introductory physics course for engineers. This study helped convince a number of faculty that these techniques will work for UBC science students. In other cases, respected peers successfully transforming their courses and conveying their enthusiasm proved to be a compelling factor. Most faculty members would like their students to perform better on exams and when faculty see improved results on exams, this can lead to the adoption of research-based teaching practises. Citing high failure rates in specific courses as evidence of the need to change teaching practices was generally not effective, because faculty were quick to blame students for not working hard enough, to blame the Dean for trying to lower academic standards, and to blame admissions for not recruiting better students.

5. University policies and procedures may pose challenges to success, but these are very difficult to change and should not be viewed as absolute barriers to success. Wieman (this volume) asserts that formal institutional incentive systems are the dominant barrier to adoption of better teaching methods. Promotion and tenure criteria for professors at research universities emphasize the importance of both teaching and research, but research excellence tends to be easier to assess (or at least quantify) than teaching excellence. Student's evaluations of teaching play a significant role in assessing teaching excellence, but such evaluations can be influenced by many factors and do not measure student learning. Peer evaluations of teaching, which are required at UBC, can help, but the peer review team needs to include faculty who support the adoption of research-based teaching methods. Increasingly I see evidence of faculty members adopting scientific teaching methods in promotion and tenure files. At UBC, we benefit greatly from having a tenure track for teaching faculty, whose promotion and tenure depends on excellence in teaching and educational leadership. A number of our teaching faculty have become educational leaders in their respective departments, demonstrating and supporting adoption of new teaching methods, collecting data on the resulting outcomes, and publishing the results. Looking ahead, we have the opportunity to quantify the extent to which modern teaching practices are used through classroom observation protocols like COPUS (Smith et al., 2013). Other policies that need to be examined, and modified where possible, include measures of teaching effectiveness used for evaluating faculty for salary increases, promotion and tenure; collective agreements for faculty and teaching assistants; and behavioural research ethics approval processes when collecting data for evaluating teaching effectiveness.

6. From my perspective the biggest ongoing challenge is *Who determines what students should learn?* The instructor? A faculty committee? The department? The government? The students? The Dean? OK, probably not. Does one's answer to this question change if the course is a pre-requisite for another course, or if the course is a required course as opposed to an elective, or if the course is a multi-section course, or if the course fulfills a general university requirement? Different departments have different teaching cultures. In some departments, the tradition is the individual faculty member has full control over the course, including learning outcomes, and suggestions to change are met by (false) assertions that one is infringing on their academic freedom. In other departments, the culture is for greater department involvement in determining learning outcomes in individual courses. Many faculty members are passionate about the courses they teach, which is a wonderful asset, but learning goals cannot be left solely in the hands of individual faculty members. Early on in the CWSEI we required all first year courses to devlop explicit learning goals, which appears to have helped our efforts.

7. The biggest concern I hear expressed by faculty is the need for time to change their courses and, to a lesser extent, sustain these changes. Faculty members have many competing demands on their time and increasing the time they devote to teaching must come at the expense of research or personal time. Most of the CWSEI funding is directed toward reducing the amount of time required to

transform one's teaching. Most departments make use of science teaching and learning fellows who work closely with faculty members who are transforming their courses. In some departments, instructors are provided with course buyouts (reduced teaching) during the planning or implementation term. In other departments, increased TA support for lectures was important. Completely transforming a course can be a daunting task. In many cases it may be better to start with a more modest set of changes focused, for example, on 2-3 topics that the instructor has struggled to teach well in the past.

8. Reward and celebrate your best teachers, in ways big and small. Nominate your best teachers for department, university, and national teaching awards. Take the time to thank individual faculty members for teaching well and incorporating the latest scientific teaching techniques. Recognize that you have excellent instructors already using research-based teaching practices. Talk early and often about the importance of teaching and teaching well, and back up your talk when conducting faculty merit evaluations. Let faculty know that a dip in one's student evaluations may occur during the initial implementation of new teaching practices, and that they will not be punished for such a dip.

9. Sustaining science education initiatives through changes in personnel requires constant attention. Carl Wieman led our efforts at UBC until 2010 when he moved to the U.S. Office of Science and Technology Policy. At that time, Sarah Gilbert took over the leadership of CWSEI. Wieman and Gilbert have now moved to Stanford University and the CWSEI has been integrated into the Faculty of Science's Centre for Learning and Teaching. Since the CWSEI began in 2007, every department head has changed and I consider support for the CWSEI to be an essential quality when assessing head candidates (Wieman, this volume). STLFs typically serve 2-3 years before obtaining faculty positions in higher education, so there is a need to continually recruit and train new STLFs.

10. Systemic institutional change is about individual people. Individual faculty members need to recognize that changing one's teaching practises is good for their students and, done well, can be very rewarding. Young STLFs trained in the latest pedagogical techniques need to learn to work closely with experienced instructor, and vise versa. Students need to take responsibility for their own learning and learn how to learn in new ways.

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