Large-Scale Change across Science Departments:
Embedded Expertise in Evidence-Based Teaching

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Introduction

The Carl Wieman Science Education Initiative (CWSEI) began in 2007 at the University of British Columbia, with the goal of achieving sustainable institutional change towards effective, evidence-based undergraduate science education. This $10.5M program funds departments to take a scientific approach to undergraduate education:

1) **Establish what students should learn;**
2) **Scientifically measure what students are actually learning;**
3) **Use instructional approaches guided by research on learning and measures of student learning;**

Underlying Reasoning

Logical unit of change is the Department
Department is the cultural unit. Small scale change (one or a few courses involving a few faculty) is an important research step, but does not result in widespread changes in instructional practices. Need change to involve majority of faculty in department.

Change must be driven by department – Faculty are experts in their science fields. The faculty and department as a whole need to decide what students should learn, adopt or develop good measures of relevant learning, and change instructional approaches.

Evidence is key – Most faculty will feel that change is necessary if there is good data showing students aren't getting important ideas/concepts, or evidence of students seeing subject as less interesting and/or useful after taking course.

Additional resources are needed to support the process of change – These changes take faculty time.

Nearly all faculty members want to teach well, but lack expertise – Needs to be recognized that effective teaching requires acquired expertise.

Effective teaching can be more efficient than current practices (and more fun!) – Re-use of materials, less repetition/overlap of material, team teaching large courses, effective use of technology, etc. can result in lower resource requirements in the long-term.

The model developed for the CWSEI and CU-SEI (at CU-Boulder) was guided by the research on what factors facilitate and inhibit the spread of innovations and organizational change, particularly the work of Everett Rogers on the adoption of innovations and the work of John Kotter on organizational change.

Everett M. Rogers, *Diffusion of Innovations*, 5th ed. (New York: Free Press, 2003).
John P. Kotter, *Leading Change* (Boston: Harvard Business Review Press, 1996).

Approach

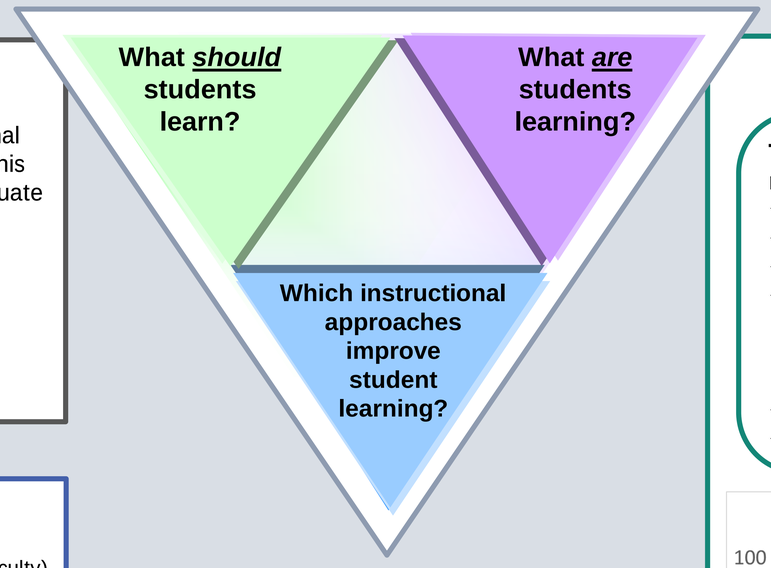
Significant 1-time investment of resources
Concentrated (~1-2 M$/dept. over ~6 years) to fund change activities; maintenance of change should not require extra resources.

Departments compete for funding – Criteria: commitment and readiness to undertake widespread sustained effort to improve undergrad education

Science Teaching & Learning Fellows (STLF) – Temporary positions funded by CWSEI; work with faculty to measure learning, change courses, evaluate curriculum, ...

Departmental culture change – Need majority of the faculty and courses to be involved and mechanisms to sustain change

Archive, Re-use, Improve materials – Developed SEI course materials system



STLF Model

Department-based Science Teaching & Learning Fellows (STLFs) as agents of change in university education

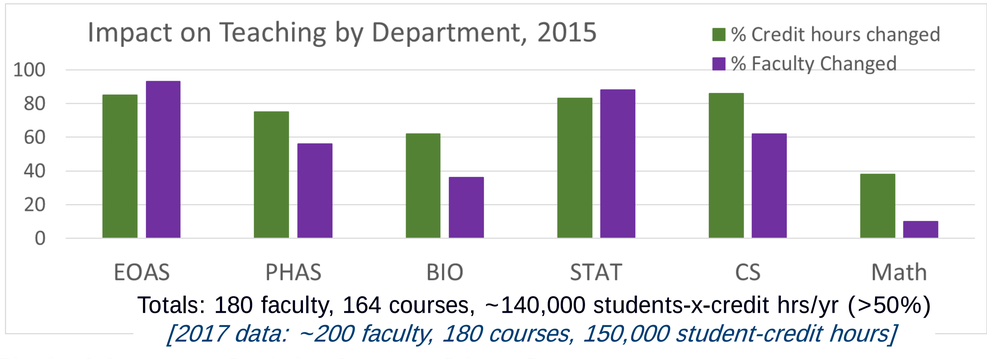
An STLF:
- Is expert in particular science discipline (usually recent PhD),
- Hired by the science dept.,
- Given considerable ongoing training & guidance on science education fundamentals by CWSEI central & other STLFs,
- Works with faculty to develop learning goals, measure learning, change assessment & instruction...

Examples:
- Facilitate course working groups (group of faculty teaching course and subsequent course if applicable) – develop learning goals and pre-post assessments
- Gather data on student thinking about topics (difficulties, misconceptions) via interviews, analyzing exams, homework, conducting & observing informal problem solving sessions, listening to student discussions during in-class activities, pre-post concept tests and attitudinal surveys ...
- Help develop course materials – in collaboration with faculty
- Serve as department resource on pedagogy – ranging from casual discussions to conducting seminars/workshops

Impact

www.cwsei.ubc.ca/departments

Typical new aspects incorporated in courses (each course will not necessarily have all of these):
- Clearly articulated learning goals defining what students will be able to *do*
- Pre-reading assignments & quizzes
- Elements to increase student interest and motivation
- Interactive engagement targeted at learning goals (deliberate practice to develop expertise), such as:
  - Clicker questions, worksheets, and peer discussion
  - In-class group activities – effective even in large (250 student) classes
- Homework problems targeted at learning goals
- Pre-post testing to measure learning, surveys to gauge perceptions about science



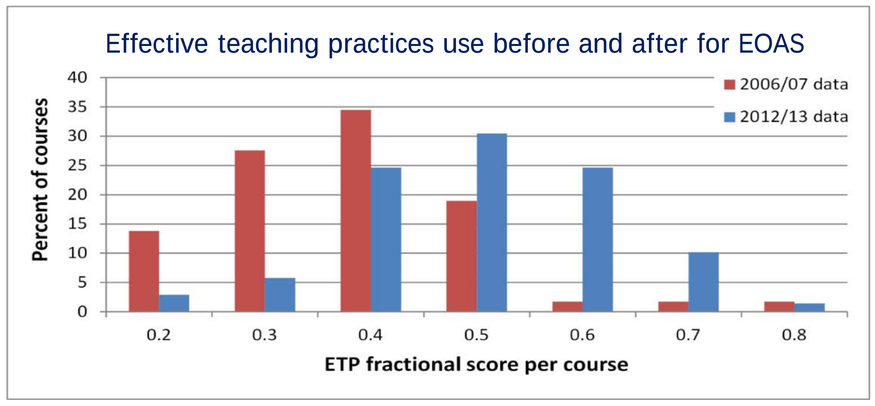
Totals: 180 faculty, 164 courses, ~140,000 students-x-credit hrs/yr (>50%)
[2017 data: ~200 faculty, 180 courses, 150,000 student-credit hours]

Physics & Astronomy, Statistics, Computer Science Departments
- Combined: 76 faculty changed the way they teach, 61 courses & ~51,000 student-credit hours changed

Biology Program (3 departments)
- 43 faculty changed the way they teach, 27 courses & ~35,500 student-credit hours/year changed

Earth, Ocean & Atmospheric Sciences (EOAS) Department *(the poster child)*
- 43 faculty (93%) changed the way they teach, 48 courses & ~15,000 student-credit hours/year changed
- Many faculty spontaneously incorporating interactive engagement in other courses
- Now have a paired teaching arrangement for new faculty

Quantified the use of effective teaching practices using the Teaching Practices Inventory*



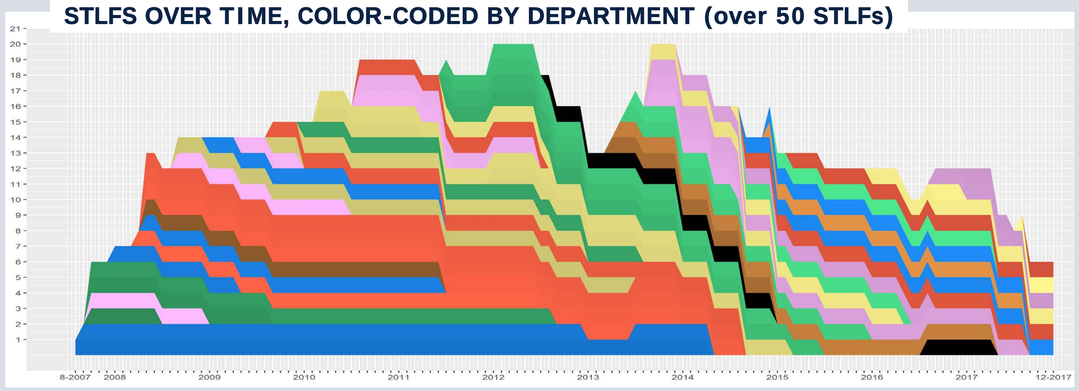
*The Teaching Practices Inventory: A New Tool for Characterizing College and University Teaching in Mathematics and Science, Carl Wieman and Sarah Gilbert, CBE-Life Sciences Education, Vol 13(3), pp. 552–569 (2014). **www.cwsei.ubc.ca/resources/TeachingPracticesInventory.htm**

CWSEI Central

STLF Development
Frequent meetings with considerable effort and emphasis on:
- Development of STLF's understanding of how people learn, effective pedagogy, evidence supporting educational approaches
- Science education research base & how to do research
- Effective ways to work with faculty & communication of good practices
- Sharing of effective strategies

Faculty/Department Interactions
- Regular meetings with CWSEI departmental Directors, department Heads/Chairs, Dean, some meetings with individual faculty & whole depts.
- Lecture series, workshops, yearly event - SEI activities

Developed Course Materials Archive System (sei.ubc.ca)



Cost

For about $60,000:
- One faculty member's change in teaching practices and participation in a teaching and learning project (in many cases, a portion of money went directly to buying faculty time), plus
- One course extensively using evidence-based practices, plus
- Student learning and/or attitudes data in that course, plus
- One published, peer-reviewed conference talk/poster or journal article.

And contributed to:
- Accumulated culture change in teaching & learning in departments
- CWSEI website development – resource available to all
- Developing future leaders in science education (over 50 STLFs)
- Adoption of the STLF model at numerous other institutions (Cornell, U. Kansas, Washington U., Stanford, ...)

Lessons Learned

Major Successful Components

Science education specialists (STLFs) embedded in departments – proved to be a highly effective way to provide the necessary knowledge, expertise, and time-saving assistance.

Competitive grant program – focused attention and sparked discussion and planning.

Oversight of departments and requiring specific commitments and timelines – kept priority high.

Focus on changing willing faculty members rather than particular courses – Work on whatever courses willing faculty are teaching. Having a few good examples in the department helped bring others along.

Major Issues

The formal (dis) incentive system – THE dominant barrier to the adoption of better teaching methods. Any time taken away from research is viewed negatively.

Difficult to establish a sense of urgency about educational improvement – Kotter's work on organization change says a sense of urgency important.

Surprise

Rewarding personal experience more important than data – we thought science faculty would be persuaded by data on student learning, but interacting with engaged students was more persuasive to most faculty.

Frequent Faculty Concerns

How much time will it take away from research? – it took about 50 hours of deliberate effort for a faculty member to learn new way of teaching.

Will it hurt my student evaluations? – common misconception, but evaluations did not go down on average.

How will I cover all the material? – if content not too bloated, use of strategies like pre-reading worked well. However, many realized they were trying to cover too much and shifted focus to how much was *learned.*

Won't these methods help the weaker students at the expense of the top students? – data on learning broken down by student achievement helps diffuse this, but is important to keep top students engaged with appropriate challenges.

Resources

Improving How Universities Teach Science; Lessons from the Science Education Initiative, by Carl Wieman, Harvard University Press, ISBN 9780674972070 (2017).

SEI Resources: www.cwsei.ubc.ca/resources (instructor guidance, student guidance, clickers, videos, learning goals, tools such as COPUS and TPI, course transformation & STLF development, recommended papers, ...)

CWSEI departmental accomplishments details: www.cwsei.ubc.ca/departments

SEI papers & presentations: www.cwsei.ubc.ca/SEI_research