

UBC Department of Computer Science – Science Education Initiative Proposal

Introduction:

Computer Science as a discipline faces unique challenges in establishing and assessing its curriculum, especially at the lower level. The Association for Computing Machinery (ACM) defined a Computer Science curriculum in 2001 that provides no fewer than six different approaches to teaching introductory Computer Science. There has been a long standing debate in the academic community on not only *how* to teach introductory Computer Science but *what* to teach. There are conflicting opinions on whether to begin with programming and, if so, which programming paradigm to use, which language; whether to promote group assignments or have students complete assignments individually; whether to use contextualized education and if so, which context; and so on.

Our department values a broad and inclusive definition of Computer Science. We believe this contributes to a vibrant research and teaching community that benefits from the cross-pollination of ideas generated by its different constituents. This broad interpretation of Computer Science requires us to lay a foundation in introductory courses that prepares students for the many different areas in which they may specialize at the upper level. We must also account for the many students who take our introductory courses as electives or as required components of other programs on campus. We are therefore faced with many challenges when defining a lower-level curriculum.

The department takes its responsibility to deliver high quality education to students very seriously. In 2003 we rolled out a completely overhauled lower-level curriculum and faculty are continually engaged in reviewing the courses that they teach at all levels. The department as a whole receives exceptionally high teaching evaluations from its students and, although such evaluations do not tell the whole story, our scores are one indication of the significant effort that we put into teaching. The fact that we reflect on the education that we deliver for our students also leads us to believe that we can do better. We have identified problems with our existing lower-level curriculum and suggested projects that will lead to improvement in some of our upper level courses. Our plans to address these issues will be detailed later in this proposal.

Our department is driven by consensus. We work hard to ensure that concerns are heard and to provide avenues for faculty to openly discuss issues that arise. Over the course of writing this proposal we have held several faculty-wide meetings at which the CS-SEI has been discussed. At these meetings, issues have been raised that have directly shaped this proposal. A process of open dialog, reflection and consultation, have led to its creation. This same mechanism will be used to guide the efforts of the CS-SEI in future in an effort to reach consensus in establishing educational goals for the department.

Although we are committed to providing the best education that we can for our students, we do not have consistent practices in place for communicating learning goals for a course or for assessing the extent to which students meet those goals. Many of us who have served on the department's curriculum committee believe that we need a better understanding of what students are supposed to be learning in our courses. All too often we rely on terse calendar descriptions or a list of topics presented in a course outline. A consistent, more detailed description of

learning outcomes will allow the curriculum committee to make more informed decisions when presented with proposals for change.

While we take the time to reflect on our courses, we often react to anecdotal evidence or to instinct. We routinely fail to formally assess the extent to which a new pedagogical technique or change to the curriculum achieves its goals. For example, some of us have used clickers in our courses in recent years and, while we all have an opinion on how successful these efforts have been, few of us (if any) have conducted more formal studies to back up our intuition.

We believe that by establishing learning goals for our courses and by developing more formal assessment techniques appropriate for our discipline, we will initiate a feedback loop that will, in part, enable us to focus our attention on endeavours that will better prepare our students to be leaders in the Computer Science community.

Overview:

Our proposal consists of four parts that collectively aim to significantly improve the quality of learning for our students. We plan to establish a feedback loop that will enable us to assess student learning and respond to data that suggests that learning can be improved. The details of each part of the proposal are presented below. For each part we provide a rationale for the work, list the deliverables and present a high level view of the budget. Budget details are presented in an appendix.

Part 1: Establish Program-Wide Course Level Learning Goals

Rationale:

A program-wide catalogue of learning goals for each of our courses will benefit multiple constituents in the department. Members of our Curriculum Committee have long felt that we have inadequate information about what students learn in each of our courses.

Curriculum changes are often made based on a terse calendar description or list of topics. A program-wide catalogue of learning goals for each of our courses will enable the committee to make more informed decisions about changes to our curriculum including the evaluation of course prerequisites, requests to make changes to course content, and proposals for the development of new courses. It will also allow all faculty to have a clear understanding of what students are expected to know on entering a course at the upper level and what students need to know in preparation for subsequent courses. Finally, students will be able to make more informed decisions when selecting their upper level elective courses.

Deliverables:

Learning goals will be established by faculty with the assistance of an STLF. The STLF will provide guidance on techniques that can be used to extract learning goals from existing course materials and on how to clearly articulate those learning goals at an appropriate level.

Given that the proposed catalogue is expected to benefit faculty and students, we will make it accessible on our web site. We expect that it will also benefit other institutions who are working towards a more clearly defined curriculum for their program.

A catalogue of program-wide course level learning goals will allow us to generate a dependency graph (or equivalent) of courses and prerequisites. Faculty teaching an upper level course will be able to trace through this graph to obtain a clear understanding of what students should know on entry to the course and what students need to know in preparation for later courses. This dependency graph will also be made publicly available on our website.

Budget:

Most of the work in this part of the proposal will be conducted by faculty with the assistance of an STLF. We anticipate that we will require one day per week of an STLF's time over the course of four terms to complete this part of the proposal.

Part 2: Treatment of Common Core Curriculum

Rationale:

One of the unique features of our undergraduate curriculum is the large number of program options available to students. In recent years we have introduced combined majors programs that allow students to pursue interests in Computer Science and another Science subject. We also have a new Bachelor of Arts program and a new combined program with the Sauder School of Business that leads to a Bachelor of Commerce. Despite these many options, we have a set of eight core courses that are required in almost all of these programs: CPSC 111, CPSC 121, CPSC 211, CPSC 213, CPSC 221, CPSC 310, CPSC 313 and CPSC 320. In addition, many students in Mathematics and Statistics programs take CPSC 111 and 211 to satisfy degree requirements, and we have many more students take CPSC 111 as an elective course.

The five core courses at the first and second year level were introduced in fall 2003 as a result of a much needed overhaul of our curriculum. Since then, some faculty have raised concerns over this new curriculum. These concerns range from cognitive overload in some courses to a lack of cohesion in the content of other courses. We need to conduct a formal assessment of our existing curriculum in the light of the concerns that have been raised. We also need to step back and ask whether or not we have established the right set of goals for our students in this core curriculum.

Deliverables:

In 2001 the Association for Computing Machinery (ACM) in conjunction with the Institute for Electrical and Electronics Engineers (IEEE) published guidelines for a Computer Science curriculum (www.acm.org/education/curricula.html#cc2001-fr). This work can provide us with a basis for our discussion. However, our discipline changes rapidly and it is essential that we develop a curriculum that reflects the current and expected developments in the area. We must also develop a curriculum that reflects the values of our department and that builds on the diverse strengths of our faculty. As a critical step in this process we will articulate a *comprehensive hierarchy of desired learning goals* for our core curriculum. This hierarchy will range from course level learning goals through topic level learning goals.

As well as relying on our own expertise, we intend to survey other Computer Science departments and industry representatives for input. We expect that other CS departments will have grappled with many of the issues we are facing and we can therefore learn from existing best practices. We also recognize that the majority of our students will be headed to jobs in industry. Input from industry will therefore allow us to better prepare our students for their future careers while ensuring that they meet the academic standards set for our program.

Our curriculum committee has been charged with the task of developing this hierarchy of desired learning goals. As a first step in this process, we held a break-out session at our 2007 department retreat to identify program level learning goals. As with any decision that potentially impacts our curriculum, the department will be presented with further opportunities to provide input. At the end of this process we will have a catalogue of desired learning goals that will be available to the department through the curriculum committee's website.

In parallel with this effort, STLFs will work with faculty who have experience teaching the core courses to extract topic level learning goals from the existing courses. We have already begun this process in CPSC 111 and 121. This catalogue of learning goals will allow us to engage in more informed discussion about the concerns that have already been raised by faculty. They will also allow us to gauge the distance between the desired curriculum and the one that we have in place. Several possible courses of action will result from analysing this difference, ranging from a repackaging of the existing courses to a slate of new courses.

It is important that we establish some baseline for measuring the impact on student learning of our revised curriculum and changes to pedagogy. Once the desired and existing sets of learning goals have been identified, we will likely see a significant number of goals that are common to both. It will therefore be appropriate to assess how well our current curriculum and pedagogical techniques enable students to meet those common learning goals. The assessment tools developed at this time can then be used to measure the impact of the new curriculum and pedagogy.

Having agreed on the new curriculum, a small team of faculty, consisting of a mix of instructors and research faculty, will be assigned to each course. This team of faculty will be charged with the development of instructional materials (lecture materials, demonstrations, labs and tutorials, as necessary) and with the task of working with an STLF to assess student learning. Assessment instruments will provide data that will allow us to tune course materials and pedagogical approaches. In turn we will enable students to engage in efficient study plans that lead to desired learning outcomes.

At each stage we will produce documented decisions and practices. These will be managed by a "course keeper" (or keepers) who will help sustain improvements. The notion of establishing a course keeper is not new to us. However, the keepers have no structured mechanism for disseminating and updating information about the course. As courses are assessed, STLFs will work with the keepers to build an online database of resources associated with each course (e.g., learning goals, assessment techniques, teaching practices, and course notes). Although maintaining these databases will be additional work for keepers,

this will be balanced by the effort saved in mentoring other faculty teaching their courses in subsequent years.

Budget:

Although there are several possible outcomes from this part of our proposal, it is anticipated that significant work will be required either to overhaul the existing courses or develop replacements. Two sections of teaching credit will be available for each of the eight courses to compensate for the time required to develop course materials, work with STLFs to generate assessment instruments and respond to the data gathered. The teaching credit could be used in a variety of different ways. It could be assigned to an individual faculty member (likely the course keeper) or to a team of two or more faculty who will share the teaching credit. For example, two faculty could team teach a course and share one section of teaching credit.

We will also require the time of an STLF to assist in the development of assessment instruments and the resulting data analysis. It is anticipated that each course will require two days of an STLF's time for two terms. The first term will be used to develop assessment instruments. The second will be used to analyze data and develop a plan for responding to the results in an effort to improve student learning.

In addition to developing assessment instruments, we expect STLFs to be engaged in numerous other activities aimed at obtaining a deeper understanding of student learning. For example, STLFs can interview students, review student work, attend labs and tutorials to assess their effectiveness, review TA work and document their findings.

Part 3: Treatment of Non-Core Courses

Rationale:

Although the eight core courses represent a significant number of the seats available in our program, we offer a diverse set of upper level courses that students take as electives. It is important to also examine the extent to which students achieve learning goals in these courses and that we develop instructional techniques that enable students to engage in efficient study.

Deliverables:

We circulated a call for proposals to all faculty asking them to provide:

- the target course
- a brief description of the project
- a statement of interest in working with an STLF to assess the impact of their project on student learning
- a description of the type of support needed to complete the project

As a result we received proposals to engage in curriculum development for the following courses: CPSC 304, 314, 317, 322, 340, 404, 405, 415, 416, 417, 418, 422, 425 and 430. We also received a proposal to develop a new service course. In total, these projects involve

23 of our 54 faculty. We have 14 faculty on leave this year and some have expressed an interest in participating when they return. It is therefore expected that other proposals will be received in future.

The proposals include the development of new demonstrations, practice problems with solutions, more effective assignments, interactive software tools to enable students to visualize complex systems and an entirely new service course.

Although these proposals encompass only a subset of upper level courses, it is anticipated that lessons can be learned that could have a much broader impact on our curriculum. STLFs will therefore attempt to extract general conclusions from the data gathered across all of these development activities.

Budget:

Our budget includes \$15,000 for each project. We anticipate that each project will require one day of an STLF's time for two terms to assist in the development of assessment instruments and the resulting data analysis

Part 4: Program-Wide Attitudinal Surveys and Interviews

Rationale:

There are some aspects of student learning (e.g., those expressed in program level learning goals) that cannot easily be measured on exams and assignments. For example, many, if not all, of us would agree that graduating students are expected to be able to learn a programming language on their own. Interviews will enable us to determine how students approach the problem of learning a new programming language. We can also track how this approach changes as students progress through the program. We expect that students obtain more expert approaches as they move towards graduation. Data gathered from interviews and surveys will enable us to measure that progression and address shortcomings.

Students' attitudes and beliefs are one of the factors that contribute to success. Courses that excite and motivate students will likely result in lower attrition and will encourage students to pursue more advanced courses. By tracking student attitudes and beliefs as they progress through our curriculum, we will have another data point that will enable us to guide students towards more effective learning.

Other questions that we may wish to investigate include:

- What are "expert" beliefs about computer science and how do students acquire those in the process of taking our courses?
- Can students achieve high grades in our courses without acquiring expert beliefs about computer science?
- What are the factors that contribute to low retention rates of women in Computer Science?
- How do student beliefs regarding intelligence affect their ability to become experts in computer science?

- Can we develop interventions that generate a "growth mind set" in students that in turn results in higher achievement?
- How does immediate, repeated, negative feedback from a compiler contribute to students' beliefs about their ability to succeed?
- What value do students place on proofs in the context of computer science? Does their attitude change as they progress through our program?

Deliverables:

STLFs will develop and deploy appropriate tools to track students' attitudes and beliefs through the program. It is expected that these tools will encompass surveys, discussion topics for focus groups and scripts for individual interviews with students.

Budget:

This work will be conducted almost exclusively by STLFs. It is anticipated that this work will require 1 day of an STLF's time per week over the lifetime of this initiative.

Plan for sequence:

Given that we have already started work on some aspects of this proposal, this discussion will use the 2007/2008 academic year as a base line and the term *year* will refer to an academic year. A graphical depiction of the timeline is included as an appendix.

Part 1:

We expect to have the deliverables for this part of our proposal in place by the end of the second year. We have already started work on CPSC 111 and 121. We expect to be able to articulate learning goals more efficiently as we gain more experience. Some faculty who play key roles in the delivery of certain courses may be on a leave of absence and so this work will necessarily be distributed over at least a two year period.

Part 2:

We expect that this part of the proposal will consume the most time. It is very hard to predict how long the top-down process of establishing desired learning goals will take. It took approximately 18 months to reach consensus on the five courses that comprise our first and second year curriculum, and yet more time to develop the necessary instructional materials. The Curriculum Committee has already begun this top-down process and it is anticipated that the process will continue through the midpoint of the 2008/2009 year.

We have also begun work on the bottom-up process of articulating learning goals for our existing core courses. The process is almost complete for CPSC 111 and 121. By the end of the current year, we expect to have topic level learning goals in place for all of our first and second year courses. By the midpoint of next year, we expect to have completed the process for the remaining three core courses.

By the midpoint of the 2008/2009 year we therefore expect to have completed the top-down and bottom-up processes and will be in a position to identify a new slate of courses. Having clearly identified our desired learning goals, we expect the process of defining a new

curriculum will be complete by the end of the 2008/2009 year. In parallel with this activity we will begin the process of developing the tools to assess how well students are achieving the learning goals that belong to the intersection of the set of desired learning goals and the set of existing learning goals. These tools will be deployed before changes are made to our courses so we have a baseline from which we can measure improvements to student learning.

The development and assessment of new courses can begin in the summer of the second year of this initiative and is expected to take four years to complete. In each of the first three of these four years we will roll out courses in the first, second and third year of the curriculum, respectively. The following year we will assess the course and iterate on the course in response to data gathered from assessment instruments. Note that many of these courses are offered twice a year and hence, over a two year period, we will be in a position to respond to up to three assessments of student learning in each course.

Part 3:

The proposed upper level course projects will be conducted over a four year period starting with the 2008/2009 academic year. Some of these proposals group together naturally, in so far as they have similar goals. For example, one group of proposals aims to develop online interactive tools. It makes little sense for these projects to proceed in parallel. A more evolutionary approach will allow future projects to advance more quickly in response to lessons learned in earlier projects. Data from the assessment of initial projects will allow future projects to be developed more efficiently and will result in the development of materials that are more effective for students. In consultation with the faculty who have submitted these proposals, we will identify groups of projects with similar goals and schedule them accordingly.

Each project will extend over a period that will allow input from assessment tools to be incorporated into a subsequent revision of the course. For courses that are offered every term, this may happen within one academic year, for others it will require two years.

Part 4:

Work has already started in this area. We expect that the development and refinement of attitudinal assessment tools will be complete by the end of the second year. The deployment of these tools and analysis of subsequent data will continue over the lifetime of the project.

Plan for achieving coherence across the program:

The process of identifying course level learning goals across our curriculum will give us a common language for communicating what students learn in our courses. We expect that all faculty will be involved in this process.

By grouping similar proposals for upper level courses together, we will achieve coherence across certain groups of courses to the extent that some projects will benefit from the lessons learned in other projects.

We expect a high degree of coherence across our core curriculum as we introduce a slate of new courses in response to our desired learning goals. Again, the gradual manner in which the new curriculum will be rolled out will allow second year courses to benefit from the lessons learned in developing and assessing first year courses and so on.

We expect that the STLFs will also help to achieve coherence. They constitute a relatively small group of people that will be involved in all aspects of this proposal. In conjunction with our Curriculum Committee they will form an umbrella under which our efforts can be guided.

Sustainability:

By the end of this initiative, we would like to ensure that faculty in the department have learned the skills developed by STLFs. Of the 54 tenured or tenure-track faculty in the department, 8 are on the instructor track. Some of these instructors have expressed a keen interest in training as STLFs. Unfortunately, due to the high number of leaves expected in the next few years, we do not have the resources (in terms of instructional staff) to provide release time for such training to take place on an ongoing basis. However, in the last few years of this initiative, we expect fewer leaves to occur and we will be in a position to offer release time to instructors who wish to train as STLFs. Each of the instructors will receive two teaching credits per year in exchange for the time that will be committed as an STLF. The instructors who engage in this work will be expected to participate in all activities expected of STLFs hired under the CWSEI and will commit two days per week to the CS-SEI. We will therefore have faculty who are well positioned to continue the project when CWSEI funding ends. In turn, these faculty will be able to train other faculty to develop assessment tools and analyse the data gathered.

Leadership and oversight:

The department's Curriculum Committee will be responsible for overseeing the implementation of this proposal. The chair of this committee reports to the Associate Head for Undergraduate Affairs who holds an executive position on the committee. The Associate Head for Undergraduate Affairs meets weekly with the department Head to discuss all aspects of the undergraduate program, including the CS-SEI. In addition, every two months, the chair of the committee will meet with the Head and Associate Head for Undergraduate Affairs for a progress report.

The Associate Head for Undergraduate Affairs will represent the department at the CWSEI working group meetings.

The Curriculum Committee will be responsible for bringing all proposals for curriculum change to the department via the existing approval process.

Participation and Recognition:

All faculty will be involved in part 1 of this project. The proposals for upper level courses involve 23 faculty. We expect this number to increase as proposals are received from faculty who are currently on leave. In addition to these 23 faculty, at least 3 more will be involved in the treatment of our core courses.

The department has a well established merit review process that already recognizes efforts to improve our curriculum. In addition to providing buy-outs for the development and assessment of courses, efforts to improve our curriculum will continue to be recognized in the annual merit review process.

We are a department that is driven by consensus. The process that led to the development of this proposal exemplifies the mechanism by which consensus is reached. We provide avenues for concerns to be heard (brown bag meetings, working meetings and department meetings) and we take the time to understand and respond to those concerns as best we can. A spirit of mutual respect leads to a process of open dialog, reflection and consultation.

Conclusion:

This proposal was born out of a process that provided an opportunity for all faculty in the department to contribute their opinions. The elements of the proposal have been shaped by input from many members of the department. Through a consensus-driven model, we have laid out a plan for the CS-SEI that will result in a more systematic approach for communicating what students will learn in our courses, for assessing the extent to which learning goals have been met and for directing our efforts to improve student learning.