Proposal for a Program in Computing Science

Submitted by
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1. Proposal Details

Overview of the Proposed Program

Proposed Program Title: Computing Science

Proposed Credential Nomenclature: Honours BSc (Computing Science)

Work experience/work placement term: Not required for degree completion, but work placements will be facilitated in industry and in conjunction with faculty-supervised research projects.

Anticipated Program Start Date: September 2005 (if there is sufficient demand to justify the required resources, students who have successfully completed the first year of any Science degree program at UOIT, or the equivalent at another university, may be admitted to year 2 in September 2005). An articulation agreement will be formulated to accommodate graduates of Durham College and of other community colleges to enter the program with advanced standing, beginning September 2007 or earlier.

Description of the Proposed Program

This proposal is for a four-year Honours Bachelor of Science degree in Computing Science. The Program is designed to meet the increasing demand for graduates with the knowledge and skills in this important field.

Curriculum (see also Program Map):

The scope of the field called “computing” has broadened to the point that it is difficult to define it as a single discipline, as noted in the document *Computing Curricula 2001: Report of the Joint Task Force on Computing Curricula of the IEEE Computer Society and the Association for Computing Machinery (ACM).* The mandate of this task force was:

“to review the Joint ACM and IEEE/CS Computing Curricula 1991 and develop a revised and enhanced version for the year 2001 that will match the latest developments of computing technologies in the past decade and endure through the next decade.”

The Program name, “Computing Science”, reflects its broad modern emphasis (this name is also used at the Un of Alberta), and the proposed curriculum has been designed using the IEEE/CS Report as a guide. The Report suggests that the discipline has identified a core set of knowledge that each computing scientist should possess. Fourteen knowledge focus groups within computing science were identified: Discrete Structures, Programming Fundamentals, Algorithms and Complexity, Architecture and Organization, Operating Systems, Net-Centric Computing, Programming Languages, Human-Computer Interaction, Graphics and Visual Computing, Intelligent Systems, Information

Management, Social and Professional Issues, Software Engineering, and Computational Science. All elements of these knowledge areas are covered in the core courses of the proposed curriculum or in the advanced elective courses. Appropriate supporting courses have been chosen from the mathematical and natural sciences, in addition to core and elective liberal studies courses.

Graduates of this Program will obtain a solid foundation in the theory and application of the principles of computing science, as well as in the cognitive capabilities and skills relating to computing science. This Program also provides the opportunity for the student to develop practical capabilities and skills, such as software design and implementation, information management, risk assessment, effective deployment of software tools and system evaluation. In addition, transferable skills such as communications, teamwork, numeracy, self management and professional development are emphasized in many courses.

The first year of the Program is similar to those of all UOIT Science programs, in order to provide a broad basic understanding of the different branches of science, and to provide flexibility in the ultimate choice of program within Science. Two specialized Computing Science courses are taken in first year, one of which (Fundamentals of Programming) is currently also an elective for all Science students, and one of which (Discrete Structures in Computing Science) is specialized to Computing Science students. In the third and fourth semesters, students begin to specialize in core computing science courses such as software systems development and integration, principles of computer science (data structures, object-oriented programming), and computer architecture. The last two years of the Program are spent developing skills and knowledge in software engineering, information management (databases), operating systems, and the theoretical basis of computing (algorithms, theory of computation), as well as advanced topics such as compilers, graphics, artificial intelligence, human-computer Interaction, high-performance computing, and distributed systems. Each student is required to take a capstone course entitled Thesis Project that will allow them to demonstrate the maturity of their discipline knowledge and skills. Professional conduct and social responsibility will be examined in the Ethics, Law and the Social Impact of Computing course. This addition to the curriculum has been suggested by the ACM/IEEE as a necessary component for the future accreditation of computing science as a profession.

The proposed Program has 19 Computing Science courses (17 core and 2 advanced electives courses selected from a list of 4), 13 Science courses (10 specified and 3 electives), and 8 liberal studies courses (4 specified and 4 electives).

Advisory Committee and Other External Input:

The proposed Computing Science Program is market-oriented, in that it was generated in response to a recognized world-wide need for graduates in this area. While the specific Program details have not yet been reviewed in detail with a Program Advisory Committee, which is in the process of being constituted from members of the School of Science Advisory Committee and additional specialists from academe and industry, the proposal is being discussed with, and is supported by, the consultants who are writing course descriptions for the new Program. One of the consultants (Deborah Stacey, University of Guelph) has recently served as an external consultant for the latest review of the computer science program at Ryerson University. In her opinion, the proposed Program is comparable to the ones at the University of Guelph and Ryerson, and in some ways presents a more modern face on computing science curricula than either of these two institutions.

To again quote from the ACM/IEEE Curricula 2001 Report,

"From its inception just half a century ago, computing has become the defining technology of our age. Computers are integral to modern culture and are the primary engine behind much of the world's economic growth."

It is clear, in view of the economic growth that has been stimulated by the high-technology sector of the Canadian economy in geographical areas such as Waterloo, Toronto, Vancouver, Montreal and Ottawa, that a graduate with a mature knowledge and skill set in the computing sciences will be well-placed to benefit society at large, both economically and socially.

Attributes of Graduates:

Graduates of this Program will obtain a solid foundation in the theory and application of the principles of computing science, as well as in the cognitive capabilities and skills relating to computing science. This Program also provides the opportunity for the student to develop practical capabilities and skills, such as software design and implementation, information management, risk assessment, effective deployment of software tools and system evaluation. In addition, transferable skills such as communications, teamwork, numeracy, self management and professional development are emphasized in many courses. The professional course in Ethics, Law and the Social Impact of Computing will help prepare the student for a workplace where issues in intellectual property law, the social impact of the digital divide, and the internationalization of trade and commerce are daily concerns.

In addition to the skills and knowledge in their chosen discipline of computing science, graduates will have a basic background in the natural sciences, enhanced by exposure to liberal studies courses. It is extremely important that computing science professionals have an appreciation of other fields of study, since their professional lives are spent developing computing systems so that others can benefit from the computational and information management capabilities of modern computers. This is especially true in the case of science, to which it is expected that many graduates will contribute in their future work; the core science studies in the program will enable graduates to communicate and interact with colleagues in this field. By means of an appropriate choice of elective courses, students may choose to further concentrate in one of the sciences to acquire a secondary area of specialization and to complement their Computing Science studies. For example, the proposed Program contains five courses in the existing Computational Science secondary area of specialization, providing an opportunity for students to readily gain recognition for this designation. Additional secondary areas of specialization may also be formulated in the future, and the School of Science looks forward to collaborating with colleagues in other UOIT Schools in their development, and in the development of related programs complementary to the proposed Computing Science Program.

The ubiquitous nature of computing also necessitates that a computing science graduate have a mature appreciation of the social impacts of their work, which will be facilitated via the course on Ethics, Law and the Social Impact of Computing. Graduates will be self-directed life-long learners with excellent scientific, management and interpersonal skills. They will also be socially, environmentally, economically and globally-aware problem solvers, who are skilled in the use of information technology.

Program Strengths:

The proposed Computing Science program has the following strengths:

- It incorporates a broad range of specialized topics in computing science, in addition to basic science fundamentals
- It follows the recommendations of the ACM/IEEE Curricula 2001 Report.
- Its incorporation of professional elements and its following of ACM/IEEE guidelines will make future professional accreditation possible.
- It provides the flexibility of either entering the workplace or a route to graduate school in Computing Science.

<u>Rationale for the Proposed Program</u>

Market Demand:

Canada is one of the most digitally connected nations in the world, with leading telephone, cable and Internet penetration. Our cost of Internet access is the lowest in the OECD. We have more fixed network digitization than the United Kingdom, France, Italy, Japan and the United States. CA*Net 4 and CANARIE are just two examples of Canada's numerous successes in network technologies and applications.

Industry Canada (www.ic.gc.ca), through forums such as the Information Technology and Knowledge-Based Economy Summit, is active in determining how Canadians and

Canadian industry can best secure the skills necessary for our new Knowledge-Based Economy. They have stated that:

“The transition to the Knowledge-Based Economy (KBE) is dramatically increasing the demand for highly-skilled workers due to both the rapid expansion of knowledge-intense industries and the sharply increasing importance of creating and exploiting knowledge and information in all sectors of the economy. Canada's ability to attract, retain and develop highly-skilled talent is of critical importance in maintaining and strengthening our competitiveness in the new economy. In addition, as the market for skills becomes global, Canadian companies must compete with other nations for highly-skilled people. This international competition is intensified by the fact that acute skill shortages exist across the OECD in areas such as software engineering, digital signalling and wireless technologies. These factors are making it increasingly difficult for many Canadian firms to recruit and retain the highly-skilled workers they need.”

The shortage of highly-skilled workers jeopardizes the growth both of high-technology companies and of the economy as a whole. Every job created in the high-technology sector tends to create two indirect jobs, so the loss to the economy of not filling positions in high-tech companies can be considerable.

The Information Technology Association of Canada (www.itac.ca) states on its website that:

“The growth (of information technology) is so rapid and widespread that demand for skilled people to design, build, install, service, and create today's and tomorrow's information technology applications far exceeds supply. Recent estimates suggest that more than 1,000,000 North Americans could be employed in rewarding, high-income jobs today if they had the appropriate information technology skills.

The IT skills gap in Canada is most severe in the core occupational disciplines of computer science, microelectronics design, photonics and wireless design, software design, and systems analysis. Many thoughtful analysts believe that Canada's future economic growth could be critically impaired unless we act decisively to reverse the continually worsening situation.”

These outlooks on the urgent need for more people trained in the computing sciences extend beyond Canada's borders. The lack of qualified workers in the computing sciences has been acknowledged by the U.S. Department of Commerce in a June 1999 Office of Technology Policy report on the digital work force:

“... the variety and complexity of software and hardware products and their applications, together with the unique business requirements of each industry, have created "spot" demand for workers with unique combinations of IT skills, experience and industry knowledge - expressed often by employers as needing "the right person, with the right skill, at the right time." The combination of time-sensitive competitive pressures and limited-time need for employees with unique combinations of technical skills, business

skills, and hands-on experience has led many employers to pursue "buy" decisions in this labor market, rather than "make" decisions (to hire, then train for the task). Thus while there is a need to address the growing demand for highly skilled IT workers, there is the additional challenge of meeting the unique demands of this niche labor market."

Alternatives for Students:

Our current competitive, global economy is driven by accelerating discovery and change. An individual's ability to innovate directly affects her/his economic success and social contribution. An ability to innovate provides students with new learning opportunities, higher incomes and better jobs. A strong commitment to innovation will also strengthen our social and cultural fabric. By strengthening our students' ability to compete in a global, knowledge-based economy, we will significantly improve the quality of life for all Canadians. This Program has been designed to provide the student with those skills that lead to innovation and discovery. Whether they choose to use those skills in the information technology industry directly or to move into fields such as science, commerce or administration, they will have the necessary background knowledge and skills to be innovators. They will be able to contribute to these other disciplines because of the broad background that this Program gives them in the sciences, both natural and computational. Their world outlook is enhanced by their liberal studies courses in the Program. Because computing technology is so ubiquitous, many computing professionals do not work directly in the high-technology sector. Manufacturing, commerce, trade, retail, resource and environmental management, and education all require the skills and innovation of professionals trained in the creation, evaluation, and utilization of information technology.

Efficient Use of Resources (see below for detailed requirements):

Some of the existing faculty, technical support staff, equipment and courses (22 courses) supporting the existing UOIT Science programs can be used to deliver the proposed Computing Science Program. There are 20 new courses in the proposed new program, requiring 5 additional faculty members. The existing emphasis on Computational Science in the School of Science will enhance interdisciplinary research and teaching synergies among current and new faculty. The UOIT laptop program will reduce the equipment requirements. UOIT's membership in the SHARCNET high-performance computing consortium will provide access to state-of-the-art equipment that can be accessed by senior-year students, and a potential opportunity to share collaborative teaching responsibilities with other member institutions.

Numbers of Students:

The Computing Science Program is expected to attract approximately 50 students starting in 2005, and to grow as the University and the School of Science develop. Development of a Business Plan for the Program is well under way.

Resource Requirements

Necessary resources can be categorized into the following areas: (1) faculty and staff, (2) laboratories and equipment, (3) research facilities, and (4) educational resources and infrastructure. This program initiative is expected to generate research and contract funding, which should offset, to an extent, the additional expenditures. In particular, the visibility of this Program initiative can be expected to facilitate the obtaining of contract funding by the UOIT Science and Technology Clinic in this area.

(1) Five (5) additional academic faculty members will be required to teach the specialized courses, supervise students and conduct research. When graduate programs are initiated, the required faculty complement is expected to increase. The Program is expected to attract adjunct faculty and sessional lecturers with extensive industrial and business experience, and such expertise will complement the more academic background and orientation of the tenured and tenure-track faculty.

Support for the laboratories will require at least one System Administrator (already in place) and one hardware technician (new).

(2) There will be modest equipment needs, which include advanced networking in laboratories (including wireless), and advanced workstations for senior courses that require more computational power and data storage facilities than are available on a laptop.

(3) Research space and startup funding will be required for the faculty members.

(4) If funding can be obtained, it would be advantageous for UOIT to commit to the SHARCNET plan to link all SHARCNET member institutions through internet teleconferencing. This would make senior courses from other universities available to UOIT students, particularly in the areas of high-performance computing and scientific computation, thereby providing enhanced collaborative opportunities for faculty and learning opportunities for students at minimal marginal cost.

The library resources must be evaluated, but since most computing science resources are now available electronically there may be little need for onsite paper-based library resources.

2. Business Plan

The Business Plan is based on the following assumptions:

- Annual intake of 50 students (case for 100 students also available)
- Attrition factors of 0.8, 0.7, and 0.65 in years 2, 3, and 4, relative to first year
- Operating Grant per FFTE = $2736 per first year student, and $7,858 for subsequent years (government instructions)
- One student = 1 FFTE
- Tuition for Computing Science = $4184
- No inflation factor is used.
- Average salary for FT faculty member is $90,000 plus 18.5% benefits.
- TA cost per hour = $35
- New lecture sections are required only for the new courses in this program.
- First and second year Science courses are taken in existing sections; faculty costs are shared according to enrolment (e.g. if 50 students in CS are part of a lecture section of 150, then 50/150 of the cost of the faculty member is attributed to CS). An alternative costing with extra sections is available.
- All marginal lab and tutorial costs are calculated on the same basis as for other Science programs. The hours for existing courses are specified in the Calendar, while hours for new courses are specified in the course descriptions.
- Electives and required business courses are estimated at $11,000 per section of 50 students.

Using the above assumptions, the following revenues and expenses are estimated as the program rolls out over 4 years (intake of 50 students each year):

	2005/06	2006/07	2007/08	2008/09
Revenue:	$346,000	$827,680	$1,249,150	$1,640,515
Expenditures:	$148,650	$308,080	$544,769	$776,965
Expenditures/Revenue:	43.0%	37.2%	43.6%	47.4%

3. BSc (Honours) COMPUTING SCIENCE PROGRAM MAP

Year-Semester	Subject	Subject	Subject	Subject	Subject
1-1	Calculus I	Physics I	Chemistry I	Discrete Structures in Computer Science	Scientific Computing Tools
1-2	Calculus II	Physics II	Chemistry II	Fundamentals of Programming	Biology for Engineers
2-1	Linear Algebra	Principles of Computer Science	Computer Architecture I	Elective*	Elective*
2-2	Computational Science I	Software Systems Development and Integration	Statistics and Probability for Physical Science	Elective*	Collaborative Leadership
3-1	Simulation and Modelling	Operating Systems and Networking	Database Systems and Concepts	System Analysis and Design in Applications	Elective*
3-2	Elective*	Computer Architecture II	Software Engineering	Analysis and Design of Algorithms	Management of the Enterprise
4-1	Scientific Visualization and Computer Graphics	Compilers	Thesis Project	Elements of Theory of Computation	Elective*
4-2	Computing Science Elective	Ethics,Law and the Social Impact of Computing	Elective*	Computing Science Elective	Elective*

*Students are required to take 3 science electives and 4 liberal studies electives

New course in Computing Science Program

New course in Computing Science; also in Computational Science secondary area of specialization

Existing course in Computational Science secondary area of specialization

Senior Computing Science Elective Courses (new courses):

Artificial Intelligence
Human-Computer Interaction
High-Performance Computing
Distributed Computing
Computational Science II