

FINAL ASSESSMENT REPORT
Graduate Review of Electrical and Computer Engineering
(MEng, MSc, PhD)
March 2013

Review Process

The self-study was produced with the assistance of a committee which included the Associate Chair, Graduate, two faculty members in ECE and two staff, who interacted with the faculty and staff in ECE. The majority of the faculty also participated in a review of the curriculum and its relationship to the Graduate Degree Level Expectations. Student input was sought through two student Town Hall meetings in the Department, and by the inclusion of a representative of the Graduate Student Association in the review of the report. The review was undertaken by Dr. Chris Damaren, Vice-Dean, Graduate Studies, Faculty of Applied Science and Engineering, University of Toronto and Dr. Douglas Williams, Senior Associate Chair, School of Electrical and Computer Engineering, Georgia Institute of Technology, and the site visit occurred on November 15-16, 2012.

The previous OCGS Program Review (2005) at the Graduate level for ECE made the following suggestions:

- Reduce the practice of hiring our own PhD graduates as tenure track professors.
- Strengthen the circuits and systems field by hiring additional faculty members.
- Find a better balance between undergraduate and graduate demands on faculty.
- Ensure comprehensive exams are held in a timely manner (within 12-16 months).

In addition during the approval process of the collaborative programs of Nanotechnology (2009) and Quantum Information (2010) the following action was recommended.

- The department should have sufficient administrative staff to support the new collaborative programs.

The Department responded to these suggestions as follows:

- Since 2005, of the 30 faculty hired, only 2 were University of Waterloo PhD's, and both of these had held other positions prior to their appointment;
- In that period 7 additional faculty have been hired in the circuits and systems field;
- Teaching loads have been standardized as two undergraduate and one graduate course per faculty member, and the ratio of students to faculty at both undergraduate and graduate levels has decreased with the new appointments;

- As part of the Vision 2015 planning exercise, the comprehensive exam will be split into two components (background, and proposal), with the former to be completed within the first 12 months in the program; and
- Graduate staff complement has doubled from three to six.

Characteristics of the Program

Program Objectives

The goal of the MAsc program is to provide the necessary background to demonstrate the individual accomplishment of a high professional and academic standard. A student who graduates from the Department of Electrical and Computer Engineering with an MAsc degree will have a strong theoretical and experimental background in his/her field of research plus a broad knowledge in related fields within Electrical and Computer Engineering. This preparation is intended to make students ready for industry needs and also to pursue further research in doctoral programs.

The objective of the PhD program is to train students to become independent researchers. The program is intended to give graduate students the required theoretical and experimental knowledge and research methodology to demonstrate accomplishment of independent and original research work.

The objective of the MEng program is to produce graduates who have a strong theoretical background and development skills which are appropriate for both analysis and design needs of industry. The objective of the specialized online power engineering program is to produce such graduates for the needs of the power industry in Canada, and internationally.

Specific Learning Outcomes

The research graduate programs each have five specific learning outcomes, and the two professional Masters each have four. The curricula have been mapped to the GDLEs.

Distinctiveness

The Department of Electrical and Computer Engineering is one of the largest in North America, with 78 tenure stream faculty as well as 5 lecturers and 18 adjunct faculty. It is the largest department at the University of Waterloo both in terms of faculty and graduate students. It has 652 graduate students, 454 in the research graduate programs (PhD and MAsc) and the balance in the professional programs (on-campus and online MEng programs).

The Department has 17 research chairs (Canada Research Chairs, Industrial Research Chairs, and University Research Professors). In 2011, \$25.8m was received in research grants. The Department acquired part of a large new building (Engineering 5) in 2010, to house the expansion. The Department has many associated research laboratories allowing for research in

a range of specialized areas. The research graduate program is among the largest in Canada: the PhD program has tripled in size over the last decade.

Academic Programs Offered

The first graduate program in Electrical Engineering began in 1959, two years after the first undergraduate program. This was merged in 1989 with the later-established graduate program in Computer Engineering.

Programs offered include:

MASc in Electrical and Computer Engineering

MASc in Electrical and Computer Engineering, specialization in Nanotechnology

MASc in Electrical and Computer Engineering, specialization in Quantum Information

MEng in Electrical and Computer Engineering

MEng in Electrical Power Engineering (online only)

PhD in Electrical and Computer Engineering

PhD in Electrical and Computer Engineering, specialization in Nanotechnology

PhD in Electrical and Computer Engineering, specialization in Quantum Information

The collaborative graduate programs in Nanotechnology and Quantum Information will be the subject of single reviews in the future. University of Waterloo participated until 2011 in the Consortium of Graduate Engineering in Software Engineering (ConGESE), which has now been phased out; this program is not reviewed here.

Interest in the on-campus MEng has been strengthened by the availability of four Type 2 Graduate diplomas, in Computer Networking and Security, Software Engineering, Sustainable Energy and Management Sciences. These were reviewed and changed from certificates to Diplomas in 2011, and are not reviewed further here. The online Masters also has an associated (Type 1) Diploma in Power Engineering.

There are 13 approved fields in the research programs, as follows:

- Antennas, Microwaves & Wave Optics
- Circuits and Systems including Computer-aided Design
- Communication & Information Systems
- Computer Hardware
- Computer Software
- Nanotechnology
- Pattern Analysis Machine Intelligence
- Power and Energy Systems
- Quantum Information
- Silicon Devices and Integrated Systems

- Systems and Controls
- Very Large Scale Integration
- Wireless Communications

Students: Graduate

The Department receives over 1500 applications annually for its programs and can only accept a fraction of qualified applicants. 20-25% of the applicants for the M.Eng, 10% of those for the MASc, and 3% of those for the PhD are Canadian or permanent residents of Canada. 55% of the Masters and 45% of the Doctoral students were Canadian or permanent residents in winter 2012. In 2010/11 17% of registered students were women: Waterloo uses outreach programs such as “Go Eng Girl” and “Women in Engineering” to try to attract more women into the discipline.

Completion times for the MASc and PhD are 5.9 terms and 13.4 terms respectively, which are quite reasonable for programs which require experimental results. Average completion times in the MEng are about 1.5 years (this combines full and part-time students); and in the Power Engineering program (where the majority of students are part-time) the average is around 2.5 years. Students are expected to publish: students currently in-program were surveyed, and on average current Masters students had one publication, and current doctoral students have on average four. According to a 2011 survey of faculty (enquiring about post-graduation placement of their students) 60% of Masters graduates go to work in industry, and the balance continue on to the PhD, 15% of all graduates going to another university, and 25% remaining at University of Waterloo. Of PhD graduates, 49% go to industry, 37% to academic positions, and 13% to postdoctoral positions.

Faculty

The Department currently has 80 regular faculty, with more than 5 open positions. More than 30 faculty have been hired since 2005, over a period of planned growth. Seventeen faculty hold prestigious research chairs. Another 30 hold prestigious awards and fellowships such as IEEE fellowships, Engineering Institute of Canada fellowships, Steacie Memorial Fellowships, Early Researcher Awards, Royal Society of Canada fellowships, etc. More than 25 serve or have served in editorial capacities in prestigious engineering journals, and all the faculty regularly review articles for journals. 61% are professional engineers, and another 13% are currently pursuing this designation.

The Department currently has 24 administrative staff and 27 technical staff, as well as some current staff vacancies.

Reviewers' Report

1. Consistency with institution's mission; are program requirements and learning outcomes clear?

Reviewers were happy with all aspects of these topics.

2. Admission requirements: aligned with learning outcomes?

Admissions requirements are appropriate.

3. Curriculum: current? Creativity? Mode of delivery appropriate?

The 13 areas of specialization provide good coverage of state of the art. ECE has exhibited significant innovation and creativity with the power engineering online program.

4. Teaching and Assessment: methods of assessment appropriate? Do means of assessment demonstrate achievement of learning objectives and DLE's?

Reviewers were satisfied, but made some suggestions to improve timely completion of PhD (see specific recommendations below).

5. Resources: effective use of human, physical and financial resources?

Faculty and staff have kept pace with student growth; labs are "world class facilities" and have "state of the art equipment". However students would like additional funding support which reviewers feel should come from University Centre and not supervisor grants.

6. Quality Indicators: faculty, student and graduate?

Assess faculty as "on the whole...excellent". Students are well-qualified, the proportion female is above the average for the discipline, attrition rates are low; time to completion for PhD (13.4 terms) is a little long as funding guarantee is for 12 terms. That 37% of graduates secure academic jobs and 15% postdocs is considered impressive.

7. Quality of enhancement: initiatives to improve program quality, learning environment?

Note that department has responded to suggestions from previous review, in particular doubling the admin staff, and changing the comprehensive structure.

8. Graduate program criteria: time to completion, quality/availability of supervision, program quality indicators for faculty, students, program, sufficiency of graduate-only courses

Recommend making an effort to nominate more IEEE fellows among faculty. Although there are 60 plus graduate courses per year, some MSc students would like more courses in their specialty area (they need to take 5 courses).

9. Other issues (graduate)

Department has responded to issues raised in previous review.

Recommendations

The reviewers' recommendations are listed below (RR), along with the Departmental response (DR). Both the comments and responses have largely been included verbatim, [but occasionally abridged].

- RR: The ECE department has a thriving, high quality graduate department. The review team was impressed with the people, facilities, and structure that make up the ECE graduate program. ECE is doing many things very well, and we did not identify any major problems with the graduate program. We do, however, have several suggestions where improvements could be made.

Faculty Development

- RR: Even taking into account the relative youth of the faculty, an ECE department as large and successful as this one should have more than 10 IEEE fellows among its faculty. [suggestions as to how to nominate more followed]

DR: an Associate Chair Research has been established to raise research profile, and initiate more faculty nominations for awards

- RR: As an observation, space does not currently appear to be a significant problem. However, the department is growing and its junior faculty have developing research programs. [Suggests strategic faculty growth, taking account of the opportunity of new space in the Quantum-Nano building].

DR: none, however does not seem to require a specific response.

• Students

- RR: We were asked to provide suggestions for increasing constructive interactions among the large number of graduate students in different ECE disciplines. A student association currently exists and increased support could provide dividends. Even something as simple as providing free coffee in the graduate student break room would help to bring students together on a more regular basis.

DR: Currently the Department together with the GSA representatives are helping to renovate the EIT Graduate student lounge (including new furniture, cupboards, coffee machine, etc)RR: Seminars can also help to encourage students' interaction. The department hosts quite a few seminars, but in a large department people tend to only attend talks closely related to their interests. PhD students are currently required to give a seminar as part of their degree requirements. If interactions are a priority, the department could also require students to attend a certain number of those seminars, particularly outside of their own area. Good interdisciplinary research is already fairly common within the department. A challenge to encouraging such work is to avoid the siloing of research groups

DR: The Department has initiated a student seminar series which has \$500 awards for best talks given by students. Additionally 5 new E&CE TA awards per term have been initiated to further reward excellent Graduate Student performance.

- RR: The department has an interest in recruiting more provincial and national students to its graduate program. This also appears to be a priority of the Dean's Office, since they have recently hired a person to help with such efforts. Working with them to recruit at other universities in Ontario would be a good first step

DR: Department is making efforts to encourage students in 3rd and 4th year undergraduate to continue, and working with Dean's office to recruit more students from elsewhere in Ontario.

Program Structure

- RR: The current strategy of having core courses in the different disciplinary areas generally appears to work well as a means of encouraging MEng students to take those courses. Nonetheless, faculty expressed some concern about MEng students taking courses intended for MASC/PhD students and, as a result, changing the nature of those courses. Taking a look at where this has happened and why could give some indication of how to avoid these problems in the future.

DR: the Department has initiated changes to filter MEng students, and is also tracking the composition of classes (MEng/MASC/PhD students) to understand better class composition.

- RR: Students expressed concern about not being able to find enough graduate courses in their areas of interest. The stated departmental teaching load includes one graduate course per faculty member per year, but the number of courses that are offered in practice (~60) falls well short of the number of faculty (~80). The department has plans to increase the number of graduate offerings, and we encourage you to move closer to an average of one graduate course per faculty member.

DR: is discussing how to move closer to one graduate course per faculty member (may include hiring a lecturer in place of a tenure-stream faculty member).

- RR: The department is in the process of dividing its PhD comprehensive exam into two parts – an earlier preliminary exam followed by a proposal. This change should help to get students pass through the comprehensive exam earlier in their studies. Another issue has been that very few students fail the current comprehensive examination, which may be partly because faculty supervisors have so much time and funding invested in the students at that point. If the preliminary examination is intended to provide an accurate measure of a student's background with the possibility of failure, decoupling the supervisor from the process would be recommended. Many programs have developed blind tests where the faculty who score written exam problems are not aware of whose papers they are grading.

DR: As a result of the external reviewers' recommendations, the examination marking will be blind (so that the examination marker is unaware of the student who wrote the exam) in order to decouple the supervisor from this process.

- RR: Faculty also mentioned that the few PhD students who fail the comprehensive examination are required to leave the program immediately. Allowing those students to earn an MASc degree would give them a fallback position, as well as giving the student and faculty supervisor an opportunity to wrap up the research project.

DR: Agree that students who fail the qualifying exam may fall back into a MASc program as recommended by the external examiners. [note however that this is not an option if the student already has a MASc in ECE from University of Waterloo, and is not desirable if the student has the same degree already from another university in North America].

- RR: To further shorten the time necessary to complete the PhD, the department should consider methods to get students to give the required seminar earlier. Currently, many students present their seminars shortly before defending their dissertations. Since the seminar is not graded, there appears to be little hazard in having students present earlier, and getting constructive feedback on their presentation skills earlier in their program would be beneficial.

DR: The Department agrees that in future 1) students must give their PhD seminars no more than a year after passing their comprehensive and 2) the entire PhD committee must be present at the seminar, which would give an opportunity for it to discuss the quality and progress of the student's work.

Alumni

- RR: The department expressed a desire for stronger ties to alumni. Instituting a departmental advisory board would be an excellent way to establish and maintain alumni connections. Such boards are fairly common, especially among programs of this size. Many alumni appreciate the opportunity to assist their alma mater. They are also likely to have good ideas of ways to engage alumni not on the board. The department is in the process of hiring a staff person to do external development, and working with the advisory board could fall under that person's responsibilities.

DR: E&CE has not yet hired the staff Industrial liaison position but is actively moving in this direction. An advisory committee has not been established.

- RR: Other approaches to improve alumni engagement include distributing an annual report and hosting an annual dinner for alumni and graduate students.

DR: E&CE continues to help with the annual engineering alumni reports.

Two-Year Plan

By August 31 2015, the Department will report on the following steps/issues:

- Increase in number of prestigious faculty awards within the Department
- Improved E&CE website
- Development of E&CE brochure to attract top Graduate students and Industrial interest
- Renovate E&CE graduate student lounge to improve our graduate student environment
- Initiation of exit surveys for graduate students to monitor and improve our graduate studies
- Admissions analysis and tracking to improve our understanding of our new admits and their previous institutions

Program Structure

PhD

- An increase in one course credit unit will be required for a PhD student holding a MASc degree. The total course credit units will include at least 2 as core courses unless the student holds a MASc degree in ECE from Waterloo (where the list of core graduate courses is to be reviewed and updated by the department on an annual basis).
- A qualifying PhD examination will be conducted by the Department for each candidate. The objective of this examination is to satisfy the Department that the candidate has a broad knowledge of his/her field. It must be held within the first 3 terms after the initial registration for the PhD degree. A student may take this exam at most two times only within the first four terms.
- The Research Seminar should be given no more than three terms after completion of the PhD comprehensive[/research proposal] examination

MASc

- ECE graduate students enrolled in our MASc program will be required to select at least 5 graduate courses (0.5 unit weight per course) where at least 2 are graduate core courses (from one or more of the OCGS research areas where the list of core graduate courses is to be reviewed and updated by the department on an annual basis)

MEng

- ECE graduate students admitted into the MEng program, will additionally have a conditional probationary requirement in their first term, specifying that they must take one of ECE.600 or ECE.650 and one other ECE 600 or 700 level course, and receive at least a grade of 75.

Timelines

Review visit by Dr. Chris Damaren, Vice-Dean Graduate Studies, Faculty of Applied Sciences and Engineering, University of Toronto and Dr. Douglas Williams, Senior Associate Chair, School of Electrical and Computer Engineering, Georgia Institute of Technology, November 15-16 2012.

Review received by GSO November 28 2012

Departmental response received by GSO March 6 2013

For discussion at Senate Graduate and Research Council April 23 2013

For approval Senate May 21 2013 (consent agenda)