

Final Assessment Report

Quantum Information Collaborative (MAsc, MMath, MSc, PhD)

April 2019

Summary of the Program Review:

In accordance with the University Institutional Quality Assurance Process (IQAP), this final assessment report provides a synthesis of the external evaluation and the internal response and assessments of the Quantum Information Collaborative graduate program (MAsc, MMath, MSc, PhD). The program is delivered by the Departments of Electrical and Computer Engineering, Applied Mathematics, Combinatorics and Optimization, Chemistry, Physics and Astronomy and the David R. Cheriton School of Computer Science. A self-study (Volume I) was submitted to the Associate Vice-President, Graduate Studies and Postdoctoral Affairs on January 20, 2017. The self-study presented the program descriptions and learning outcomes, an analytical assessment of this program, including the data collected from a student survey along with the standard data package prepared by the Office of Institutional Analysis & Planning (IAP). Appended to Volume I were the course outlines for all courses in the program. The CVs for each full-time faculty member in the Department were included in Volume II of the self-study.

Two arm's-length external reviewers were selected from Volume III of the self-study. Dr. Christian Kurtsiefer, Professor of Physics and Quantum Technologies, National University of Singapore, and Dr. Robert Boyd, Professor of Physics, University of Ottawa were ranked and selected by the selected by the Associate Vice-President, Graduate Studies and Postdoctoral Affairs, as well as one internal reviewer (Dr. Larry Swatuk, Associate Professor of Environment, Enterprise and Development).

Reviewers appraised the self-study documentation and conducted a site visit to the University on October 30 and 31, 2017. The visit included interviews with the Vice-President, Academic and Provost; Associate Vice-President, Graduate Studies and Postdoctoral Affairs; Deans of the Faculties of Engineering, Math and Science; Faculty Associate Deans of Graduate Studies; Chairs/Directors of the Departments, Faculty members, staff and meetings with a group of current graduate students. The visit also included a tour of the facilities, including the Quantum-Nano Centre and Research Advancement Centre.

This final assessment report is based on information extracted, in many cases verbatim, from the self-study, the external reviewers' report and the program response.

Program characteristics:

The Quantum Information Collaborative program offers degrees as specializations within the six respective units. The degree conferred is that of the home program and the completion of the collaborative program is indicated by a transcript notation to the degree, and an adjunct qualification to the degree.

Thesis Master's program

The objective of the thesis Master's collaborative program is to provide students with a strong and broad foundation in quantum information science together with knowledge and expertise from their home program discipline. This prepares the students for a range of career opportunities in, for example, research establishments, industry, or government. It also prepares students for further graduate study and research leading towards a PhD. The following Master's degrees are offered:

- Master of Applied Science in Electrical and Computer Engineering (Quantum Information)
- Master of Mathematics in Applied Mathematics (Quantum Information)
- Master of Mathematics in Combinatorics and Optimization (Quantum Information)
- Master of Mathematics in Computer Science (Quantum Information)
- Master of Science in Chemistry (Quantum Information)
- Master of Science in Physics and Astronomy (Quantum Information)

PhD Program

The objective of the PhD collaborative program is to prepare candidates for a career as scholars and researchers with advanced expertise in quantum information science and their home program discipline. Graduates are expected to have acquired autonomy in conducting research, preparing scholarly publications, and communicating their research and its importance and relevance. The program is designed to provide a broad knowledge of quantum information, including theory and implementations, and in their home program discipline, as well as advanced expertise in some aspect of quantum information science, and training in basic research. The following Doctoral degrees are offered:

- Doctor of Philosophy in Electrical and Computer Engineering (Quantum Information)
- Doctor of Philosophy in Applied Mathematics (Quantum Information)
- Doctor of Philosophy in Combinatorics and Optimization (Quantum Information)
- Doctor of Philosophy in Computer Science (Quantum Information)
- Doctor of Philosophy in Chemistry (Quantum Information)
- Doctor of Philosophy in Physics and Astronomy (Quantum Information)

Summary of strengths, challenges and weaknesses based on self-study:

Strengths

- Offerings: QIC is a cutting-edge, interdisciplinary program that includes regular offerings of courses on introductory as well as advanced topics, a weekly colloquium, several weekly informal institute-wide meetings, and an active visitor and conference program;
- Faculty: taught by arguably one of the strongest and most diverse faculty in quantum information;
- Connections: students have the opportunity to interact with a cohort of 100 students, 30 postdoctoral fellows and 15 affiliated faculty members working on a wide variety of theoretical and experimental aspects of quantum information;
- Balance: the graduate program carefully balances the goals of the home academic units with rigorous training in quantum information science and technology.

Challenges

- Faculty recruitment: leading researchers often get competitive offers from several other top universities;
- Faculty retention: many faculty members have resigned from the University of Waterloo to take positions at other prestigious institutions, most often in their country of origin. These include: Technical University of Munich, University of Innsbruck, University of Latvia, etc.
- Gender balance: females are underrepresented in faculty and graduate student numbers;
- Graduate student recruitment: competition between institutions conducting quantum information research is fierce. High-quality domestic students are often attracted to top US schools such as Berkeley, Caltech and MIT, causing a slow decrease in domestic graduate students;
- Curriculum: The diversity of students in the program sometimes makes it difficult to design and deliver courses effectively. The challenge is often in finding the right balance between the needs of students with little background versus the needs of those with adequate training;
- Space: As the IQC has outgrown the Quantum-Nano Building, graduate students are split across campus. This presents a barrier to interaction as well as participation in regular events such as colloquia and seminars. A frequent shuttle between the buildings mitigates this issue.

Summary of key findings from the external reviewers:

The program is in excellent standing. It has a fantastic international reputation: the program is able to attract top talent internationally, and graduates are able to find excellent job opportunities all over the world. It also appears that most graduates seem to have no difficulty

finding attractive opportunities in academia. The program appears to be very well set up and thought out from the beginning.

However, its students come from three faculties and seven academic departments, each with its own set of degree requirements; there were significant complications related to the fact that IQC [Quantum Information] is not itself an academic unit. The only issue that arose in the discussions repeatedly was some concerns about transportation between the two physically separated locations, which seems to be addressable with relatively minor effort. This would encourage better interaction between the two student bodies residing in the two locations, and provide better safety at late hours.

Program response to external reviewer recommendations:

1. We suggest that a review be conducted to determine if better transportation between the campuses can be arranged.

Response

Transportation between RAC and QNC is an ongoing issue that has received considerable attention and will continue to be monitored and considered. Prior to 2016, shuttle hours were limited to business hours, but extended operation hours began in 2016 offering shuttle service until 1am.

As of April 2019, at the urging of IQC faculty, the University has greatly increased the level of service. There is now a night-time safety shuttle, managed by campus police, that services RAC after normal business hours.

2. It might be beneficial for the students at IQC to implement a weekly journal club meeting (if this is not already in place). Such a meeting could encourage more student interactions, but this may increase the total number of seminars and talks offered at the Institute, thereby diluting the importance of each.

Response

There is a weekly journal club, which is mainly focused on experimental research that takes place at RAC on Fridays. An IQC postdoc is currently investigating the possibility of a theory focused reading group that discusses recent <https://arxiv.org/> postings of interest.

3. We have obtained hearsay evidence that there are not enough seminars that are more mathematically focussed. One specific suggestion would be to invite Anne Broadbent or someone working in a similar area to present such a seminar.

Response

There are many mathematically focused seminars given by IQC students, postdocs, faculty, and visitors. For example, the Quantum Innovators in Computer Science and Mathematics Workshop in September 2017 featured 15 talks, each one hour in length, given by early career researchers working on theoretical aspects of quantum information science. Every PhD student enrolled in the QI graduate program, including students working on mathematical aspects of quantum information, is required to present two research-level seminars as part of their studies. The IQC colloquium committee routinely issues invitations to researchers in all areas of quantum information science, including mathematically focused areas. In addition, seminars at Perimeter Institute and in departmental seminar series and colloquia (such as C&O's Tutte Seminar) often feature talks on mathematical aspects of quantum information. It is therefore difficult to take this bit of hearsay evidence as a basis for further action.

4. We have been told that international students would very much appreciate increased help from the university regarding administrative procedures for obtaining visas.

Response

IQC naturally supports both its international student members and the request on their behalf for administrative help from the university concerning visas. As a specific action, IQC will add links to the IQC Graduate Studies webpage that connect students to University resources already supporting international students, e.g., the "International Student Services" page:

<https://uwaterloo.ca/discover-graduate-studies/international-students/international-student-services>

5. We have heard that in some departments TA assignments to graduate students especially for introductory courses require an excessive amount of time; however, in most departments this seemed not to be an issue.

Response

While TA assignments are a departmental responsibility, we feel it is important for our students in different departments to feel like equal citizens. Accordingly, IQC will seek to help graduate students feel that their TA assignments are out of alignment with their peers, by advocating to the departments on their behalf.

6. We heard that, for some departments, it can take substantial time to provide an offer letter to a graduate student after the prospective advisor has accepted the student. Such

a delay can be a problem in a competitive environment where one tries to hire the best students on the market. We recommend looking into this issue, as streamlining this process could provide a competitive advantage to the University of Waterloo.

Response

IQC agrees that graduate student offer letters should be sent to accepted graduate students as soon as possible, and makes every attempt to work with the departments and schools to do this in a timely manner. However, IQC does not handle graduate student admissions. IQC will, however, make sure that no IQC process slows down the generation of offer letters.

7. We were told that restrictions in some departments on the composition of the thesis committee put unnecessary constraints in bringing in members outside the department. In an interdisciplinary operation like IQC this seems to be an inappropriate limitation.

Response

This is a departmental/faculty issue which is difficult for IQC to address directly. However, it is clear that allowing more interdisciplinary committees would be of benefit to the IQC program and students. Where possible, IQC will advocate to the departments and faculties for this.

Implementation Plan:

Recommendations	Proposed Actions	Responsibility for Leading and Resourcing (if applicable) the Actions	Timeline for addressing Recommendations
1. Review transportation between RAC and QNC.	After hours shuttle service has already been implemented. Satisfaction will continue to be monitored.	Na Young Kim (IQC faculty member); Kevin Resch (IQC Executive Director)	Completed
2. Implementation of weekly journal club	No follow up required, there already is a weekly journal club (and the possibility to implement a second).	n/a	n/a
3. Increase the number of mathematically focused seminars	No follow up required, the number of mathematically focused seminars is deemed ample.	n/a	n/a
4. Offer help to international students in obtaining visas.	IQC will add links to the IQC Graduate Studies webpage that connect students to University resources already supporting international students, e.g., the " International Student Services " page.	n/a	n/a
5. Investigate time requirements for introductory course TA assignments	IQC will help graduate students who feel that their TA assignments are excessive.	Chris Wilson (IQC Graduate Director)	Ongoing
6. Investigate graduate student offer letter timeliness	IQC will assure that no IQC process slows the production of offer letters	Chris Wilson (IQC Graduate Director)	Ongoing

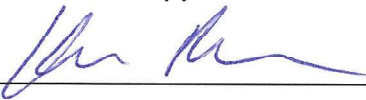
Recommendations	Proposed Actions	Responsibility for Leading and Resourcing (if applicable) the Actions	Timeline for addressing Recommendations
7. Investigate thesis committee membership compositions	Where possible, IQC will advocate for more liberal policies on interdisciplinary committees	Chris Wilson (IQC Graduate Director)	Ongoing
8. Take steps toward achieving gender equity [self-identified need].	Continue to prioritize hiring women faculty members and bringing in female researchers to give colloquia and seminars. Maintain gender balance in the recruiting events Quantum Innovators and USEQIP.	Kevin Resch (IQC Executive Director); IQC Colloquium Committee; IQC Equity and Inclusivity Committee; IQC Conference Committee; QCSYS, USEQIP and Quantum Innovators organizing committees	IQC is actively recruiting female faculty, with promising results. The “Quantum Innovators” workshop held each fall invites top postdocs to IQC for a three day conference. Many of our faculty hires first come to IQC to attend this workshop. Over the last few years, we have actively pursued gender equity goals in inviting and recruiting participants. In 2018, approximately 50% of the participants were female. This has been very effective in recruiting female faculty, with IQC hiring three new female faculty members in the last five years, all of whom participated in Quantum Innovators before applying to IQC.

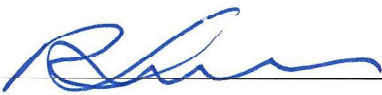
The Department Chair/Director, in consultation with the Dean of the Faculty shall be responsible for monitoring the Implementation Plan.





Date of next program review: 2022-2023
Date

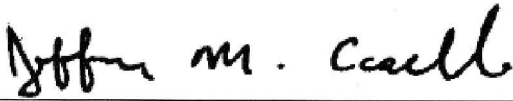
Signatures of Approval:


Chair/Director Date


Faculty Dean (Science) 22-7-19
Date


Faculty Dean (Math) 25-7-2019
Stephen M. Watt, Dean
Faculty of Mathematics Date


Faculty Dean (Engineering) 17 July 2019
Date

Associate Vice President, Academic
(For undergraduate and augmented programs) Date

May 7, 2019

Associate Vice-President, Graduate Studies and Postdoctoral Affairs
(For graduate and augmented programs) Date