Department of Chemistry, Memorial University of Newfoundland

Self-Study Report, Academic Program Review

December 2009

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1 INTRODUCTION

1.1 Background

The Department of Chemistry offers undergraduate major and minor programs as well as programs leading to an Honours degree or to Joint Honours in Chemistry/Biochemistry, Earth Sciences/Chemistry, Applied Mathematics/Chemistry or Physics/ Chemistry. Graduate programs leading to Master of Science (M.Sc.) and Doctor of Philosophy (Ph.D.) degrees in chemistry are also offered. The department has a faculty complement of 21 academic staff members (ASM) supported by 14 permanent instructional staff and 12 office and other support staff.

Enrollment in both the undergraduate and graduate programs has grown substantially over the past 10 years, while both faculty and staff numbers have declined. There has been a major faculty renewal during this period with 15 retirements/departures of tenured faculty and 8 new tenure track faculty joining the department. This has led to substantial increases in research activity, research funding and research equipment/infrastructure. As a consequence of these changes, the department is facing a severe shortage of research and office space. There are also increasing concerns regarding the quality of the laboratory space, which very clearly does not meet the standards currently expected for teaching and research in chemistry.

Faculty workloads have increased greatly due to the decrease in faculty numbers and increases in student numbers, particularly the increase in graduate student enrollment from 33 in 1999 to a current enrollment of 79.

This is the first academic program review of the department.

1.2 Departmental Objectives:

- To provide Memorial University (MUN) students with a rigorous, classroom and laboratory based background in chemistry appropriate to their chosen area of study

- To provide chemistry majors and honours students with a rigorous and comprehensive education and training in chemistry, meeting the requirements of accreditation by the Canadian Society for Chemistry (CSC)

- To maintain and expand world-class M.Sc. and Ph.D. programs

- To maintain and expand world-class research programs in fundamental areas of chemistry and strategic research programs of importance to the province and Canada

- To provide the university, province, and Canada with expertise in chemistry and chemical education

- To promote community awareness of the importance and benefits of chemistry

1.3 Supporting Memorial's Strategic Plan

A copy of the Memorial University of Newfoundland Strategic Plan is attached as Appendix 1. The University's commitment to "creativity, innovation and excellence in teaching and learning, research and scholarship" described in this plan is supported by the excellence of our undergraduate and graduate programs, and in particular by our focus on world-class research conducted by students in these programs. The University's "obligation to the people of Newfoundland and Labrador" is reflected in the large amount of teaching that the department provides in support of programs in the Faculty of Engineering, and in the Departments of Biology, Earth Sciences, and Biochemistry which are all central to the economic development of the province. The Department of Chemistry is also providing a growing number of high quality chemistry professionals to fill the expanding need in the province. Our programs welcome students from all over the world, and their research contributes knowledge and shares expertise locally, nationally, and internationally.

1.4 Preparation of the Self-study Document

Following consultation with the faculty, an *ad hoc* committee was struck to gather information for the self-study and prepare the self-study report. The members of the committee are:

Peter Pickup (Head of Chemistry; Chair)
Chris Flinn (Deputy Head (Undergraduate Programs))
Graham Bodwell (Deputy Head (Graduate Programs and Research)
Dave Thompson
Travis Fridgen

The committee initially solicited material to address the questions posed in the Self-Study Guidelines and drafted answers to these questions. A meeting open to all members of the department was held on 23 September, 2009 to explain the process, discuss key issues, and solicit input. The Academic Program Review (APR) was also an agenda item for five departmental (faculty only) meetings from 22 May, 2009 until the self-study was completed. A draft report was presented to the department on 25 Nov 2009. All relevant material submitted to the committee was included in or appended to this report. Tables of student enrolment and graduate data, and student/faculty ratios were provided by the Centre for Institutional Analysis and Planning (CIAP).

Following discussion at a departmental meeting on 4 Dec 2009, the draft report was revised by the Chair of the APR committee based on the consensus opinions expressed as the meeting and written submissions from faculty and staff.

2 UNDERGRADUATE PROGRAMS

2.1 Program Objectives

The chemistry program is intended to produce graduates who can proceed to post-graduate degrees in chemistry, to work in industry or government laboratories, or to other degree programs such as education, medicine, and other health-related fields. To this end, many of our chemistry majors gain valuable career-related experience while completing their degree. This includes the opportunity to work in the research laboratories of faculty members during the period from May to the end of August through funding programs such as the Natural Sciences and Engineering Research Council of Canada (NSERC) Undergraduate Student Research Awards (USRA), Canada Summer Jobs (CSJ) and Student Work and Services Program (SWASP), Memorial University Career Enhancement Program (MUCEP) and research grants. Also, students can gain teaching related experience by working as a laboratory demonstrator or as a MUCEP student in the Help Centre, the Chemistry Resource room, or the Chemistry Computer Room.

2.2 Program Descriptions

Full details are provided in Appendix 2, which includes calendar descriptions for the chemistry undergraduate programs and courses, as well as detailed descriptions of the undergraduate courses.

Degrees Offered

B.Sc. Major in Chemistry (CSC accredited)
B.Sc. Honours in Chemistry (CSC accredited)
The following CSC accredited joint programs are also offered: Chemistry/Biochemistry Joint Honours Degree, Earth Sciences/Chemistry Joint Honours Degree, Applied Mathematics/Chemistry Joint Honours Degree, Physics /Chemistry Joint Honours Degree.

B.Sc. Major in Chemistry

The major program offers a broad background in all branches of chemistry including courses in analytical, physical (both experimental and theoretical/computational), organic, and inorganic chemistry. Majors take 14 required chemistry courses, 5 math courses, 2 physics courses and a biochemistry course.

B.Sc. Honours in Chemistry

Honours students take 20 required chemistry courses (the honours project counts as 2 courses), 5 math courses, 2 physics courses and a biochemistry course. Honours students are required to do a research project over the fall and winter semesters of their final year under the supervision of a faculty member. Students are required to give a presentation of their research to the department and to submit a thesis at the end of the winter semester.

Minor in Chemistry

Students doing a minor take 8 required chemistry courses (2 at the 3rd year level). A minor in chemistry is useful for students intending to pursue an education degree following a B.Sc.

First Year Chemistry Courses

Chem 1050 and Chem 1051, General Chemistry I and II, are courses for students with a strong chemistry background from high school, covering topics in basic physical chemistry underlying all branches of chemistry.

Chem 1010 and Chem 1011, Introductory Chemistry I and II, cover topics in basic physical chemistry underlying all branches of chemistry but at a lower level than Chem 1050 and Chem 1051. These courses are for biology majors and a number of other programs not requiring an in-depth knowledge of basic physical chemistry.

Chemistry 1031 is a make-up course for students who take Chem 1010 and Chem 1011, or have completed Advanced Placement chemistry in high school, and plan to do degrees requiring an in-depth knowledge of basic physical chemistry.

Special Chemistry Courses Offered Beyond First Year

Chem 2440 is a terminal course in organic chemistry required by a number of degrees including biology and pharmacy.

Chemistry courses offered beyond first year taken by chemistry majors, minors, and honours students as well as those in joint honours programs involving chemistry.

Organic Chemistry courses

Chem 2400 Introductory Organic Chemistry I
Chem 2401 Introductory Organic Chemistry II
Chem 3410 Bio-organic Chemistry
Chem 3411 Synthetic Organic Chemistry I
Chem 4430 Synthetic Organic Chemistry II
Chem 4420 Physical Organic Chemistry

Physical Chemistry Courses

Chem 2300 Introductory Physical Chemistry
Chem 3300 Physical Chemistry I
Chem 3301 Physical Chemistry II
Chem 4300 Advanced Physical Chemistry I: Quantum Mechanics and Spectroscopy
Chem 4302 Statistical Thermodynamics

Analytical Chemistry Courses

Chem 3100 Analytical Chemistry I
Chem 4110 Analytical Chemistry II
Chem 4151 Analytical Separations and Organic Mass Spectrometry
Chem 4152 Electroanalytical Techniques

Inorganic Chemistry Courses

Chem 2210 Introductory Inorganic Chemistry
Chem 3211 Inorganic Chemistry

Chem 4201 Coordination Chemistry in Biological Molecules - Structural, Mechanistic and Magnetic Studies
Chem 4203 Organometallic Chemistry
Chem 4204 Inorganic Reaction Mechanisms and Catalysis
Chem 4205 Photochemistry of Transition Metal Complexes

Spectroscopy Course

Chem 3500 Spectroscopic Analysis: Spectroscopy and Structure.

2.3 Curriculum Overlap with Other Departments/Programs

Overlap With Physics

Physics 3400 (Thermodynamics), Physics 3410 (Statistical Mechanics), Physics 4850 (Quantum Mechanics) and Physics 4851 (Advanced Quantum Mechanics) have some overlap with our physical chemistry courses. The possibility of combining/sharing the above-noted courses has been seriously looked at in the past. However, upon close examination, the physical chemists realized that our courses are quite different from those in physics and that it is important to focus on applications relevant to chemistry. Furthermore, our fourth year courses have computational chemistry projects not relevant to physics.

Overlap With Engineering

ENGI 3901 (Thermodynamics I) and ENGI 4901 (Thermodynamics II) have some overlap with Chem 2300 and Chem 3300. However, the engineering courses apply thermodynamics to very specific problems in engineering such as turbines, refrigeration, air conditioning etc. which are not relevant to chemists.

2.4 Undergraduate Student Numbers (inc. Degrees Awarded)

The number of chemistry majors peaked at 95 in 2006 (Table 2.1). Our number of majors is similar to those reported in the CCUCC database by Dalhousie U. (83 in 2005; 96 in 2007), UPEI (74 in 2005; 92 in 2007), and U. Saskatchewan (54 in 2005; 90 in 2007).

Table 2.1 Number of Registered Majors and Minors, Fall 2004 – Fall 2008, Department of Chemistry					
	Fall 2004	**Fall 2005**	**Fall 2006**	**Fall 2007**	**Fall 2008**
Majors	71	71	95	92	81
Minors	58	56	48	44	36

The number of chemistry graduates has risen sharply in the last 2 years, from 12 in 2006 to 25 in 2008 (Table 2.2). Only a few students complete the joint chemistry programs with other departments, and this has not changed significantly over the last 5 years.

Table 2.2 Number of Graduates from Chemistry Undergraduate Programs

Degree	**Major**	**Year**				
		2004	**2005**	**2006**	**2007**	**2008**
Bachelor of Science (B.Sc.)	Chemistry	8	8	8	13	18
B.Sc. (Honours)	Chemistry	2	3	4	4	7
B.Sc. (Honours)	Chemistry/ Biochemistry	3	0	0	2	0
B.Sc. (Honours)	Chemistry/ Earth Sciences	0	0	0	0	0
B.Sc. (Honours)	Chemistry/ Applied Mathematics	0	1	0	0	1
B.Sc. (Honours)	Chemistry/ Mathematics	0	0	0	0	0
B.Sc. (Honours)	Chemistry/ Physics	1	0	0	1	1
Total		14	12	12	20	27

2.5 Student Demand and Enrolment in Undergraduate Chemistry Courses

Enrolments in undergraduate courses are summarized in Tables 2.3 and 2.4, and enrolments in individual courses are listed in Appendix 3.

Demand for chemistry courses at all levels grew significantly from 2003 to 2008 (Tables 2.3 and 2.4), although demand for 1000 level courses has dropped since 2005. The Department of Chemistry has the 2nd highest 1000 level enrollment in the Faculty of Science and ranks 5th of 8 for senior level courses. These numbers reflect the high level of training the department provides for other disciplines, particularly biochemistry, biology, and engineering. In addition to the 1000 level courses, programs in the Departments of Biochemistry and Biology provide a large demand for our 2000 level organic (Chem 2400 and 2401 for biochemistry; Chem 2440 for biology) and physical chemistry (Chem 2300 for biochemistry) courses, while the School of Pharmacy program also requires Chem 2440. Many biochemists also take Chem 3100 (Analytical) and as required course option.

Table 2.3 Faculty of Science Registrations Per Department for 1000 Level Courses From 2003 to 2008

Department	Year				
	2007-08	2006-07	2005-06	2004-05	2003-04
Faculty of Science	22881	27193	22961	22709	23011
Biochemistry	206	196	168	159	173
Biology	3146	3026	3118	3088	3324
Chemistry	4507	4595	4905	4525	4384
Computer Science	494	463	353	479	494
Earth Sciences	660	518	538	638	848
Mathematics and Statistics	5376	5094	5426	5427	5048
Physics	3966	3908	3886	3560	3626
Psychology	3606	3123	3608	3663	3834
Science Other	920	870	959	1170	1280

Table 2.4 Faculty of Science Registrations Per Department for Senior Undergraduate Courses From 2003 to 2008

Faculty/Department	Year				
	2007-08	2006-07	2005-06	2004-05	2003-04
Faculty of Science	21243	21569	22416	22752	22265
Biochemistry	2631	2489	2473	2454	2311
Biology	4250	4454	4530	4838	4656
Chemistry	1895	1962	1684	1476	1778
Computer Science	1499	1417	1527	1623	1762
Earth Sciences	1711	1435	1453	1585	1680
Mathematics and Statistics	4764	4482	4596	4578	4533
Physics	716	787	834	745	762
Psychology	3770	4541	5310	5445	4781
Science Other	7	2	9	8	2

Notes:

1. Registration includes lecture, laboratory, practical experience and other.

2.6 Feed-back from Undergraduate Students

The results of a survey of current students and students who have graduated within the last 5 years are attached as Appendix 4. These show broad satisfaction amongst students, although there is clearly room for improvement. The changes advocated in this self-study will address areas where student satisfaction can be improved and will address some of the specific items highlighted by students' comments (specific comments from students are not included in Appendix 4 for confidentiality reasons).

The results of the survey indicate that a majority of current students do not feel that they have been negatively affected by class sizes. Students who have graduated appear to have been more concerned about class size, particularly at the 1st and 2nd year levels. The fact that this is less of a concern for current students may reflect improvements in our tutorials, help center and resource room. The importance of these learning resources is indicated by the very positive responses to questions 17a and 17b and the opinion that Chem 1050 and 1051 should also have tutorials (Q19). The answers to questions 18a and 18b indicate heavy and efficient use of the help centre and resource room, and that expansion of these services would be beneficial.

Opinions on whether we have sufficient 4th level offerings are mixed, but this is clearly an area in which there could be a large improvement. Specific comments from a number of students also indicated a desire for more course diversity at lower levels that would allow some options for chemistry majors.

The survey indicates broad satisfaction with our lab manuals, but opinions on the lab content are less positive, particularly those expressed by students who have completed their programs and have seen or used facilities elsewhere. Clearly, renovating and re-equipping our teaching laboratories has the potential to significantly increase student satisfaction.

2.7 Meeting the Program Objectives

Graduating students have been successful in gaining admission to graduate programs in other universities, in finding work in industry, and in gaining admission to professional schools such as medicine. Several are chemistry teachers in this province and others. We have been successfully meeting our objectives so far but need some updating of our programs if we are to continue to do so.

The program is being effectively delivered within the largely aging physical plant of the university. The university has endeavoured to modernize as many classrooms as possible, helping out the situation significantly, but more classrooms with multimedia terminals are needed. Another problem is a lack of up-to-date laboratories for undergraduate students. Some safety issues are being addressed by the university, but there is also a need to update the equipment used, and develop new laboratory experiments that provide broader exposure to modern instrumental methods. A list of high priority teaching equipment needs is attached as Appendix 5. It is anticipated that most of this equipment will be acquired this year.

The chemistry department has comparable research-grade equipment to other major universities in Canada which is made available to students in some of our higher level courses to enhance their learning. This includes the high performance computing facilities of ACEnet. The department also has wireless internet in some areas, and a computer room for chemistry majors and honours students.

At present, the undergraduate programs need some improvements to better respond to students' needs. Such changes have already been agreed upon in principle by members of the department. The proposed new programs will be more flexible in order to better respond to students' needs and varied interests, especially for the honours program. Employers require strong laboratory skills and a comprehensive understanding of basic chemistry concepts which we have always provided. A revised program will offer additional skills in instrumental methods and computational methods that have become of central importance in the workplace.

2.8 Proposed Changes and New Initiatives

In line with the University's Strategic Plan, the department's programs are evolving and new teaching/learning initiatives are being pursued. These efforts are organized below based on the relevant strategic goals described in the Plan.

GOAL 1: Foster Student Success and Retention

Program changes aimed at modernization of our courses and laboratories will enhance the learning experience in chemistry courses. New courses and programs will provide more options to meet students' needs and interests. At the first year level, we have found that scheduled tutorial sessions with assignments are an essential aspect of student success and retention in Chemistry 1010 and 1011, and would therefore like to extend these to Chemistry 1050 and 1051. At the higher levels, involvement in research is an important component in success and retention, and this will be expanded if resources allow.

GOAL 2: The Teaching and Learning Environment

The Department of Chemistry has taken a proactive role in using various technologies in the classroom. These technologies include online assignments where students complete assignments using technology developed by publishers. Students in some of our classes use personal response systems which helps engagement in large lectures. Most recently, in conjunction with Distance Education and Learning Technologies (DELT), the Department of Chemistry is piloting lecture capture technology for the University. With this technology students will have the option of reviewing their lectures at a later time, online.

GOAL 3: Program Innovation and Development

Our undergraduate program is being updated to provide our students with the best, and most current education experience. Currently we are in the process of updating our physical chemistry and inorganic chemistry streams including providing students with a meaningful research experience and complete flexibility to choose their sub-discipline concentration. We are currently updating some laboratory exercises to include research-level instrumentation.

First Year Offerings

The department will consider streamlining our first year offerings by discontinuing Chemistry 1031, and making changes if necessary to 1010, 1011, 1050, and 1051. One possibility being considered is that students in the 1010 → 1011 → 1031 stream will instead be expected to follow a 1010 → 1050 → 1051 path if they wish to proceed to 2nd year chemistry courses (except Chemistry 2440). This will provide these students with a stronger background in 1st year chemistry and integrate them into the normal chemistry cohort at an earlier stage. Students who wish to take 2nd year chemistry courses after already completing Chemistry 1011 may take the 1010 → 1011 → 1051 path, but this will be discouraged and will require high marks in 1010 and 1011.

Physical Chemistry Courses

The undergraduate curriculum as it stands now is sufficiently rigorous in its expectations of student academic achievement. It has a little too much duplication of material covered, especially in physical chemistry courses which need reorganization and the addition of new material to make them more current and relevant to our students. The development of new physical chemistry courses is now complete and is waiting for approval by the Senate Undergraduate Studies Committee. Details of the proposed calendar changes, including descriptions of the proposed new courses are provided in Appendix 6. Other changes in the chemistry program will be implemented in the very near future to complete its renewal and to make it more flexible to respond to students' needs and varied interests.

Analytical Chemistry Courses

The department is planning to convert Chem 3100 (Analytical Chemistry I) to a 2nd year course and Chem 4110 (Analytical Chemistry II) to a third year course. This will provide students with earlier exposure to analytical chemistry, which is consistent with other chemistry programs in Canada, and will allow more opportunity for students to specialize in analytical chemistry.

New Laboratory Experiments

New laboratory experiments will be developed in order to increase a student's exposure to modern instrumental methods. This is already underway in our 2nd year physical chemistry course (2300) where computer based data collection is being implemented. New experiments have also been developed for inorganic chemistry (Chem 3211) and the laboratory will benefit from an injection of funds for equipment modernization and replacement.

New Courses

The department currently offers optional courses at the 4th year level, but these are unsuitable for many chemistry majors and minors, and for students in other programs who have interests in specific areas of chemistry. In order to more broadly promote awareness of the importance and benefits of chemistry, and to provide chemistry majors with more opportunities to develop their knowledge of specific areas of chemistry, the department would like to be able to offer a selection of new courses. These would generally be used as electives in both chemistry and other programs, but in some cases will be required courses in new programs that are being developed.

Proposals for the following new courses are provided in Appendix 7:

Chem 2500 Chemistry in Society

Chem 3212 Main Group and Materials Chemistry

Chem 3304 Computational Chemistry

New Programs

New programs that are more focused than our general chemistry programs will allow us to target the needs and interests of students. For example, a proposed undergraduate program in Computational Chemistry is described in Appendix 7. This program combines the fields of mathematics, computer science and chemistry, and will train students in an area of growing importance in the commercial, public and academic sectors.

GOAL 4: Increase Undergraduate and Graduate Enrollment

Further increases in undergraduate enrollment in chemistry can be achieved through a combination of modernization of programs and facilities and more effective recruiting. We have been very successful at graduate student recruiting, and can extend this to our undergraduate program.

3 GRADUATE PROGRAMS

3.1 Program Descriptions

The department offers M.Sc. and Ph.D. programs in all of the main areas of chemistry and also participates in interdisciplinary master's programs in environmental science and computational science. The M.Sc. and Ph.D. programs of study consist of courses and research work, and require the submission of a thesis describing the results of original research. Both M.Sc. and Ph.D. students are required to give departmental seminars, and Ph.D. candidates must also pass a comprehensive examination.

Details of these programs can be found in Appendix 8 and further information is included in Appendix 9 (Graduate Brochure). A list of graduate courses and course descriptions are provided in Appendix 8. Note that the Instrumental Analysis program described in the calendar is no longer offered due to lack of resources. The comprehensive examinations in physical, analytical and inorganic chemistry have been changed this year to include an oral component in addition to a written component. This not only allows for a much more "comprehensive" examination, but also provides students with practice in thinking on their feet. The new calendar entry is included in Appendix 8.

3.2 Graduate Student Numbers

Graduate student numbers have increased steadily over the past 5 years (Table 3.1). There are currently 79 students registered in chemistry M.Sc. (18) and Ph.D. (61) programs (Fall 2009), which is double the number in Fall 2004.

Table 3.1 Graduate Course Enrollment From Fall 2004 to Fall 2008

Course	Fall 2004	Fall 2005	Fall 2006	Fall 2007	Fall 2008
Chem 9000*	38	50	54	61	67

* All graduate students have to enroll in Chem 9000.

The number of students graduating from chemistry graduate programs went through a minimum in 2005 and has increased to 10 in 2009 (Table 3.2). The minimum was due to a large and rapid growth in the Ph.D. to M.Sc. student ratio, since Ph.D. students typically require 2 to 3 years longer to graduate. Since the increase in enrollment has been mainly in the Ph.D. program, its effect on graduation numbers is only just beginning.

Table 3.2 Number of Students Completing Graduate Programs in Chemistry

Degree	Year					
	2004	2005	2006	2007	2008	2009
Master Of Science (M.Sc.)	5	4	4	2	2	3
Doctor of Philosophy in Chemistry (Ph.D.)	0	0	3	6	6	7

3.3 Graduate Courses

The demand for chemistry graduate courses has risen sharply over the past 5 years, from 146 registrations in 2003-4 to 266 in 2007-08 (Table 3.3). This rise has been the greatest experienced by any department in the Faculty of Science, 82.2% over 4 years, and we now have the second highest number of graduate course registrations in the Faculty of Science.

Table 3.3 Faculty of Science Registrations Per Department for Graduate Courses From 2003 to 2008

Department	Year				
	2007-08	**2006-07**	**2005-06**	**2004-05**	**2003-04**
Faculty of Science	1963 (20.9)*	1691	1850	1709	1623
Biochemistry	92 (0.0)	95	85	88	92
Biology	332 (9.2)	299	298	330	304
Chemistry	266 (82.2)	197	204	175	146
Computer Science	134 (1.5)	133	178	141	132
Earth Sciences	195 (3.7)	169	247	220	188
Mathematics and Statistics	215 (29.5)	213	210	192	166
Physics	164 (31.2)	122	119	119	125
Psychology	246 (35.2)	162	204	190	182
Science Other	319 (10.8)	301	305	254	288

*% increase since 2003-04

3.4 Graduate Student Funding

Graduate students are funded from a combination of sources. These include the School of Graduate Studies (SGS), TA funding, and their supervisor's grant. SGS provides the department with baseline funding of $3,914 pa. per eligible M.Sc. student and $7,828 pa. per eligible Ph.D. student, with eligibility based on years in program (maxima of 2 and 4 years, respectively). Since not all students require and can be awarded SGS support, and additional funding has been made available through entrance awards, the SGS baseline funding currently provides $10,000 pa. per funded M.Sc. student and $12,000 pa. per funded Ph.D. student. We have achieved these high funding levels by growing our enrollments (i.e. using entrance awards), and having a relatively large number of students funded from external sources (NSERC; contracts; scholarships from other countries).

TA funding is typically $2,925 pa., although not all students are provided with a TA. Minimum levels of funding for qualified students (maintaining a 75% average and within the eligible time period) are $17,000 pa. (M.Sc.) and $19,000 pa. (Ph.D.).

3.5 Supervision of Graduate Students

Faculty members can only supervise graduate students if they are able to provide the financial support needed to meet the minimum requirements of the department and to provide the materials, equipment, and services needed for the student's research program. Faculty members who cannot provide sufficient funding can act as co-supervisors. Currently, our 79 registered graduate students are supervised by 15 faculty members, with one term (contractual) faculty member (Karen Hattenhauer), one cross-appointed faculty member (Kristin Poduska; Physics), and one adjunct professor (Joe Banoub; Department of Fisheries) acting as co-supervisors.

Each student is assigned a supervisory committee consisting of three faculty members (or other qualified scientists) including the supervisor(s). The committee meets with the student at least annually, and submits an annual progress report to the School of Graduate Studies. All members of the committee read the student's thesis prior to submission.

A number of faculty members in the department also supervise graduate students in engineering (Bottaro) and in interdisciplinary programs in environmental science (Bottaro, Helleur, Gogan) and computational science (Merschrod, Poirier), teach graduate courses in these programs (Helleur), and have served on Boards of Study (Merschrod, Poirier).

3.6 Post-graduation Activities

Since 2002, 31 people have graduated with a M.Sc. and 30 people have graduated with a Ph.D. Following the completion of a M.Sc., the majority of our 31 M.Sc. graduates (17, 55%) entered a program of doctoral study either at Memorial (6, 19%) or at another institution within Canada (8, 32%) or internationally (3, 10%). The remaining M.Sc. graduates accepted a chemistry-based position in the private sector (7, 23%) or a position at an academic institution (teaching: 1, 4%; research support: 2, 8%). One M.Sc. graduate (4%) could not be accounted for.

The current positions of 5 (20%) M.Sc. graduates could not be determined. What is known is that 10 (40%) M.Sc. graduates are still enrolled in doctoral programs, 1 (4%) is a post-doc, 1 (4%) is employed at a government research organization, 5 (20%) are employed in chemistry-based positions in the private sector, 2 (4%) are employed at an academic institution (teaching: 2, 6%; research support: 3, 10%) and 1 (3%) is a patent officer.

Following the completion of a Ph.D., the majority of our 30 Ph.D. graduates (21, 70%) accepted a post-doctoral position either at Memorial (3, 10%) or at another institution within Canada (10, 33%) or internationally (8, 27%). The remaining Ph.D. graduates accepted a position in the private sector (chemistry-based: 2, 7%; non-chemistry-based: 1, 3%) or a position at an academic institution (tenure stream: 4, 13%; non-tenure stream: 1, 3%; research support: 1, 3%).

At present, 14 (47%) Ph.D. graduates are still in post-doctoral positions, 4 (13%) are employed in the private sector (chemistry-based: 3, 10%; non-chemistry-based: 1, 3%), 11 (37%) are employed at an academic institution (tenure stream: 7, 23%; non-tenure stream: 3, 10%; research support: 1, 3%) and the occupation of 1 (3%) is unknown.

In summary, of the 61 people that left the Department of Chemistry with a graduate degree since 2002, 59 (97%) either moved on directly to higher studies in chemistry (39, 64%) or took a chemistry-based position (academia: 11, 18%; industry: 9, 15%). Only one graduate (2%) took a non-chemistry-based position (financial analyst). Only one graduate (2%) was unaccounted for. Currently, the occupations of 7 (11%) of our graduates are unknown. For the 54 people that have been accounted for, 52 (96%) of these people are either still receiving education in chemistry (26, 48%) or are gainfully employed in a chemistry-based position (academia: 16, 30%; industry: 9, 17%; government: 1, 2%). The data indicate that a graduate degree in chemistry from Memorial provides the graduate not only with the opportunity to move to high profile institutions within Canada and around the world for further study, but also with the basis for a rewarding career in their chosen field.

3.7 Feed-back from Graduate Students

The results of a survey of current graduate students and students who have graduated within the last 5 years are attached as Appendix 4. These show broad satisfaction amongst students, although there is room for improvement. Students are/were least satisfied with the research environment, the conditions of the infrastructure, and safety training. Clearly, maintaining and improving the quality of our graduate programs requires, at the least, substantial and ongoing investment in our research laboratories and in safety training.

4 RESEARCH AND SCHOLARLY ACTIVITY

Fifteen of our sixteen tenured/tenure-track faculty members currently hold NSERC Discovery Grants and supervise graduate students in their research programs. Our other faculty members, including those in term (contractual) positions are involved in collaborative research, and undertake a variety of research related tasks such as co-supervision of students, and service on supervisory and examination committees. Details of each faculty member's research and scholarly activity can be found in Appendix 10.

4.1 Research Funding

Total NSERC Discovery Grant funding (Figure 4.1) for the department has grown from \$515,336 pa. in 2005 to \$642,430 pa. in 2009, with the average grant growing from \$39,641 pa. to \$42,829 pa. Average chemistry grants for all universities increased from \$39,399 - \$46,370 (Analytical and Physical Chemistry) and \$46,792 - \$51,146 (Inorganic and Organic Chemistry) from 2005-2008 (http://www.nserc-crsng.gc.ca/_doc/Discovery-Decouverte/2009_Stats_e.pdf). The department is therefore close to the national average, although growth has been slightly lower due to the effects of faculty renewal.

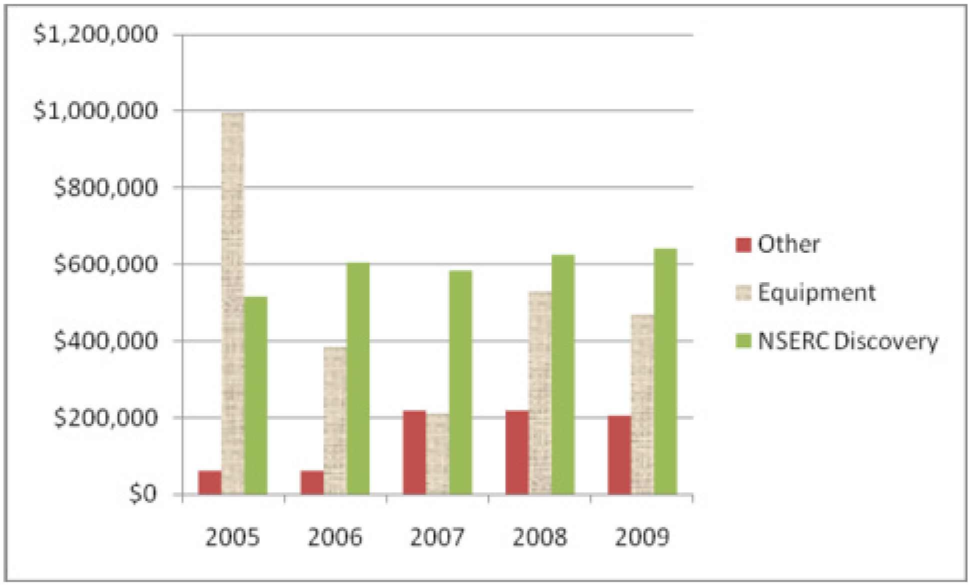

Figure 4.1. Research funding received by chemistry faculty from 2005 to 2009 (equipment funding does not include in-kind contributions from suppliers).

Funding from sources other than NSERC Discovery Grants has increased significantly (Figure 4.1) and now represents approximately 25% of the operating funding. In 2009, this funding component consists of NSERC Strategic Project Funding (\$96,336; Pickup), NSERC CRD Funding (\$17,875; Bottaro), CEE/ACOA/MUN funding for the Humber River Basin Project (\$46,450; Merschrod and Bottaro), an ACEnet/Sun Microsystems Research Fellowship (\$20,000; Merschrod), an ACEnet Postdoctoral Fellowship (\$10,000; Poirier), and MUCEP funding for Undergraduate Research Assistants (\$13,977). SWASP and Canada Summer Jobs funding is not included here.

The department has also been very successful in obtaining funding for new equipment, with an average of over \$500,000 pa. being obtained over the past 5 years (Figure 4.1). Most of this funding has been obtained by new faculty members from the Canada Foundation for Innovation

(CFI) with matching funding from the Province's Industrial Research and Innovation Fund (IRIF). In addition, $150,000 was obtained from NSERC (RTI) and $124,125 from IRIF for a 300 MHz NMR Spectrometer (Kozak and 7 others; 2009), while Poirier was part of a group of 28 researchers who received CFI funding ($20,357,842 in 2004 and $7,917,085 in 2005) for the Atlantic Computational Excellence Network (ACEnet).

Research funding is used mainly to support student research, which in turn supports our strategic goals of rigorous undergraduate programs and growth of our world-class M.Sc. and Ph.D. programs. Our students focus on research programs in fundamental areas. We are also securing an increasing number of grants and contracts in strategic areas, which allows us to increase the productivity and level of our research with Postdoctoral Fellows (currently 5) and Research Associates (currently 2).

4.2 Research Productivity

Since 2002, over 300 peer-reviewed publications (communications and articles) have come from the Department of Chemistry. This approximate total was obtained using a Web of Science search, in which the terms "Mem Univ Newfoundland", "Dept Chem" and "A1B 3X7" were used. Current faculty members account for the majority of this total (266). The remaining 34 publications are from former faculty members (26) (retired, moved), current and former post-docs, graduate students or staff (6), cross-appointed faculty (1) and summer students who spent time in other departments (1).

Using the data described above, the output of the Department of Chemistry has increased considerably in recent years. During the years 2002-2004, 26 papers were published each year. During the years 2005–2007, 41–43 papers were published. The total in 2008 was 57.

Considering the large turnover in faculty during the past decade, it is useful to look at the productivity of just the current tenured/tenure-track faculty members. These people have a combined total of 356 peer-reviewed publications since 2002. This total was obtained using a combination of Web of Science searches for individual faculty members and faculty-supplied information (CV or NSERC Form 100). The total includes all publications of current tenure-stream faculty members and not just those with the Department of Chemistry of Memorial University of Newfoundland as the faculty member's address. If active retirees (emeritus faculty and those with Honorary Research Professor appointments) are included, the total rises to 371. Contractual faculty members (Dawe, Flinn, Ghumman, Van Biesen, Warburton) have a total of 35 publications, but most of these papers are coauthored with current and former tenured faculty members.

4.3 Quality of the Research

To assess the quality and impact of the scholarly contributions coming from the Department of Chemistry, numerical indicators such as citations, journal impact factors and h indices were considered in addition to non-numerical indicators such as research awards and news/highlight articles.

A Web of Science search for citations of publications from the Department of Chemistry was conducted (search conditions: Mem Univ Newfoundland SAME Dept Chem SAME A1B 3X7) for the period "all years". The first record of citations of publications from the Department of Chemistry is in 1978. Since that time, the annual number of citations has risen steadily, reaching 49 in 1982, 345 in 1992, 801 in 2002, and 1,349 in 2008. In total, the 935 publications identified in the search were cited 15,560 times, for an average of 16.64 citations per publication. The h index for this data set is 55 (there are 55 publications with 55 or more citations).

If just the publications that appeared during the period 2002–2009 are considered, the 317 publications identified in the search were cited 2,488 times, for an average of 7.85 citations per publication. The h index for this data set as a whole is 23. The average number of publications per faculty member is 15.3 and the average h index per faculty member is 6.5. By comparison, faculty members in the Department of Chemistry at Dalhousie University produced 765 publications, which were cited 6,805 times. The average number of publications per faculty member is 30.6 and the average h index per faculty member is 6.9. In the Department of Chemistry at the University of New Brunswick, 204 publications were produced and these were cited 857 times. The average number of publications per faculty member is 14.6 and the average h index per faculty member is 3.0.

The 300 publications from the Department of Chemistry since 2002 appeared in 94 separate journals. Overall, the average impact factor of journals that were published in more than three times is 4.02. The two most popular journals (*Inorg. Chem.* and *J. Phys. Chem. B*) were published in 20 times each.

Several recent papers have been highly cited. These include papers by Pansare (*J. Am. Chem. Soc.* **2006**, *128*, 9624–9625, 75 citations), L. Thompson (*Coord. Chem. Rev.* **2002**, *233*, 193–206, 72 citations; *Inorg. Chem.* **2003**, *42*, 128–139, 55 citations; *Phys. Rev. Lett.* **2002**, *88*, 066401, 37 citations), Pickup (*J. Electrochem. Soc*. **2003**, *150*, C745–C752, 66 citations; *Electrochim Acta* **2004**, *49*, 4119–4126, 40 citations), Mezey (*J. Comp. Chem.* **2005**, *26*, 461–470, 38 citations), Bodwell (*J. Org. Chem.* **2003**, *68*, 2089–2098, 32 citations; *Angew. Chem. Int. Ed.* **2002**, *41*, 3261–3262, 31 citations; *Cryst. Growth. Des*. **2003**, *3*, 513–519, 30 citations) Fridgen (*Phys. Chem. Chem. Phys.* **2006**, *8*, 955–966, 31 citations) and D. Thompson (*Inorg. Chem.* **2003**, *41*, 1254–1262, 31 citations).

Several papers published by members of the Department of Chemistry have been the focus of scientific news and/or highlight-type articles. A paper by Bodwell (*Angew. Chem. Int. Ed.* **2009**, *48*, 5487–5491) was a chosen as a *VIP* (very important paper), was the subject of a *Highlights* article and was featured on the inside cover of the issue in which it appeared. A paper by Fridgen (*Phys. Chem. Chem. Phys.* **2006**, *8*, 955–966) was promoted by the journal as a *Hot Article*. A paper by Pansare (*Org. Biomol. Chem.* **2009**, *7*, 319–324) was listed as a *Top 10* paper and another paper by Pansare (*J. Am. Chem. Soc.* **2006**, *128*, 9624–9625) was listed as a *Hot Paper*. A paper by Kozak (*Dalton Trans.* **2008**, 2991-2998) was listed as a Top 10 paper. Papers by Bodwell were highlighted in *Chemical Shifts* in the Nov/Dec 2002 issue of *Canadian Chemical News (ACCN)* (*Angew. Chem. Int. Ed.* **2002**, *41*, 3261–3262), featured as an *Editor's Choice* by *Science* (*Science* **2003**, *299*, 981) (*J. Am. Chem. Soc.* **2003**, *125*, 1720–1721), and chosen as a *VIP* (*Angew. Chem. Int. Ed.* **2003**, *42*, 2547–2550).

Kerton was invited by the Royal Society of Chemistry to write a book on 'Alternative Solvents for Green Chemistry', which has been published (January 2009) and since reviewed in journals and trade magazines including *J. Am. Chem. Soc.* and *Chemistry and Industry*. Bodwell's commentary on a breakthrough paper in his area of research was used in a *Concentrates* piece in *Chem and Eng. News*. Bodwell has also been invited to write a *News and Views* article for *Nature Nanotechnology* (in preparation).

4.4 Awards and Other Recognition

Members of the Department of Chemistry have received several research awards since 2002. Bodwell was the recipient of the *Merck-Frosst Centre for Therapeutic Research Award* from the Canadian Society for Chemistry in 2005. In 2009, Mezey received a research award from the European Society of Computational Methods in Sciences and Engineering Award as well as the *ICCMSE 2009 Award* at the 2009 International Conference on Computational Methods in Sciences and Engineering. Mezey was also awarded the *IMI Distinguished Lecture Award* from the University of South Carolina in 2008. In 2007, Mezey was given the *Magan Professor Award* from Eotvos University of Budapest. Mezey also won the *Pro Universitate et Scientia Award* from the World Council of Hungarian University Professors in 2003 and the *Nobel Laureate Szent-Györgyi Award* from the Republic of Hungary in 2002. L. Thompson was the recipient of the *Alcan Award* from the Canadian Society for Chemistry in 2004. Zhao won the *PetroCanada Young Innovator Award* in 2007. L. Thompson (1995) and Pickup (2005) have been awarded University Research Professorships.

Mezey is also the recipient of one non-research award, namely the *Bolyai Award for the Support of Hungarian University Education in Transylvania*

4.5 Experiential Learning: The Connection Between Research and Teaching

There is considerable overlap of teaching and research because most of the research in the department is conducted by students. This is recognized formally as teaching credit (typically equivalent to one course per year) for the supervision of graduate and honours students. A number of faculty members incorporate research components into courses that they teach.

Experiential learning is fundamentally important to the sciences since it allows students to apply their classroom learning to practice. Although chemistry relies on significant laboratory components to most of its course curriculum, it is only when placed in the context of a true research environment that students gain in-depth problem solving skills and self-confidence. Research projects allow students to explore a problem in much more detail and with more independence than can be achieved in a teaching lab. This is clearly and increasingly a feature of the undergraduate program that students benefit from, and expect to be offered.

The undergraduate program is notable for the degree to which students participate in the research programs of the academic staff members. The growing graduate program in chemistry at Memorial provides undergraduates with a high degree of exposure to senior researchers on a daily basis and they often have graduate students or post-doctoral fellows as mentors. The combination of a strong Ph.D. granting graduate program as well as broad early-stage (1st year in some cases) undergraduate research training is not common among departments with comparable or larger graduate programs. Upon completion of their program, many Memorial chemistry undergraduates have completed two or more summer work terms in research laboratories, in addition to part-time work in labs during the regular teaching semesters as well as their Honours research project (Chemistry 490A/B). Memorial undergraduates who go on to graduate research programs here or elsewhere are often ahead of the learning curve regarding practical chemistry and confidence in a research environment.

Financial assistance for undergraduate researchers is obtained from a variety of sources. The NSERC Undergraduate Student Research Awards are the most prestigious and sought after by undergraduates. The Department routinely hosts between six and ten students funded by this program during the summer months. The eagerness for academic staff members to hire summer students means there are many diverse research projects for the students to choose from. Memorial University's Centre for Career Development has also been vital for providing undergraduate summer research student salaries through the various Career Development and Experiential Learning Programs. Some programs provide student salaries in the form of tuition vouchers such as the Student Work and Services Program where students are paid for 260 hours over 8 weeks. These financial assistance programs provide strong incentives to hire undergraduates and allow supervisors to match these funds using their research grants, giving summer research students 16 weeks of full time lab experience.

The research projects of undergraduates are demanding and of high calibre, often leading to the students becoming co-authors on journal publications. Furthermore, they are encouraged and supported financially from various sources to attend regional or national conferences (such as the APICS Chemcon, Ontario/Quebec and Atlantic Inorganic Discussion Weekends, Canadian Society for Chemistry Conferences) where they communicate their work through poster or oral contributions. This is of utmost importance for students pursuing graduate studies where NSERC doctoral level postgraduate scholarships (PGS-D) place a high significance on research potential, in addition to academic ability. As a result, Memorial graduates are exceptionally well prepared for careers in research.

4.6 Research Facilities

The department's laboratories were built in the mid-1960s. Some have been renovated including installation of additional fumehoods. However, in many cases there have been no upgrades. Appendix 11 provides a summary of the available laboratory space, excluding rooms for major instruments. The capacities of these rooms to accommodate researchers (mainly graduate students) have been estimated based on approximately 200 sq ft per person. This space generally includes a desk for the researcher, and if this is the case they will not likely have access to any office space. We have laboratory space for approximately 72 researchers.

In addition to approximately 37 desks in laboratories, the department has desk space in offices for approximately 48 researchers. These are generally for researchers in physical and analytical chemistry who use multi-user labs and instrument rooms for their research. It should be noted that not all of the desks in laboratories can be assigned to individual researchers for safety reasons or because they are communal desks for researchers using the laboratory.

Based on the space analysis presented in Appendix 11, the department can accommodate approximately 80 researchers. The current complement is 79 graduate students, 10 honours students, 7 PDF/RAs, and 3 visiting scientists. Some of the graduate students are completing their theses off campus, and some researchers are using temporary space in other departments. The space available for research by undergraduates is very limited, except in the spring/summer when space in undergraduate laboratories can be used.

4.7 Research Equipment

Major and communal research equipment in the department is managed by the University's Core Research Equipment and Instrument Training Network (CREAIT; www.mun.ca/creait/home/), which is a pan-university network designed to enhance access to and utilization of major research equipment. Major facilities used extensively by the department include:

Nuclear Magnetic Resonance. The Bruker AVANCE III 300 MHz and AVANCE 500 MHz are user (student) run, following training, while the Bruker AVANCE II 600 MHz is run by a research laboratory associate. (http://www.mun.ca/creait/c-cart/nmr.php)

X-Ray Crystallography. This research associate run facility is equipped with an AFC8-Saturn 70 single crystal diffractometer from Rigaku, with an X-stream 2000 low-temperature system and a new Rigaku SHINE optic, which replaced the conventional graphite monochromator and enables equivalent data collection in a fraction of the time. (http://www.mun.ca/creait/c-cart/x-ray.php)

Separation Science and Mass Spectrometry. Students have full access to gas (GC), liquid (LC), and ion chromatography, capillary electrophoresis, as well as the GC-MS, LC-MS, MALDI-TOF and tandem mass spectrometry facilities of the Centre for Chemical Analysis (www.mun.ca/creait/c-cart).

Magnetic Studies. A room temperature Faraday magnetometer and a Quantum Design MPMS5S DC/AC SQUID magnetometer (1.8-400 K), with continuous low temperature attachment, are available for use by graduate students.

Chemical Dynamics Laboratory for Fast Kinetics Research. The facility includes an Agilent 8425A diode array absorption spectrophotometer, a Photon Technology International (PTI) Quantamaster 6000 photon counting emission spectrofluorometer coupled with a PTI GL-3300 laser subsystem with subnanosecond time resolution, and an Applied Photophysics LKS 60 transient absorption spectrometer with a Big Sky Laser Brilliant B Nd:Yag laser (Coherent).

Laboratory for Green Chemistry and Catalysis Research. This facility consists of a world-class suite of instruments for Green Chemistry and Catalysis Research, including four inert-atmosphere workstations, solvent purification system, two microwave reactors, a supercritical fluid phase monitor, GC-MS, GPC (Gel Permeation Chromatography) and high pressure reactors.

Laboratory for the Study of Structures, Energetics and Reactions of Gas-Phase Ions. This world-class facility houses an Apex Qe70 Fourier transform ion cyclotron resonance mass spectrometer and a set of tunable infrared lasers (OPO).

Materials Characterization. Located in C-CART are user-run instruments suitable for materials characterization, including, a UV-Vis-NIR (Ultraviolet-Visible-Near-Infrared) instrument, an FT-IR (Fourier Transform Infrared) instrument, a differential scanning calorimeter, a thermogravimetric analyzer, and an atomic force microscope. (http://www.mun.ca/creait/c-cart/). Other facilities to which students have access through Memorial's Core Research Equipment and

Instrument Training Network (CREAIT) include a microanalysis facilty (http://www.mun.ca/creait/maf/) and Genomics and Proteomics (GaP) Facility (http://www.mun.ca/creait/GaP/).

Computational Facilities are provided through The Atlantic Computational Excellence Network (ACEnet; www.cvc.mun.ca/) and Memorial's Computing, Simulation and Landmark Visualization Facility www.mun.ca/creait/CSLV/.

4.8 Collaborative Research Programs and Relationships with Business, Government, Cultural or other Relevant Communities

Several members of the department have collaborations and relationships with governmental organizations. For example, Helleur: Dept. of Fisheries and Aquaculture, Health Canada; Bottaro and Banoub: Fisheries and Oceans Canada; Pickup: Defence Research and Development Canada. Faculty also have or have had industrial collaborations, including Bodwell with AnorMED; Merschrod with NewLab Life Sciences, Husky Energy, P&P Optica, Voda LLC, C-CORE, Canadian Space Agency and the Atlantic Cancer Research Institute; Kerton with Newfoundland Nutraceuticals, DuPont Canada, Chitinworks; Helleur with Quinlan Brothers; Fridgen with LaserSpec; Bottaro with Prosolia Inc., Vale Inco, Voda LLC and Husky Energy; Pickup with H Power Enterprises of Canada, Polyfuel Inc., Tekion Canada Inc. and 3M Canada.

Other projects that are funded by industrial partners include Merschrod: NewLab Life Sciences, ACEnet and MITACS; Helleur: Quinlan Bros, Atlantic Innovation Fund and ACOA; Poirier: ACEnet; Bottaro: Vale-Inco, Husky Oil (with ACOA and RDC (NL)). Some department members also participate in research that is intended to shape government policy, namely Merschrod and Bottaro who are involved in the Humber River Basin Project.

4.9 Technical Support

The university provides a comprehensive range of services including fully serviced electronics, glassblowing and machine shops in support of research through the Department of Technical Services located in the Chemistry-Physics Building. The Department of Physics operates a liquid helium and a liquid nitrogen plant to provide cryogens for research.

4.10 Areas of Research Strength and Strategic Planning

4.10.1 Preamble. Memorial University's strategic research plan includes *'Industrial Development and Environmental Sustainability'* and the department's research on the development of sustainable energy sources and in renewable resources is in line with that plan and with global concerns regarding climate change and environmental remediation. For some aspects of research in this field, collaborations with other disciplines are essential and links with investigators in the Faculty of Engineering and Applied Science, the Ocean Sciences Centre and the Faculty of Medicine exist and are being developed.

The Department of Chemistry will develop a research plan over the coming year as part of the development of the Memorial University Research Plan, which was launched in Nov 2009. The Memorial University Research Plan will inform the consideration "of matters such as budget proposals and allocations, recruitment and retention of faculty members and support staff, infrastructure and capital needs, strategic initiative proposals to government, and growth of graduate programs." We anticipate that the research plan will explicitly assign resources to the thematic research areas outlined in Memorial University's Strategic Research plan. This includes defined needs such as health, the oceans, energy and renewable resources.

4.10.2 Current Areas of Research Strength. The Department of Chemistry is internationally recognized for strength in areas such as synthetic chemistry (Bodwell, Georghiou, Pansare, Zhao, Kozak, Kerton, L. Thompson), materials chemistry (Mershrod, Pickup, D. Thompson, L. Thompson, Zhao) marine/environmental chemistry (Helleur, Parrish, Bottaro, Banoub), and computational chemistry (Poirier, Mezey, Fridgen, Keefe). The department has two University Research Professors, Prof. L.K. Thompson, and Prof. P. Pickup and one endowed Canada Research Chair in Scientific Modelling and Simulation, Prof. P. Mezey

4.10.3 Strategic Research Areas. The Department of Chemistry is well-positioned to make significant contributions in the following research areas that are critical to the province and ultimately to Canada.

New Synthetic Methodologies and Sustainable Chemical Processes. Newfoundland and Labrador is a resource rich province whose economic health has relied on harvesting these resources for export. Technological sustainability requires the transition away from a resource based economy to creation of a knowledge based economy. Research in the Department of Chemistry provides new knowledge and methodologies that have the potential for technological innovation that will minimize environmental impact. Such technologies utilize the conceptual framework provided by "green chemistry". Leadership in low environmental impact chemistry is being provided by Kerton and Kozak who have already made substantial contributions in the development of new methodologies in metal-mediated catalysis in this area.

Our organic chemists form what is certainly the strongest center for synthetic organic chemistry in Atlantic Canada. Their research focuses on areas of importance to medicine, such as asymmetric catalysis (Pansare) and natural product synthesis (Bodwell, Georghiou, Pansare), on the synthesis of biologically active materials relevant to pharmaceutical companies (Bodwell, Pansare, and Georghiou), and on organic molecules and materials with technological applications (Zhao and Bodwell). The complexity of the synthetic targets rivals that of any research group in Canada. A significant number of high-calibre M.Sc. and Ph.D. graduates in organic synthesis have continued to make substantial contributions to synthetic methodologies as post-doctoral appointments in Canadian universities, *Carnegie Research Universities* in the United States and in laboratories of Nobel Laureates. Many of these scientists have expressed interest in returning to this province if it could become an attractive place to set up specialty spin-off companies providing employment for HQP.

Renewable Energy Resources. There is a critical need to refine and optimize current renewable energy technologies such as fuel cells (Pickup) and to develop new alternative energy resources based on conversion of solar energy to high-energy chemicals/fuels (D. Thompson, Bodwell, and Zhao), and on the use of biomass (Helleur, Kerton).

A research initiative towards artificial photosynthetic devices is currently under development in the department. The investment of oil revenues into alternative energy programs will place the province as a leader in energy sustainability. At present, an international collaboration with the Energy Frontiers Research center at The University of North Carolina is being planned to develop the fundamental science of solar energy conversion. This could ultimately place Memorial as the leading Canadian research center in solar energy research.

Materials Chemistry. Materials chemistry is intimately linked with emerging technologies. The Department of Chemistry has extensive research programs in the chemistry of materials. L. Thompson has a world class research program in inorganic nano-materials directly applicable to molecular magnets, switches and molecular electronics as well as storage media. Materials chemistry research relevant to health sciences, such as the development of a fundamental understanding of the molecular architecture of hierarchical substances such as bone and cartilage (Merschrod and Poduska) and designing nanoscale “lab on a chip” devices for use as molecular sensors for environmental sensing applications (Merschrod, Bottaro) are actively being investigated. New nanoscale materials for improved fuel cells performance (Pickup) are being developed, and nanoscale mesoporous metal oxide assemblies are being used as a basis for artificial photosynthetic devices and light induced C-H activation and catalysis (D. Thompson). Our efforts in materials chemistry have already led to Strategic Grants (NSERC) and to liaisons with companies in the province and elsewhere in Canada. Thus, materials chemistry in our Department is already involved with economic development. Further details are provided in Appendix 12.

Environmental Sustainability. Global concerns regarding climate change, sustainable sources of energy and pollution are ever increasing – expertise in this area will continue to be needed and the field will continue to be one of the most rapidly growing areas of modern chemistry. As such analytical method development with reduced environmental impact (Bottaro, Merschrod) and environmental monitoring (Bottaro) and the development of biomass applications (Helleur, Kerton, Kozak) are sustainable research programs already in progress. Further details are provided in Appendix 12.

Computational Chemistry. Modelling, Simulations and Cheminformatics, which cover all aspects of theoretical and computational chemistry, are a growing area of chemical research. Industry relies on modeling for enhanced throughput and pre-screening of experimental work. This reliance continues to grow as computational power increases, allowing for modelling of ever more complex systems. The Department of Chemistry is perfectly positioned to increase its involvement in this growing field. Further details are provided in Appendix 12.

Fundamental Investigations. Research addressing a broad range of fundamental issues is critical to maintaining the ongoing health and intellectual quality of the department. This is highlighted by studies of the structures and fundamental interactions of gaseous ion-molecule complexes, the structures and energetics of self-assembled ion complexes in the gas phase (Fridgen), and the synthesis of highly strained molecules such as non-planar aromatic compounds (Bodwell), which are challenging standard paradigms in science.

5 PROFESSIONAL AND COMMUNITY SERVICE

Most faculty members in the Department of Chemistry are active with relevant professional organizations institutionally, locally, regionally, nationally and internationally. This includes membership and active involvement in organizations that aim to promote chemistry, such as organizing committees of conferences, grant selection committees, science fairs and professional societies.

Within Memorial University, members of the department have founded and/or organized various meetings, colloquia and symposia. For example, Bodwell founded in 2004 and continues to organize the annual Summer Organic Chemistry Conference on Everybody's Research (SOCCER). He is also the founder and organizer of the annual Chemistry Colloquium Contest (1993 to present), which is a public speaking competition for undergraduate and graduate students. Kerton organized the inaugural Summer Student Symposium in the Departments of Chemistry and Physics in 2007. Kozak expanded this Symposium to include all Departments/Divisions within the Faculty of Science in 2008 and 2009. Within the province of Newfoundland and Labrador, members of the department are involved in the Local Section of the Chemical Institute of Canada, with many members of the faculty holding positions on the executive (Kozak, Kerton, Poirier, Bottaro, Helleur). Members of the department are involved in organizations and initiatives such as Institutional Sustainability Initiatives (including the Dialogue on Advancing Global Sustainability). Helleur is an active member of the

Newfoundland Environmental Industries Association. He was also a member of the NL Biotech Advisory Committee/GENESIS Group from 2002 – 2005.

Regionally, Pickup has served on the Materials Technology Network for Atlantic Canada (MatNet) Steering Committee. Flinn has represented MUN Chemistry at the Atlantic Provinces Council on the Sciences (APICS) and has been Chair of the APICS Chemistry Committee for two years. Merschrod has acted as chair of the steering committee for the ACEnet Institute for Materials Modeling and Simulation (2007-09). Poirier is a co-chair of the ACEnet Institute for Computational Chemistry (2008-present). Bodwell has acted as CIC Atlantic Local Section Tour Coordinator (2006-08).

Nationally, most faculty are active members of the Chemical Institute of Canada and the Canadian Society for Chemistry. Many members are also active in discipline-specific organizations. For example, Kozak and Kerton are active members/participants in the Inorganic Chemistry Exchange Program and the Atlantic Inorganic Discussion Weekends, and Fridgen is an active member of the Student Internship in Mass Spectrometry. Kozak and Kerton are also members of the Canadian Green Chemistry Network. Kerton is also on the Board of Directors for GreenCentre Canada. Poirier was Chair of the Canadian Society for Theoretical Chemistry in 2007 and is a member of the executive. Pickup and Bodwell have sat on the NSERC Value Added Products and Processes Strategic Projects Panel. Pickup has served on the Advisory Committee for the Quebec Network on Fuel Cells and Hydrogen Research, the NSERC Selection Committee for the Special Opportunities Program, Inter-American Collaboration in Materials Research and the NSERC site visit committee for an Industrial Research Chair. Kerton was chair (2009) and a member of the NSERC Scholarships and Fellowships Committee for Chemistry.

Many faculty members have been on the organizing committees for conferences and symposia on the national and international level. For example, members have organized symposia at Canadian Society for Chemistry Conferences (Bodwell, L. Thompson), Pacifichem 2005 (Bodwell, L. Thompson), the Trent Conference on Mass Spectrometry (Fridgen), the 2007 Atlantic Theoretical Chemistry Symposium (Fridgen), the 16th Canadian Symposium on Theoretical Chemistry (Poirier), the Chemical Biophysics Symposium (Merschrod), International Conference on Molecular Magnetism (L. Thompson), the 22nd International Congress on Heterocyclic Chemistry (Bodwell, Pansare, Georghiou, Zhao), the 11th International Symposium on Novel Aromatic Compounds (Bodwell, Conference Chair).

On the international stage, members of the department are members of professional societies such as the American Chemical Society, the German Chemical Society and the Royal Society of Chemistry (UK), the International Society for Heterocyclic Chemistry, the Biophysical Society, International Green Chemistry Networks, the International Society of Analytical and Applied Pyrolysis, International Chitin Society, the American Crystallographic Society, the American

Society for Mass Spectrometery, the Canadian Society for Mass Spectrometry and the International Society for Electrochemistry. Members have sat on editorial or advisory boards for journals such as the Journal of Solid State Electrochemistry (Pickup), Polyhedron (L. Thompson), Pure and Applied Chemistry (Bodwell) and the Canadian Journal of Chemistry (Bodwell). In addition, almost all faculty members have acted frequently as referees for a variety of international journals and funding bodies such as NSERC, the NSF (USA), the PRF (USA) the EPSRC (UK), the Research Corporation (USA), CFI and others.

Members of the department also participate in a wide range of outreach activities that serve the local and provincial community. Many faculty members regularly volunteer their time at local daycares, elementary schools and high schools to promote science in general and chemistry in particular. This includes "Chemistry Magic Shows", advising/judging at Science Fairs (Bodwell, Bottaro, Flinn, Helleur, Kerton, Kozak, Fridgen, Merschrod, Dawe), the WISE Summer Student Experience Program (SSEP) (Merschrod, Kerton, Kozak, Bottaro, Flinn), chemistry demonstrations as part of the Faculty of Medicine's "MedQuest" Program (Bottaro, Merschrod, Kerton, Kozak, Zhao, Dawe, Fridgen, Pansare, Helleur), the Sanofi-Aventis BioTalent Challenge (Kerton, Bottaro, Merschrod), the Shad Valley program (Merschrod), Discovery Day in the Health Sciences (Merschrod), and Let's Talk Science, (Kerton). In addition, faculty members participate in selecting excellent undergraduates for the London International Youth Science Forum award. The LIYSF award selects up to three students of exceptional caliber, who are funded to attend a forum of talented young scientists in London, UK. Christopher Flinn is an honorary vice president (associate) of the LISF for his long term service as the LIYSF coordinator. The department (Mary Flinn) administers the annual Chemical Institute of Canada (CIC) Canadian Chemistry Contest in the province.

6 DEPARTMENT ORGANISATION AND HUMAN RESOURCES

6.1 Administrative Organisation

The department is administered by the Head of the Department, currently Dr. Peter Pickup, an Administrative Staff Specialist III (Gina Jackson) and two Deputy Heads, currently Dr. Christopher Flinn (Undergraduate Studies) and Dr. Graham Bodwell (Graduate Studies and Research), with the assistance of the Head's Secretary (Rosalind Collins) and Secretaries to the Deputy Heads (Mary Flinn and Viola Martin, respectively). The division of their duties is outlined in Appendices 13 (Faculty Information) and 14 (Staff Information).

6.2 Faculty Complement and Information

The Chemistry Department currently consists of nineteen full-time tenured (13), tenure-track (3) and term (3) faculty members. In addition, Dr. Azra Ghumman is currently working at 75% of a full load (term appointment) and Dr. Louise Dawe has a part-time (50%) teaching term appointment with the department and a part-time (50%) appointment with CREAIT as a research assistant. The department has two Professor Emeriti, Dr. Hugh Anderson and Dr. Niall Gogan, one Honorary Research Professor, Dr. Robert Lucas, a cross-appointed faculty member (Dr. Kristin Poduska (Physics), and four Adjunct Professors (Dr. Joseph Banoub (Department of Fisheries), Mr. David Miller (CREAIT), Dr. Celine Schneider (CREAIT) and Dr. Dale Keefe (Cape Breton University).

From a teaching perspective, our full-time faculty can be categorized as follows:

	1st year	**Analytical**	**Inorganic**	**Organic**	**Physical**
Graham Bodwell				✓	
Christina Bottaro		✓			
Robert Davis	✓				✓
Christopher Flinn	✓				✓
Travis Fridgen	✓				✓
Paris Georghiou				✓	
Karen Hattenhauer	✓			✓	
Robert Helleur	✓	✓			
Francesca Kerton			✓		
Christopher Kozak	✓		✓		
Erika Merschrod	✓		✓		
Paul Mezey	✓				✓
Sunil V. Pansare				✓	
Peter Pickup	✓	✓			
Raymond Poirier					✓
David Thompson	✓		✓		
Laurence Thompson	✓		✓		
Peter Warburton	✓				✓
Yuming Zhao				✓	

6.3 Faculty Workloads

All faculty members in the department are involved in teaching, research, and service. The balance varies significantly between the most active researchers and faculty members with term appointments. In general, our teaching and research commitments, together with service outside the department, leave insufficient time for many service roles within the department. Important areas such as the department web materials, services for students, training and program/curriculum development are very difficult to develop and maintain.

As can be seen from the data in Table 6.1, student/faculty ratios in the department have been increasing much faster than for the Faculty of Science as a whole.

Table 6.1 Full-Time Equivalent Student/Regular Full-Time Faculty (2003 to 2008)

Department	**Year**				
	2007-08	**2006-07**	**2005-06**	**2004-05**	**2003-04**
Faculty of Science	15.6	15.9	14.4	14.1	13.4
Biochemistry	14.3	15.4	15.8	15.1	14.5
Biology	16.3	14.6	16.2	12.5	11.6
Chemistry	9.2	8.3	7.5	6.9	5.9
Computer Science	4.4	4.2	5.9	8.0	8.6
Earth Sciences	11.9	6.9	6.1	5.9	6.1
Mathematics and Statistics	6.8	7.2	6.8	8.1	7.4
Physics	3.8	4.4	5.1	4.7	3.8
Psychology	12.8	13.3	12.1	11.7	10.9

To better understand the workload of faculty members, the Department of Chemistry at Memorial can be compared with the analogous department at Dalhousie University which has similar chemistry enrollments. Table 6.2 is based on information found on Dalhousie's Department of Chemistry website (Dec 2009) and correspondence with Giselle Andrews, Department of Chemistry, Dalhousie University. Based on this information, MUN's Department of Chemistry is significantly understaffed relative to Dalhousie's Department of Chemistry, while student enrollments are currently higher.

Table 6.2. Comparison of the Departments of Chemistry at Memorial and Dalhousie Universities.

Category	Memorial	Dalhousie
Full Time Faculty	19	26
Part Time Faculty	2	0
Professor Emeritus	2	4
Adjunct Professors	4	13
Instructors or Per Course Appointments Per Year	3	7
Visiting Scientists/PDF/RA Per Year	16	20
Graduate Students	80	70+
Undergraduate Courses Offered Per Year	43	45
Undergraduate Majors and Honours	81	60-70

6.4 Faculty Hiring Plan

The number of tenured/tenure-track faculty in the department has decreased from 23 in 1999 to the current complement of 16 including a CRC Chair. In the same period, graduate student enrollment has increased from 33 to 79. Teaching loads have increased, and are now slightly higher on average than specified by the MUNFA Collective Agreement. An increasing number of term and per course appointments have been required to offer required courses and course offerings have been decreased to minimal levels. Additional tenure track appointments will be necessary if the department is to:

- Rejuvenate undergraduate programs and provide more offerings in strategic areas
- Develop strategic research areas and research collaborations/partnerships
- Further increase graduate student enrolment
- Properly address safety in the department

Determining the appropriate complement of tenured/tenure-track faculty is not just a question of providing the minimal level of teaching and service needed to run the department and offer our programs. Consideration must also be given to providing faculty with time for the multitude of other tasks needed for the department to meet its objectives and fully support Memorial's Strategic Plan.

The general areas of analytical/physical chemistry and organic computational chemistry have been identified as the highest priorities for new tenure-track hires. These positions will target the health/environmental strategic areas which both the department and university have identified as high priority areas. Suitable space can be made available in the department for research in these areas, which will need limited or no access to fume hoods.

In subsequent years, the department will need to hire new tenure track synthetic chemists in the materials/sustainable processes strategic areas. This will require laboratory facilities that are not currently available in the department. These positions will therefore be retirement replacements, or associated with new initiatives using space outside the department.

6.5 Support Staff Information

The Department of Chemistry support staff currently consists of four administrative, management and support positions; three supply personnel that manage and operate the Faculty of Science Physical Sciences Stores, including one position that is equally shared for budgeting purposes between the Departments of Chemistry and Physics; five Science Technicians, including one position that assists in the Physical Sciences Stores unit from May to August; ten full-time Laboratory Instructors (LI) and Instructional Assistants (IA), including one position that provides full time computer and network support; four sessional LIs and IAs that are employed from September to April inclusive; and four to five contractual IA positions that are hired on an as needed basis for four or eight month contracts depending on course offerings and enrollment.

Details and gender and age profiles are provided in Appendix 14.

The LIs and IAs run all of the undergraduate labs and are responsible for revising lab manuals in consultation with the faculty member(s) responsible for each course. They also run tutorials for Chem 1010 and 1011, and operate the Help Centre for these courses and the Resource Room for higher level courses. They are assisted in the teaching labs by undergraduate and graduate Teaching Assistants (TA). Typically, a first year lab with approximately 40 students is run by an IA, an undergraduate TA, and a graduate TA, while more use is made of graduate student TAs in higher level courses.

7 DEPARTMENTAL EXPENDITURES

A copy of the department's budget is attached as Appendix 15. The department's operating budget, as approved for 2009/10 is $3,701,591. The majority (92.6%) of this amount, $3,425,841, is used for faculty, staff and student assistant salaries. Because of union contracts, there is little flexibility in salary costs. Any decrease in employee or student assistant numbers would result in a direct loss of services to students.

Almost all of the remainder of the budget ($250,000 or 6.8%) is used for materials and supplies, mainly for the undergraduate labs. Additional minor amounts are available for equipment repair and maintenance ($20,000), and travel (mainly for students) and hosting (mainly visiting speakers) ($20,000). There is very little funding for building repairs and maintenance ($3,000) and none for important items such as new and replacement laboratory equipment, research, laboratory upgrades and furniture replacement.

Cost per registration is well below the average for the Faculty of Science and has not changed significantly since 2003. This is remarkable in light of the expensive lab component of most of our courses, and the use of four or five lectures + tutorials per week for our first year courses.

Table 7.1 Cost per Registration by Department From 2003 to 2008

Faculty/Department	Year				
	2007-08	2006-07	2005-06	2004-05	2003-04
Faculty of Science	$651.77	$655.02	$615.81	$604.65	$607.34
Biochemistry	$855.53	$873.53	$860.49	$816.49	$829.64
Biology	$498.65	$486.05	$499.67	$493.76	$512.10
Chemistry	$524.76	$521.46	$493.08	$525.47	$539.89
Computer Science	$1,378.90	$1,341.83	$1,233.65	$1,055.88	$999.94
Earth Sciences	$1,151.04	$1,429.70	$1,284.32	$1,138.31	$998.76
Mathematics and Statistics	$349.11	$381.74	$368.74	$349.01	$388.09
Physics	$523.02	$505.66	$505.21	$481.39	$487.91
Psychology	$471.75	$448.27	$408.07	$388.84	$398.77

1. Registration includes lecture, laboratory, practical experience and other
2. Cost per Registration = Total Expenditures/Total Registrations

8 ADMINISTRATIVE SUPPORT/EFFICIENCY

This section is written to specifically address the questions posed in the guidelines for the self study.

8.1 Is the unit/program receiving appropriate direct resources and support from the University?

The department is able to offer its programs in a very cost effective way, but the quality of these programs is compromised by constant erosion of resources. There are many issues here, but the most serious concern is the quality of our laboratory rooms and the equipment therein. These laboratories are, in most cases, little changed from when they were built in the mid-1960s. The delivery of chemistry programs in other universities world-wide has progressed massively since then, and we are being left further and further behind. Most of our students receive no idea of what a modern chemistry laboratory is like, and receive limited training using modern instrumental techniques. Our laboratory programs are outdated because we have not had the resources to purchase equipment for new experiments. In addition to support for renovation and re-equipping of laboratories, the department also needs personnel (faculty and staff) to undertake the development and delivery of new laboratory programs.

The situation with respect to most of our research laboratories parallels that of our undergraduate laboratories. We have been very successful at growing our graduate programs and attracting high quality senior researchers (PDFs, Research Associates, Visiting Scientists) in recent years, but only have correspondingly high quality research space for a fraction of them. Further growth in graduate programs is limited both by the quality of our laboratory space and by the shortage of office space. As with the teaching laboratories, there is therefore an urgent need to begin a systematic renovation of our research laboratories and to remove researchers' desks from them to more appropriate locations.

8.2 How adequate and effective are infrastructural resources and support (e.g., library, promotion and recruitment, media, space) for achieving program goals?

Library and research support services (CREAIT Network, ACEnet, technical services) are excellent. Appendix 16 is a report from the library on the current book holdings, journals and periodicals for chemistry.

Classroom quality, availability, and support (computer based projection; repairs) are poor. Space is inadequate in quantity and quality. There is insufficient support for the development of web-based services. Often it is difficult to find rooms for tutorials, group meetings and informal teaching initiatives. When rooms are available, they are often poorly suited for the purpose in terms of size, seating arrangement, and projection equipment.

8.3 How effectively do the unit and its programs promote new initiatives, plans, collegial spirit, and active community involvement?

All members of the department work together effectively to deliver its programs very cost effectively, and to provide services to students. We are involved in many activities that promote the department's programs and promote community awareness of the importance and benefits of chemistry. We also provide the university, province, and Canada with expertise in chemistry and chemical education. Although there is a need for new initiatives in the department, they are limited by workloads and the available physical infrastructure and support.

8.4 How well are administrative and professional support staff contributing to the academic and strategic goals of the unit/program?

The administrative and professional support staff members of the Department of Chemistry are very specialized in their duties, contributing to very effective and efficient support for its programs and strategic goals. These specializations allow the staff to be very knowledgeable in their field of expertise, and thus, able to provide students and faculty members with needed information in short turnaround time. This allows the department's faculty members to focus on their research and academics, rather than other administrative issues.

9 CONCLUSIONS

This self-study describes a department that has been increasing its performance and impact in all areas while dealing with declining resources and a deteriorating physical plant. Enrollments in undergraduate programs have increased significantly and the number of graduate students has doubled in 5 years, with a large increase in the Ph.D./M.Sc. ratio. Research funding and productivity have grown significantly, and the department has significantly increased research activity in strategic areas that complement and expand our established areas of expertise.

The continued development of the department and its contribution to Memorial's Strategic Plan requires a substantial investment in both laboratory space and personnel. The department will develop specific plans to address the following Goals and Targets specified in the Strategic Plan.

<u>GOAL 1: Foster Student Success and Retention</u>

The department will focus on modernizing programs, introducing more course and program options, and providing more opportunities for undergraduates to be involved in research.

GOAL 2: The Teaching and Learning Environment

The department will increase the use of new classroom and learning technologies including the use of online tutorials and assignments, personal response systems, and lecture capture technology.

GOAL 3: Program Innovation and Development

Our programs will be modernized and new courses and programs will be introduced to target students' needs and interests.

GOAL 4: Increase Undergraduate and Graduate Enrollment

Recruiting materials and efforts will focus on promotion of program innovations and research opportunities in the department.

GOAL 5: Serve Off-Campus Students

The need for laboratory based learning in chemistry limits the services that the department could provide to off-campus students, although selected courses could be offered via web-based delivery.

GOAL 6: Enhance Student Recruitment and Financial Support

The department actively recruits graduate students and obtains financial support for them from diverse sources. It will support the university's initiatives to enhance student recruitment at the academic unit level.

GOAL 7: Student Support

The department provides academic advising services to its students, annual information sessions on undergraduate research and graduate studies, and organizes the Faculty of Science Summer Student Symposium. Additional services including enhanced career advising services will be developed.

GOAL 8: Focus on High Need (Research) Areas

The department will develop strategic research initiatives in the areas of energy, renewable resources, and environmental sustainability. In addition, we will look for opportunities to apply our key areas of expertise (synthetic chemistry, materials chemistry, computational chemistry and modeling) in high need areas such as health (drug design and synthesis; protein chemistry) and the oceans (environmental monitoring).

GOAL 9: Research Collaborations and Partnerships

The increase in the department's research funding outside the NSERC Discovery program is due to our increasing involvement in research collaborations of strategic importance. These include sustainable energy, environmental monitoring and applications of computational chemistry. The research initiatives targeted under GOAL 8 will involve cross-disciplinary groups and local, national and international collaboration.

GOAL 11: External Funding

Fifteen of the sixteen tenured or tenure-track faculty members in the department hold NSERC Discovery Grants, and eight have obtained funding from additional external sources during the past 5 years. Members of the department have obtained over $2.5 M in funding for equipment and infrastructure during this period. Our increased graduate student numbers and productivity should allow us to continue to increase external funding, although we are disadvantaged in national competitions by the very limited government and commercial funding for research in the Province of Newfoundland and Labrador. Seed and travel funding for the development of national partnerships would help us generate higher levels of external funding and make our NSERC funding base more secure. The prospects for increasing funding in strategic areas are excellent.