UNIVERSITY OF CALGARY

University of Calgary | Faculty of Science

Curriculum Review - Public Report

Department of Chemistry

December 2018

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Curriculum Review Team

Curriculum review process for the Chemistry program took more than two years, and several of our faculty members were involved in this process.

Curriculum Review Lead: Farideh Jalilehvand

Former Curriculum Review Lead: Ashley Causton

Advisor: Patti Dyjur

Program Level Outcome & Graduate Attributes: Ashley Causton, Ian Hunt, Todd Sutherland

Developing Course Learning Outcomes and Mapping: Max Anikovskiy, Thomas Back, Thomas Baumgartner, Wendy Benoit, Viola Birss, Yuen-ying Carpenter, Darren Derksen, Juergen Gailer, Scott Hinman, Ian Hunt, Julie Lefebvre, Chang-Chun Ling, Hans Osthoff, Roland Roesler, Nicole Sandblom, Yujun Shi, Erin Sullivan and Kevin Thurbide.

Curriculum Mapping Data Analysis (March 2018), and Action Plan (November 2018): All Chemistry faculty members were invited to participate.

Curriculum Committee Members (2017 – 2018): Max Anikovskiy, Wendy Benoit, Belinda Heyne, Ian Hunt, Farideh Jalilehvand (Chair), Amanda Musgrove, Hans Osthoff, Erin Sullivan, Guest: David Cramb (the Department Head)

Executive Summary

The Department of Chemistry has 34 faculty members (24 research faculty, and 10 instructor-stream), who are committed to providing students with the best Chemistry experience possible. The Chemistry program with typical enrollment of 300-450 students is accredited by the Chemical Institute of Canada (CSC). Our Department is vigorously active in research, and our research strength is reflected in diverse undergraduate courses that are offered as options.

Based on a survey from Chemistry faculty members, the top three strengths of our program are: *i*) Experiential learning (Labs) and undergraduate research opportunities (CHEM 402/ 502); *ii*) Curriculum content and the breadth of Chemistry content; *iii*) Dedicated faculty/ staff members. Indeed several of our faculty members and Teaching Assistants (TAs) have been recipients of Teaching Excellence Awards in the Departmental and Faculty of Science levels.

Experiential and inquiry-based learning is currently being explored in a number of different Chemistry courses. Chemistry students gain at least 379 hours of hands-on lab experience during their core courses. Our emphasis on the importance of creativity and innovation in teaching and learning led us to recruiting a Canada Research Chair (CRC) in "Creativity in Post-Secondary STEM (science, technology, engineering, and mathematics) Education", as a joint position with the Werklund School of Education. Several faculty members from the Department of Chemistry actively participate in the "*Creativity in STEM – Community of Practice*" workshops to promote creativity in their courses. This is aligned with the "*Driving Innovation*" priority in the University Academic Plan (2018 – 2022). Through our Departmental "Outreach Committee", we also connect with the local community by interacting with high school teachers, organizing high school student's visits to the Department, participating in Beakerhead, and organizing recurring events such as "Mall Show" and "School of Magic". All of these community outreach activities are aligned with another pillar of the University Academic Plan, "*Connecting Communities*".

Based on the surveys from Chemistry undergraduate students and alumni, the following are what they greatly appreciate and would like to maintain in the program:

- Staff members (high quality teaching, engaged/ passionate Profs and TAs)
- Laboratory hands-on experience, and labs in the EEEL building
- Opportunity to get involved in research by taking research courses CHEM 402/ 502 and have one on one interaction with Profs

- Selection of core courses and diversity of optional courses; CHEM 400/ 500 level courses being tailored to the Professor's interest
- CHEM 555/559 and also the writing course SCIE 311
- Tutorials and in-class demonstrations

Comparing the National Survey of Student Engagement (NSSE) in 2017 *vs*. 2014 shows that Chemistry program has improved in several Engagement Indicators. For example in 2017, our first-year students' performance in "forming a new idea" was better compared to the Faculty of Science. With respect to Effective Teaching Practices again we did better than the Faculty of Science in "providing feedback on tests or work in progress". The ability of our senior students in "applying theories to practical problems" (Higher-order Learning) has considerably improved. Also, regarding Quantitative Reasoning, our senior students' ability to "reach conclusion based on own analysis of numerical information" was better compared to the Faculty of Science. NSSE 2017 "High Impact Practices (HIP)" shows that almost half (46%) of our first-year students participated in at least one HIP, compared with only 28% in the Faculty of Science. Also, 58% of them would like to conduct research with a faculty member, which is comparable to 68% of 4th year Chemistry majors that either have participated, are involved, or are planning to do such research.

Curriculum Mapping analysis revealed that the majority of Chemistry courses address all the Program-Level Learning Outcomes (PLOs), giving the students the opportunity to grow. The 200 level CHEM courses introduce the students to all the PLO pillars, including communication skills. The 300 level CHEM courses allow students to build on and develop those skills. In 400 and 500 courses, the students are challenged by advanced "Theory of Chemistry" and "Doing Chemistry", while the "Analysis of Results" and "Connecting the dots" are still being developed in some 500 level courses. However, the "Professional skills/ Communications/ Ethics/ Awareness" outcome does not reach to the advanced level in any of the Chemistry courses.

Our faculty members are looking for more communication among themselves and with TAs to better understand the content of other Chemistry courses, and the lab skills that students develop in each required Chemistry course. They are also concerned about students taking courses without considering the "Suggested Program Sequence"; as a result the students are not building on their knowledge and skills as desired. Data show that the performance of Chemistry

majors in 200 - 400 level Chemistry courses is generally lower than non-majors, and only in 500 level Chemistry courses their performance is comparable. Students would like to have more opportunity to get involved in research, suggesting one of CHEM 402/ 502 courses to be mandatory for Chemistry majors. They also want Math courses that are geared toward Chemistry majors, and courses in which computer skills are taught. They hope to see higher enrolment in SCIE 311, so they can take this course in their first or 2nd year, and build on their writing skills as they progress through their program.

History and Context of the Program[1]

In its early days at the University of Calgary, Chemistry (and Biochemistry) was part of the Chemistry Department at the University of Alberta dating back to 1947. By 1960 the first 2 years of the B.A. and B.Sc. programs were available in Calgary and the first year of the B.Sc. (Hons. Chemistry) program was introduced. The 1960–1961 calendar listed seven undergraduate Chemistry course offerings at the 200 and 300 levels and nine graduate courses at the 500 and 600 levels (with others "as required"), leading to a workload of 477 course enrollees and 2117 weekly student hours of instruction. There was an academic staff complement of four, plus some sessional instructors, and there were five full-time graduate students who had teaching duties. In 1962–1963, all 3 years of the 3-year B.Sc. program were offered for the first time, and the second and then all years of the B.Sc. (Hons. Chemistry) program were introduced in 1963–1964 and 1964–1965, respectively. A course in the Chemistry of Biological Systems was offered for the first time in 1962–1963. By the time of the University of Calgary's autonomy in 1966, the Department was 16 faculty strong and had both chemists and biochemists as undergraduates and graduate students. In 1966–1967, a full-year Inorganic Chemistry course was taught for the first time. The Department also saw the total number of majors (in the 3-year program) and honours students increase from 163 in 1965–1966 to 218 in 1966– 1967 (a 34% increase).

Following a year of intensive undergraduate program review, which recognized that 3 years of university-level study had become inadequate, the Faculty of Arts and Science introduced the 20-course (4-year) B.Sc. program in 1970. The period 1975–1976 involved considerable planning in preparation for the splitting of the Faculty of Arts and Science and the formation of the new Faculty of Science. The Department prepared its recommendations for entrance requirements, program structures, and graduation requirements. Other changes involved the combination of half-courses into full-year courses. Extensive effort was devoted to liaison work with prospective high school students and with teachers, and relations with schools became a major thrust of the External Affairs Committee.

Significant growth and change have occurred over the past five decades, including the introduction of the Applied Chemistry (1980) and Nanoscience (2011) Programs.[2] The current

[1] "The Department of Chemistry at the University of Calgary: 50+ years of discovery" *Can. J. Chem.* **2016**, *94*, pp. vii-x.

[2] The Applied Chemistry program was suspended in 2018 due to low enrolment.

staffing complement includes 35 faculty members (24 research and 11 teaching, all tenure stream), and 20 support staff (administrative and technical).[3] This makes us a medium-sized Canadian Chemistry Department, similar to McMaster (34) and McGill (37) and smaller than University of British Columbia (65), for example.

Currently three Chemistry degrees are offered at the undergraduate level, namely B.Sc. Chemistry, B.Sc. (with Honours) Chemistry, and B.Sc. Applied Chemistry. The B.Sc. Chemistry or Applied Chemistry, and B.Sc. (with Honours) Chemistry degrees are accredited with the Canadian Society of Chemistry. Typical enrolment in the Chemistry program is 300–450 students and the average entering grade directly from high school has remained close to 82% over the last 5 years. Averaging over the last 5 year, the Chemistry Department has graduated approximately 31 students per year. The Chemistry Department also contributes strongly to interdisciplinary undergraduate programs such as Environmental Science, Natural Sciences, and Nanoscience.

A large number of students take Chemistry through service courses. The majority are non-Chemistry science majors, or from the Faculty of Engineering. For example, in the 2013–2014 academic year, there were 2439 students enrolled in various first year Chemistry courses that were non-Chemistry science students, and 1130 engineering students registered across the 4 years taking Chemistry-for-engineers course offerings.

Our Department is vigorously active in research, publishing on the order of 100 journal papers per year for the past 5 years. Much of this research activity is carried out in concert with our M.Sc. and Ph.D. students as well as some talented undergraduate students as summer research assistants (or as participants in the Research in Chemistry courses).

The Department of Chemistry's commitment to teaching and learning is reflected, as a core philosophy, by the appointment of tenure-track teaching stream faculty members. In addition, each faculty member, whether research or instructor stream, has a 3-year teaching plan, allowing them to invest heavily in developing the courses that they know they are teaching in the foreseeable future. In the Chemistry Department, we are poised to become national leaders in undergraduate education. Our faculty are fully engaged in bringing science to undergraduate students and to help them become scientists through unique classroom, laboratory, and tutorial experiences. This effort is being driven by a strong contingent of instructors in our Department with commitment and support from our professor stream. Many have won awards in teaching.

[3] As of June 2018, there are 34 faculty members: 24 research faculty and 10 instructors/ senior instructors.

Graduate Attributes and Program-Level Learning Outcomes for Graduating Chemistry Students

	Sub-Category	Description from Faculty of Science Graduate Attributes Document	Program-Level Learning Outcomes for Graduating Chemistry Students
Knowledge	Disciplinary Knowledge	Acquire knowledge (conceptual and technical) specific to chosen area of study.	Predict, describe, research, elucidate, interpret the structure, bonding, and properties of chemical entities at all levels, from the sub-atomic to the macroscopic.
			Select appropriate spectroscopic and instrumental methods to detect and quantify chemicals, determine structure and investigate molecular properties.
			Qualitatively or quantitatively describe the energy changes associated with chemical systems; apply this to justify their thermodynamic and kinetic properties.
			Knowledge of chemical reactions; why and how they occur, and an ability to rationalize a multistep synthesis.
			Recognize the hazards associated with certain chemicals. Practice high standards of laboratory safety. Know how to handle, use , and dispose of chemicals and chemically contaminated materials safely, ethically, and responsibly.
		Be able to understand and analyze issues across the spectrum of math and sciences and integrate knowledge from other fields of study.	Have a broad and continually growing baseline of scientific knowledge.
		Understand how scientific and mathematical knowledge continually evolve and that it is subject to change.	Understand that chemistry, it's underling theory, and what is currently "accepted knowledge" has changed over time, and may change in the future.
	Science in Society	Understand the impact and ethics of scientific discoveries on influencing society locally, globally and ethically.	Be aware of the public perception of chemistry and the impact of Science on society and the environment.
		Understand that science is a social endeavor. Scientists work together and within local and global communities seeking to improve understanding and explanations of the natural world.	Appreciate the impact of society on directing scientific endeavours.

	Sub-Category	Description from Faculty of Science Graduate Attributes Document	Program-Level Learning Outcomes for Graduating Chemistry Students
Skills	Critical Thinking	Ability to assess scientifically-based arguments and/or information and critically evaluate the basis of the included ideas.	Differentiate between opinions and fact based information. Understand why primary literature is the most reliable source for information. Be able to assess whether the published results support the published conclusions; be unafraid to express an alternate explanation.
		Ability to distil salient points from assimilated information.	Evaluate experimental results and collected data, identify anomalies, identify trends, draw appropriate conclusions. Ask further questions, design future experiments.
	Research	Ability to find information, collect data and assess its relevance and reliability.	Be aware of what is considered a reliable scientific resource, and where to find them. Have the ability to evaluate published material for its rigor and relevancy.
		Ability to formulate or articulate a problem and recommend/implement solutions.	Have experience with hypothesis-driven research enquiry.
	Problem Solving	Understand how scientific knowledge is used to identify, define and permit analysis of problems, and arrive at solutions.	Use a logical approach to investigate any anomalies in scientific results.
	Technical skills	Acquire skills specific to chosen area of study.	Be able to set up and perform a common chemical experiment, employing all appropriate experimental best practices.
			Be able to use basic instrumentation.
			Be able to analyse and process data.
	Collaboration	Ability to work effectively as member of inter- and intra-disciplinary teams.	Have the knowledge of what is required to work effectively as part of a team.
	Communication	Explain and present ideas effectively to different groups of people (scientific and non-scientific audiences).	Ability to communicate clearly, appropriately, and effectively with a wide variety of people.
		Explain and present ideas effectively in multiple formats (written, oral, graphical, symbols)	Clearly and concisely present scientific information in written, diagrammatic, and oral form.

	Sub-Category	Description from Faculty of Science Graduate Attributes Document	Program-Level Learning Outcomes for Graduating Chemistry Students
Skills	Self-directed learning	Ability to evaluate personal performance and independently seek and act upon means of improvement to allow for the advancement of knowledge and skills.	Ability to think and work independently. Have self-awareness and be self-reflective with respect to their current level of knowledge and skills
	Creativity and curiosity	Ability to adapt to new situations. Use or modify materials or equipment at hand to obtain results. Develop divergent and convergent ways of thinking. Ability to pick out unusual associations of ideas. Thirst for knowledge.	Understand how cross-over from different areas of chemistry (and other areas of science) can result in generation of new ideas. Be able to propose and implement logical improvements to current technology.
	Career skills	Organization, time management, professional approach to learning.	Be aware of the benefits of being organized, having time management skills, being professional, and having a work-life balance.
Commitments	Diversity	Understand that people from other disciplines and backgrounds bring different skills, knowledge and tools to problem solving.	Develop awareness that terminology, perspective, and priorities can vary between subject disciplines and different cultures.
	Ethical Practice	Demonstrate an understanding of the scope of ethical principles and a commitment to applying these principles in decision-making and scientific practice.	Honesty in scientific endeavours, and in reporting scientific findings. Developing the personal fortitude to advocate for ethical practice.
	Sustainability	Understand the importance of sustainability and the impact of scientific activities and discoveries on sustainability and environmental stewardship.	Be aware of the credo of sustainability and be an advocate whenever appropriate.
	Social Responsibility	Understand the responsibility of contributing or transferring one's knowledge, skills and expertise to community (community can incorporate local, municipal, national and international scopes)	Respect yourself and others; be aware of your skills and disciplinary knowledge and status within the context of your community. Contribute these attributes to make your community and Planet a better place.

Chemistry Curriculum Review Guiding Questions

1. How are our core values and desired outcomes addressed in our Chemistry program, and what high-impact educational practices are students experiencing in our program?

2. What are the gaps in the context of our program outcomes?

3. What are our, and the students', desired outcomes for student-faculty interactions with respect to mentorship?

4. What can the performance of our Chem major students, and any movement away from the Chemistry program, tell us about our program?

Action Plan

Recommendations – Program Level / Student Advising				
Recommendation		Action Item	Timeline	Lead Responsibility*
1	Building Community & Means of Communication	Recurring Departmental Retreats	On-going	*Department Head*
		Meetings with focused topics (investigate suggested 'interest streams' or official concentrations within the major)	Start by Jan. 2019	*Curriculum Committee*
		Introduce Teaching Squares or similar opportunities for peer observation and feedback	On-going	*Teaching & Learning Committee*
2	Improving Research Skills and Problem Solving in Students	Discussion about CHEM 402/502 courses: What is required to sustain these courses? Safety concerns; Budget; Presentation requirements (posters/ presentation in group meetings, formal skills training); Grading criteria; Documenting the needs	Year 1	*Department Head and Faculty Members*
3	Explore students practical lab skills	"Curriculum Mapping for Labs": Map laboratory contents/ skills	Start by May 2019	*Curriculum Committee*
		Emphasize on good lab note taking and report writing skills in core courses	On-going	*Faculty Members*
4	Improving students' Math/ writing skills	Discuss at a departmental retreat what is currently occurring in SCIE 311, what the department perceives as the goals, and decide whether working with SCIE 311 faculty to align curriculum will meet these goals.	On-going	*Department Head*
		Meetings focused on students' Math skills	Started in Nov. 2018 On-going	*Curriculum Committee*
5	Students Involvement in the Department (among each other, and with faculty members)	Investigate existing frameworks to connect students together (like Student Mentoring Program)	Years 1-2	*Associate Head Undergraduate and CSC Student Chapter Liaison*
		Marketing: Develop relationship with Chemistry Student Club or encourage growth of a Departmental club and encourage Chemistry majors to join the club (e.g. at 1st year Orientation)	Started in Sept. 2018 On-going	
6	Explore "Suggested Program Sequence"	Revisit core and optional contents in the program. Re-evaluate pre-requisites at Departmental Meetings and Retreats	Started in Sept. 2018 On-going	*Department Head and Faculty Members*
		Making the information available to the students early in the program (e.g. at 1st year Orientation), and to the advisors	Started in Sept. 2018 On-going	*Associate Head Undergraduate*
7	Course Learning Outcomes	Maintain current Course Learning Outcomes and include CLOs in Course Outlines	Years 1 - 2	*Faculty members*

* All discussions will be shared with the faculty members at the monthly departmental meetings.
department.