

Curriculum Review – Department of Chemistry

1a) Chemistry - Curricular Coherence and Accessibility

The Chemistry undergraduate curriculum is largely prescribed by the expectations of a national professional organization and the AACU's High-Impact Educational Practices. The course sequence is predominantly taught by Chemistry faculty, leading to a high level of consistency in achieving the core learning goals for our students. As there are fewer than 50 new majors per year, Chemistry students experience a high degree of coherence in their course selections and experiences.

The lower-division courses are foundational in nature, and include many general education courses shared with many of the other natural science majors. There are few challenges for our students to successfully complete these lower division courses within the first two years at UMass, other than a lack of off-sequence Chemistry courses. Upper division courses are more specialized, with relatively few choices for our students in terms of elective courses. The limited choice of electives creates some challenges for our students to fulfill more specialized learning goals. The capstone experience for students is very strong, as every BS major performs research within an active research lab alongside graduate students.

Lower division courses:

At the foundational level, our majors complete a full year of Chemistry, Calculus, and Physics. Due to the placement of Chemistry at the nexus of life science and physical science, our students also complete one semester of Biology and a full year of Organic Chemistry; a third semester of Calculus is required for the BS degree.

The sequencing/accessibility of lower division courses is not typically a problem, however Honors general chemistry is only offered in a Fall/Spring sequence. A sophisticated level of Calculus and Physics is required for the BS Chemistry degree, making it challenging for students who wish to switch into this major. This carries over to students who wish to go on to medical school, as the perception is that the Calculus and Physics courses required for Chemistry may depress the GPA, leading to relatively few pre-med students majoring in Chemistry.

Lower division courses taught by Chemistry faculty range in enrollment from 30 – 60 students, making for a good student experience.

Upper division courses:

Chemistry majors are required to complete 4 – 6 upper division lecture courses along with 3 – 5 advanced laboratories, and at least one semester of Independent Research for BS students. This leads to an experience that is rich in terms of exposure to and training in graduate-level research for our undergraduates.

Approximately half of the upper-division lecture courses taken by a typical Chemistry major will be graduate courses, creating some challenges in terms of accessibility due to the sequencing of pre-requisites and the scarcity of Spring-term electives. Our students would be better served by upper-division courses that have fewer pre-requisites and that primarily serve the needs of undergraduates.

Laboratory course offerings are limited, and most elective laboratory experiences come through a research placement. This can lead to overly specialized training for our students in fundamental experimental techniques, but it may also train students to be better prepared for graduate school research.

1b) Communication

Advising/Mentoring: All advisors in the Chemistry Department are faculty who meet one-on-one with advisees a minimum of two times each academic year to discuss plans for futures classes. Those who enter the major late

or have a second major represent the bulk of advising challenges. The flexibility built into the junior and senior years of our curriculum generally allows for students in these two groups to graduate on time as long as they have taken some science courses prior to declaring chemistry as a major. In addition to coursework, all BS chemistry majors are required to do independent research during their tenure. Advisors play a key role in helping students determine an appropriate lab in which to satisfy this requirement by identifying the student's interest and suggesting possibilities both within chemistry and neighboring departments. Toward the end of each student's academic career, advisors may also assist with career decisions including BS/MS job opportunities and graduate/professional education.

While mentoring students as to curricular requirements is straightforward in most cases, the department generally lacks a coherent "why am I doing this" message especially in the early stages of advising. If a student's interest can be identified at an early stage, we should be helping them to think broadly about how to get the most from their experience in the major. Additionally, students who struggle to identify interests or are inherently exploratory types should be exposed early on to effective strategies for best preparing themselves in the fundamentals in order to take advantage of varied course opportunities later on. With information on summer programs, internships, semesters abroad, etc. coming from many disconnected sources, it is often difficult for faculty advisors to keep current on these opportunities and pass the information to students.

Chemistry Website: The Chemistry Department website was overhauled several years ago (and we are planning to convert it fully to the common University platform Drupal). Although some minor updates are needed, all information pertaining to the undergraduate curriculum is available. That said, students now expect a very particular web experience and further improvements will be incorporated in the move to Drupal. Below are a few potential problem areas that we plan to address.

- 1) The website is not mobile friendly
- 2) Updates to the curricular checklist and suggested course sequence are needed
- 3) The layout of the site is not particularly interactive
- 4) A complete updated set of descriptive course listings is needed, especially now that course information is typically only available through Moodle to enrolled students
- 5) The roles of the undergraduate program director and chief undergraduate advisor are not clearly defined

1c) Class Size

The Chemistry Department has made limiting class size for our majors a high priority. Since the expectations we have of our majors are significantly higher than those of nonmajors, for the large enrollment general and organic chemistry courses at the freshman and sophomore levels, we offer major-specific versions of these courses where enrollment is limited to certain Honors College students, physical science majors or chemistry majors only. Classes that are limited to chemistry majors provide a great opportunity for establishing camaraderie and collaboration among our students. The summary below describes what a typical chemistry major should encounter, in terms of class size, throughout his/her academic career.

Freshman: Generally, freshman Chemistry majors take general chemistry, math, and physics. General chemistry is offered as an Honors course with typical enrollments of 20-30 for each section. The introductory physics courses are much larger with enrollments around 250 while calculus courses are split into numerous sections with roughly 40-60 students enrolled in each. As of last academic year, all chemistry majors are required to take introductory biology.

Sophomores: In their sophomore year, all Chemistry majors are required to take Organic Chemistry in both the Fall and Spring. Our organic sequence is limited to Chemistry majors only and generally sees enrollments of

40-60 depending on the year. Sophomores also take the large enrollment, second semester physics course at this time. The Chemistry Department offers a Sophomore Seminar course for all Chemistry majors with enrollments similar to the majors' organic lecture. During the spring semester, students are encouraged to take quantitative analysis with the corresponding lab. This course is limited to Chemistry majors and thus has similar enrollment numbers to organic and sophomore seminar.

Juniors: Junior Chemistry majors generally take both inorganic and physical chemistry courses. Inorganic enrollment numbers are similar to Sophomore Organic. We offer two sections of the writing course with enrollments of approximately 20 students in each. During the spring semester, students begin to tackle the upper-level course requirements. Enrollments in these courses vary as described below.

Seniors: For Chemistry majors who have successfully followed the recommended sequence detailed above, most of the senior year is spent taking upper-level electives. Students can choose from graduate-level chemistry offerings and a variety of courses taught by other science departments such as biochemistry, biology, chemical engineering, and polymer sciences. Enrollments in these courses vary from less than 10 for some particular specialized topics to over 50 for the more popular offerings.

Part 2 – Goals for Student Learning and the Student Experience

In 2013, The Chemistry department identified learning goals that were tightly focused on scientific practices, as follows: “The overall learning objectives of an undergraduate education in Chemistry are to describe the structure and transformations of matter from a molecular perspective, and to develop and perform controlled experiments to test hypotheses. This encompasses the acquisition of concepts and experimental skills, as well as the perspectives to relate a molecular view of nature to fields as diverse as energy and biology.”

While these goals supplement the general education goals of UMass, we have recently begun a visioning process to better articulate the connections between these department-specific goals and the many skills and habits of the mind that are needed for professional success. This includes helping our students to adapt to a working environment that is increasingly international, and a workforce that is increasingly diverse in composition.

2a) Internationalization – Over the past 3 years, the Chemistry Department has worked with the International Programs Office (IPO) in an effort to facilitate internationalization, in the form of “semester abroad” experiences, for our majors. The inherent inflexibility in our junior and senior year curricula suggests students should focus on international programs in their sophomore year at UMass. The primary difficulties in finding acceptable opportunities continue to be 1) identifying sufficiently similar courses that satisfy our curricular expectations and 2) laboratory requirements. Working with IPO, we have discovered international courses that coincide well with lectures offered by the Chemistry Department, particularly organic chemistry I and II, but these are limited. Laboratory-based courses, especially within the European system, that coincide with our departmental learning goals and timeline are especially difficult to find abroad. As a result, we have encouraged students who are interested in exploring international programs to concentrate on general education requirements and approved organic chemistry lecture courses while away from UMass, leading to our suggestion of the sophomore year.

The undergraduate research experience is a primary focus in the Chemistry Department as all BS majors are required to complete at least 3 credits of independent research prior to graduation. Blending study abroad programs with independent research has generally not been explored in Chemistry but could greatly increase the value of the student experience while also contributing to curricular requirements. In addition, our international, academic partners would benefit from increased awareness of their research programs and diversification of their laboratory personnel.

Increasing student access to and awareness of international programs has not been thoroughly examined within the Chemistry Department in recent years. Our continued work with IPO will lead to expanded opportunities for students and an appropriate “sales” strategy will be needed. All academic advisors need to be up to date on current opportunities and a consensus amongst the faculty as to how best to promote these programs should be put in place.

2b) Diversity – The Chemistry Department placed significant attention on improving diversity within our graduate program. By partnering with institutions that historically serve underrepresented student groups, actively recruiting women and minorities through interdisciplinary programs, and participating in the NEAGEP program we have established a sustainable setting of multiculturalism.

In contrast, our undergraduate program has not received this level of active recruitment. Small departments within the physical sciences are not a traditionally popular destination for women and underrepresented minorities. However, enrollments in several required courses indicate that approximately 45% of our chemistry majors are women. With investment in diversity programs at the undergraduate level we should be able to increase this to 50% and to begin to address the greater challenge of increasing the very small numbers of chemistry majors from under-represented minorities. Chemistry is an often mistakenly overlooked major for students interested in careers as health professionals. Taking a more active role in campus activities such as Majors Fair and Open Houses may help showcase the advantages of being a Chemistry major (smaller entry-level classes, research exposure, etc.) to a broader and more diverse audience.

With funding from the Camille and Henry Dreyfus Foundation, Craig Martin, Head of Chemistry, has created an informal education opportunity in the Molecular Playground (<http://MolecularPlayground.org>), an interactive display in which the public can interact with molecules. He has teamed with a faculty member from the School of Education, Meg Gebhard, to create an installation in the Springfield Central High School, in progress. They have very recently teamed with Leykia Brill, Assistant Provost for Diversity, to facilitate this and expand it to other schools in the system. A key feature of this interactive exhibit will be UMass branding. Thus the project will promote both Chemistry and the University of Massachusetts Amherst, in schools with significant diversity potential.

Our department is one of the CNS departments partnering to submit a proposal to the Inclusive Excellence program at HHMI (2016 submission deadlines) which, if funded, would provide resources to provide additional support for recruiting and supporting a more diverse undergraduate population in our major. In addition, we plan to work with Charlana Simmons, director of student success and diversity in the College of Natural Sciences to better understand the demographics of our undergraduate student body, and how to provide specialized services for our students to help them reach their maximum levels of student success.

Examples from other institutions have demonstrated that certain types of active learning approaches are effective at closing performance gaps between underrepresented students and white students in chemistry and other STEM disciplines. This results in improved retention of those students in the majors. Faculty members in chemistry have a history of using innovative teaching approaches that have been shown to be effective. We will continue to work on course redesign to more deeply engage students beginning with the foundational courses in the sequence.

Part 3: Curriculum Revision Action Plan

3a) With existing resources

By the beginning of Spring Semester...

1) Faculty discussion: Advising students beyond basic curricular matters including career advising, Updating advising documentation

2) Faculty discussion: Website improvement

- 3) Update and expand course descriptions on the Chemistry website
- 4) Define specific roles for the Undergraduate Program Director and Chief Undergraduate Advisor
- 5) Discuss best practices for TBL implementation in majors Chemistry courses with emphasis on learning retention
- 6) Continue Chemistry Department “learning goal” visioning process initiated during Summer 2015, which originated with a team of chemistry faculty being awarded participation in a chemistry and physics educational reform workshop by the APLU. The team has been leading an all-faculty discussion following a “backward design” approach to the chemistry majors’ curriculum.

By the end of Spring Semester...

- 1) Develop a resource for advisors and students that includes information regarding international programs, internships, and summer research programs
- 2) Develop specialty concentrations (biological, materials) to add to our existing curriculum
- 3) Faculty discussion: Adding a professional development seminar to the junior/senior year
- 4) Faculty discussion: Diversity in Chemistry with Charlana Simmons
- 5) Increase awareness of newly formed UMass Undergraduate Chapter of the American Chemical Society and establish a partnership with the UMass Chemistry Club
- 6) Identify specific measurements for targeted learning goals to begin the process of taking quantitative stock of the Chemistry undergraduate curriculum.

Within 1 year...

- 1) Develop a resource for students to facilitate finding a research group
- 2) Faculty discussion: Developing an “Introduction to Laboratory Research” short-course or other approaches to engage students in undergraduate research earlier in their sequence.
- 3) Faculty discussion: Optimizing partnerships between tenure-track faculty and lecturers for teaching large enrollment courses
- 4) Build on current successful partnerships (University of Glasgow, DAAD, Heriot Watt University) with international institutions and publicize study abroad opportunities to students and advisors
- 5) Expand learning goal assessments, and begin to institute new curricular and pedagogical interventions in specific, targeted areas of need (as determined by assessment and visioning results) to enhance Chemistry undergraduate education.

3b) With additional resources

- 1) Restore tenure system faculty numbers to allow more participation in lower division courses - **Increased faculty, TAs needed**
- 2) Restore our ability to offer upper level advanced courses, while updating them to current research thrusts: biomedical chemistry, materials chemistry, renewable energy- **Increased faculty, TAs needed**

- 3) To complement the core curriculum, add modular upper level electives (e.g., imaging cellular chemistry, physics of photovoltaics, vehicles for drug delivery, adaptive materials) - **Increased faculty, TAs needed**
- 4) Expand career guidance courses in the junior and senior years, including resume building, networking, and employment search skills - **Increased faculty, TAs needed**
- 5) Properly address website improvements with professional developers- **Partnering with web development professionals needed**
- 6) Further develop nascent relationships with local high schools servicing primarily underrepresented minority groups - **Additional staff needed**
- 7) Expand new curricular and pedagogical interventions in broader areas of need (as determined by assessment results) to enhance undergraduate education - **Increased faculty, TAs needed**