Fitchburg State University
The Department of Biology and Chemistry

Chemistry Program Review

2013-2021

I. Executive Summary

The chemistry program at Fitchburg State University has an interesting history. We lost the major in the early 2000's, merged with the Biology Department shortly after, and then finally in 2014, had the major reinstated after a thorough needs assessment and careful curricular planning. Currently, we have 2 major degree programs (one with 2 concentrations): a B.S. in Chemistry, a B.S. in Chemistry with a concentration in biochemistry, and a B.S. in Chemistry with Initial Teacher Licensure. Since 2014, we have graduated over 20 students, and currently have 13 enrolled majors and 20 students in the minor. Our students matriculate through a series of rigorous coursework based on the guidelines of the American Chemical Association which include core coursework in General Chemistry I and II, Organic Chemistry I and II, Inorganic Chemistry, Analytical Chemistry, Biochemistry, and Physical Chemistry (including Physical Chemistry Laboratory) as well as Calculus, Physics, and Biology. Furthermore we offer a range of chemistry electives such as Environmental Chemistry, Medicinal Chemistry, and other topics courses. Because we are a liberal arts university, all chemistry majors must also participate in a broad range of General Education courses that includes writing, the arts, history, wellness, ethical reasoning, and literature.

One of the biggest strengths of our department is our faculty and their commitment to student success. We currently have 6 full-time chemistry faculty members. The faculty of the BIology and Chemistry programs work collegially on committees to write proposals and develop programs and policies for the department and have often collaborated on research programs. Faculty teach a 4/4 load (12 credits per semester) and are also involved in advising, scholarship and service. Each faculty member meets with 8-11 advisees every semester and helps them with coursework and career planning. Additionally, faculty-student research projects that promote continued scholarship are readily available to interested students and offer high-impact teaching practices outside of the classroom. Many of our faculty are also active participants in the regional chapter of the American Chemistry Society, which helps build networks and opens opportunities for both faculty and students. Service is also an important component of faculty load and all of our faculty serve on a variety of departmental and university-wide committees. In addition to on-campus service, faculty also are actively involved in community outreach projects with local organizations and schools.

We have been fortunate as a department to have access to a new science facility with updated labs equipped with state of the art equipment and safety features. These include UV-vis, NMP, IR, Vis and AA spectrophotometers, a GC-MS spectrometer, several GC instruments, HPLC, UHPLC and a potentiostat/Galvanostat. Access to this equipment has allowed us to work with students on various research projects and present findings in publications and at conferences. We are provided with departmental funds to support course and lab supplies and have opportunities to seek additional funding for instrumentation through annual extrabudgetary requests.

The chemistry program has offered many services courses to outside departments, including Nursing, Exercise and Sport's Science, and Biology. In fact, due to the number of required chemistry courses within the biology major, students only have to take two additional courses to attain a minor in chemistry. Additionally, we have supported graduate programs in the M.Ed. in Science Education and M.Ed. in

Curriculum and Teaching programs by offering evening graduate-level chemistry courses mostly for practicing Chemistry Teachers pursuing a Master's Degree. One of our primary service courses is Chemistry for Health Sciences; typically we offer 4-5 sections every semester for Nursing majors. Additionally, faculty teach non-majors courses such as Chemistry in a Changing World which fulfills requirements for the Liberal Arts & Sciences (now General Education) curriculum across campus.

One of the major challenges of our department is low enrollment. We have been unsuccessful in recruiting chemistry majors to fulfill our initial goal of 50 majors over our first 5 years since the major was reinstated. To ensure student success in upper-level courses we have implemented minimum grade requirements and prerequisite policies in introductory courses. Many of our majors are from underrepresented groups which often find college difficult to navigate in the first year. Because of this, most (if not all) of our introductory majors courses, including labs, are taught by full-time faculty. We also have a policy that students must maintain a 2.0 in core introductory courses to continue with the major. This helps us identify struggling students early to either help them develop the skills they need or to encourage them to find a more suitable major. Many of our students struggle due to the math intensity that is typical of chemistry courses. Because of this, many of our faculty have begun addressing math skills upfront in their introductory classes and offer additional help with learning the math needed to succeed in chemistry. Our small class sizes and access to faculty and tutoring on campus are just some of the means that have helped our students move through the program. An encouraging point is that once graduated, our students are easily able to find chemistry-related jobs in the area.

Recruiting and enrollment over the last 5 years has been a university-wide concern and measures have been taken to address them. For example, we have hired a new VP for Enrollment Management, started offering more open houses and department tours, and have bolstered our Academic Coaching Center on campus. Recruitment and retention will continue to be one of primary priorities as we move into the future of the chemistry program. We also are encouraged by the new General Education curriculum that includes mandatory courses like First Year Experience to help new students navigate the intricacies of college by teaching them important executive functioning and reading skills so they can be successful doing the work that is required of them. In the interim, our faculty will continue to participate in outreach programs with local community colleges, boy's and girl's programs, and school districts to improve relationships and possibly recruit students.

The Department of Biology and Chemistry is committed to using evidence-based approaches that employ authentic and innovative ways to engage, recruit, assist, and retain students. Our students are our first priority. As a department, we are committed to our mission of providing all of our students with enriching classroom, laboratory, and research experiences that teach them important skills that will stay with them throughout their personal and professional lives.

II. Overview and Vision

1. Overview of the Department

Historically, the department had offered a minor and major in chemistry, but these were discontinued in the early 2000s. The department began to offer the chemistry minor again in 2008. In 2013, the new chemistry major was approved by the Massachusetts Board of Higher Education (BHE). The programs approved were a Bachelor's of Science (B.S.) in Chemistry and B.S. in Chemistry with Initial Licensure in Secondary Education. A new concentration in Biochemistry was added to the program in 2019. Currently, three bachelor of science programs in chemistry are offered: B.S. in Chemistry, B.S. in Chemistry with concentration in Biochemistry and B.S. in Chemistry with Initial Licensure in Secondary Education (which includes a minor in Middle School and Secondary Education). The department also offers a minor in chemistry.

Since 2001, the disciplines of biology and chemistry have been operating as one department when the two individual departments were merged. Since the two departments have joined, the chairs have been Dr. George Babich (now retired) and Dr. Meg Hoey, both biologists, Dr. Meledath Govindan, a chemist (2014 - 2021) and Dr. Michael Nosek, a biologist elected in 2021. Dr. Nosek is on sabbatical in the Spring semester 2022, and the position is being filled by Dr. Erin Rehrig on an interim basis. The University created a Dean structure in 2014. Dr. Meg Hoey was appointed initially as an interim dean overseeing the chemistry, biology and other disciplines. Following a nation-wide search, Dr. John Schaumloffel assumed the position in 2017. He resigned in 2019 and Dr. Hoey was reappointed as the permanent Dean. Since the creation of the Dean structure there has been some restructuring of disciplines. And currently, the Biology and Chemistry Department is housed in the School of Health and Natural Sciences along with Computer Sciences, Exercise and Sport Sciences, Mathematics, Nursing, Psychological Sciences, Earth & Geographic Sciences, and Engineering Technology. Currently, the full-time faculty include 6 chemists and 11 biologists. In June of 2021, Dr. Govindan retired, and his position will not be refilled. In addition to teaching undergraduate day students, faculty members may choose to teach courses in the evening and summers at the undergraduate and/or graduate level through the School of ONLINE, Graduate and Continuing Education (SGOCE). In most years, a number of part-time faculty (adjuncts) teach introductory biology and chemistry courses for undergraduate, day courses as well as evening and summer courses. However, in AY21/22, no adjuncts have been used for chemistry courses in either day or SGOCE courses, and we do not anticipate the use of adjuncts in AY22/23. Department staffing also includes a full-time administrative assistant (shared with the Earth and Geographical Sciences (EGS) department), and 2 full-time technicians. One of these technicians works full-time in biology, the other is full-time in chemistry. The roles of the technicians include setting up labs, ordering, stocking lab supplies, and most importantly, maintaining and enforcing health and safety regulations.

2. Program's vision, mission and objectives

Vision Statement for the Department of Biology and Chemistry

"The Department of Biology and Chemistry provides undergraduate and graduate students with the opportunity to learn in the physical and life sciences. Focusing on process, concepts, and critical thinking skills, we build the foundation students need to actively participate in scientific inquiry and the discovery of knowledge. Our approach to education and research imparts students with a way of thinking about and understanding our natural world that will guide them throughout their professional and public lives

The Department places a high value on interdisciplinary research, collaboration, and partnerships with other educators on and off campus. A rich collaborative community is fostered through internships, independent studies, and student collaborations with active faculty research programs; an environment that mirrors the diverse world that we share. As a department we work diligently to incorporate innovations in technology, research, and education that build upon our current strengths and meet the demands of a dynamic environment."

In order for our department to implement strategies to meet this vision we hold monthly meetings as an entire department and also have sub-committees that focus on curriculum, assessment, equipment, student affairs, graduate programs, or peer-evaluations. In addition to serving on department committees, our faculty also serve on many university-wide committees. A detailed manual of departmental procedures as well as a list faculty serving on departmental and university committees can be found in **Appendices A, B, and C.**

Mission Statement and Objectives for the Department of Biology and Chemistry

The Biology and Chemistry Department believes that every student deserves a first-class education. We are educators at Fitchburg State because our personal values align with the campus values of equity and excellence. We strive to ensure that our students have the best of what we can offer them as they gain an in-depth knowledge of science that is part of a larger interdisciplinary, multicultural liberal arts and sciences education. In order to achieve our mission, we strive to meet the following objectives:

● Produce students who are well prepared for diverse careers or advanced study in the biological and chemical sciences or related disciplines as well as gain the skills necessary to successfully adapt to future changes within their disciplines.

● Build lasting relationships with students that will advance their professional growth by recognizing the unique needs of each individual and reflecting our passion for engagement in authentic learning experiences.

● Maintain a high level of scholarly activity in a variety of fields associated with biology, chemistry and science education.

● Serve the needs of the university and specific academic departments through our curricular offerings and involvement in the university community.

● Endeavor to demonstrate leadership as stewards of the environment.

● Provide state of the art pedagogical approaches as well as utilize appropriate equipment, technology, and resources for teaching, learning and research in the sciences and science education.

● Work to support the University's mission of providing leadership and support for the economic, environmental, social, and cultural needs of North Central Massachusetts and the Commonwealth.

● Recruit and retain qualified students for our academic programs from diverse backgrounds.

3. Relationship to the University Mission, Vision, and Strategic Plan

"Fitchburg State University is committed to excellence in teaching and learning and blends liberal arts and sciences and professional programs within a small college environment. As a community resource, we provide leadership and support for the economic, environmental, social and cultural needs of North Central Massachusetts and the commonwealth"

Chemistry is one of the fields in the forefront of the current technology revolution and, as such, it plays a crucial role in solving many of the problems faced by today's society. Chemists work in all facets of life including the development of new drugs for treatment of diseases such as cancer, AIDS, COVID-19, and heart diseases, the creation of better methods for the production of food, clothing and shelter, and the discovery of environment friendly energy sources. They also work on solving problems such as acid rain, ozone depletion, and climate change. The chemistry program at FSU, owing to its geographical location, attracts students mainly from towns in the North Central Massachusetts area and prepares them for pursuing professional careers in the chemical, pharmaceutical, biotechnology or related industry as well as secondary school teaching.

In the Chemistry Program, students take a diversity of General Education courses, including courses that incorporate diverse perspectives, ethical reasoning, procedural and logical thinking, civic engagement, fine arts, and others that integrate and apply learning with high impact practices. Additionally, our students complete a rigorous curriculum in chemistry that prepares them for the aforementioned professional careers. This optimal blend of Liberal Arts and Professional courses helps meet our primary Strategic Goal of *"forging innovative paths to knowledge acquisition, career readiness, social mobility, and lifelong learning."*

4. Overview of the program

The chemistry program was designed based on the needs of the job market and in accordance with the recommendations of American Chemical Society (ACS). Although our chemistry degree program was designed to follow ACS guidelines, it is not an ACS accredited program and we do not envisage seeking ACS accreditation in the near future. This is due in part to the small size of our program, the rigor associated with the accredited program and our current limited ability to attract top high school talent. In addition, there is a high demand for chemistry graduates in our area who are able to secure employment without an ACS accredited degree. Expected learning outcomes include competencies in the five primary areas of chemistry - analytical, organic, inorganic, physical chemistry and biochemistry. In addition, students will also gain competencies in the following areas - (1) laboratory safety and green chemistry (2) chemical literature and information retrieval (3) developing effective oral and written communication skills (4) professional ethics. Students will also receive training in related fields, such as mathematics and physics. The curriculum leaves enough room for electives, which the students can use for additional coursework in chemistry or related fields, such as biology, geophysical sciences, computer science or industrial technology. In fact, a second major in biology (or vice versa) would be relatively simple given the overlapping curricular requirements between the two majors.
The degree requirements for each of the Chemistry programs are listed **below:**

Degree Requirements B.S. in Chemistry

Core Courses in Chemistry	
CHEM 1300 - General Chemistry I	4 cr.
CHEM 1400 - General Chemistry II	4 cr.
CHEM 2000 - Organic Chemistry I	4 cr.
CHEM 2100 - Organic Chemistry II	4 cr.
CHEM 2400 - General Analytical Chemistry	4 cr.
CHEM 3030 - Biochemistry I	3 cr.
CHEM 3200 - Physical Chemistry I	4 cr.
CHEM 3600 - Descriptive Inorganic Chemistry	3 cr.
CHEM 4750 - Chemistry Seminar	3 cr.
Sub-Total	**33 cr.**
Required Courses in Related Disciplines	
PHYS 2300 - General Physics I	4 cr.
PHYS 2400 - General Physics II	4 cr.
MATH 1300 - Precalculus	4 cr.
MATH 2300 - Calculus I	4 cr.
MATH 2400 - Calculus II	4 cr.
BIOL 1800 - General Biology I	4 cr.
Sub-Total	**24 cr.**

Chemistry Electives

Students must choose two electives from the following list:

CHEM 3040 - Biochemistry II

CHEM 3060 - Biochemical Techniques

CHEM 3300 - Physical Chemistry II

CHEM 4000 - Natural Products
CHEM 4020 - Medicinal Chemistry
CHEM 4040 - Advanced Synthetic Methods
CHEM 4200 - Polymer Chemistry
CHEM 4400 - Forensic Chemistry
CHEM 4500 - Organic Spectroscopy
CHEM 4600 - Chemical Instrumentation
CHEM 4900 - Independent Study in Chemistry
CHEM 4940 - Internship

Sub-Total	**6 - 8 cr.**
Total number of credit hours required in the major and related areas	63-65 cr.
General education coursework	33 cr.
Total number of credits for required coursework	96 - 98 cr.
Free electives	22 -24 cr.
Total credits required for the degree	**120 cr.**

Degree Requirements B.S. in Chemistry with Concentration in Biochemistry

Core Courses in Chemistry	
CHEM 1300 - General Chemistry I	4 cr.
CHEM 1400 - General Chemistry II	4 cr.
CHEM 2000 - Organic Chemistry I	4 cr.
CHEM 2100 - Organic Chemistry II	4 cr.
CHEM 2400 - General Analytical Chemistry	4 cr.
CHEM 3030 - Biochemistry I	3 cr.
CHEM 3040 - Biochemistry II	3 cr.
CHEM 3060 - Biochemical Techniques	3 cr.
CHEM 3200 - Physical Chemistry I	4 cr.
CHEM 3600 - Descriptive Inorganic Chemistry	3 cr.
CHEM 4750 - Chemistry Seminar	3 cr.
Sub-Total	**39 cr.**
Required Courses in Related Disciplines	
PHYS 2300 - General Physics I	4 cr.
PHYS 2400 - General Physics II	4 cr.
MATH 1300 - Precalculus	4 cr.
MATH 2300 - Calculus I	4 cr.
MATH 2400 - Calculus II	4 cr.
BIOL 1800 - General Biology I	4 cr.
BIOL 2800 - Genetics	4 cr.
Sub-Total	**28 cr.**
Total number of credit hours required in the major and related areas	67 cr.
General education coursework	33 cr.
Total number of credits for required coursework	100 cr.
Free electives	20 cr.
Total credits required for the degree	**120 cr.**

Degree Requirements B.S. in Chemistry with Initial Teacher Licensure (8-12) & Minor in Middle School and Secondary Education

Core Courses in Chemistry	
CHEM 1300 - General Chemistry I	4 cr.
CHEM 1400 - General Chemistry II	4 cr.
CHEM 2000 - Organic Chemistry I	4 cr.
CHEM 2100 - Organic Chemistry II	4 cr.
CHEM 2400 - General Analytical Chemistry	4 cr.
CHEM 3200 - Physical Chemistry I	4 cr.
CHEM 3600 - Descriptive Inorganic Chemistry	3 cr.
CHEM 3030 - Biochemistry I	3 cr.
CHEM 4750 - Chemistry Seminar	3 cr.
Sub-Total	**33 cr.**
Required Courses in Related Disciplines	
PHYS 2300 - General Physics I	4 cr.
PHYS 2400 - General Physics II	4 cr.
MATH 1300 - Precalculus	4 cr.
MATH 2300 - Calculus I	4 cr.
MATH 2400 - Calculus II	4 cr.
BIOL 1800 - General Biology I	4 cr.
Sub-Total	**24 cr.**
Minor Requirement	
CHEM 1860 - Introduction to Education 5-12	3 cr.
CHEM 3015 - Methods of Teaching Chemistry (8-12) I	3 cr.
CHEM 4850 - Methods in Teaching Chemistry (8-12) II	3 cr.
EDUC 2011 - Diversity in Education (5-12)	3 cr.
EDUC 2012 - Teaching the Adolescent Learner (5-12)	3 cr.
SPED 3800 - Inclusive Instruction (5-12)	3 cr.
Sub-Total	**18 cr.**
Licensure Courses	
CHEM 4012 - Practicum Seminar (5-12)	3 cr.
CHEM 4860 - Practicum in a Secondary School I	4.5 cr.
CHEM 4870 - Practicum in a Secondary School II	4.5 cr.
EDUC 3122 - Sheltered English Immersion	3 cr
Sub-Total	**15 cr.**

Total number of credit hours required in the major and related areas	90 cr.
General education coursework	30 cr.
Total number of credits for required coursework	120 cr.
Free electives	0 cr.
Total credits required for the degree	**120 cr.**

Requirements for a Chemistry Minor

CHEM 1300 - General Chemistry I (Lecture & Lab)	4 cr.
CHEM 1400 - General Chemistry II (Lecture & Lab)	4 cr.
CHEM 2000 - Organic Chemistry I (Lecture & Lab)	4 cr.
CHEM 2100 - Organic Chemistry II (Lecture & Lab)	4 cr.
CHEM 2400 - General Analytical Chemistry (Lecture & Lab)	4 cr.
One additional course selected from any 2000 level or higher CHEM course	3-4 cr.
Total	**23-24 cr**

Graduate Courses offered in Chemistry

Graduate courses in chemistry are focused on providing degree opportunities to chemistry teachers seeking advancement in their teaching licenses. We offered a M.Ed. Science Education program that included a curriculum required for high school teachers to advance from a chemistry initial license (8-12) to a chemistry professional license (8-12). Due to consistently low enrollments the last few years, the M.Ed. in Science Education degree program was suspended by the administration. We are currently in teach-out mode with our last remaining enrolled students. Moving forward, we hope to collaborate with the M.Ed. in Curriculum and Teaching program offered by the Education Department to find a pathway for chemistry teachers seeking professional licensure. Due to the small size of the chemistry department, a more research-intensive degree such as the MA in Chemistry is not offered. Here is a list of graduate courses that have been offered in the last few years:

- CHEM 800X- Forensic Chemistry (Fall 2013)
- BIOL/CHEM 7003-Food Chemistry/Food Science (Summer 2015)
- BIOL/CHEM 700X- Medicinal Chemistry (Spring 2015)
- SCED/CHEM/BIOL 7011 Building a Global Garden (Lowell School District Grant, Summer 2016)
- BIOL/CHEM 800X- Proteomics (Summer 2016)
- BIOL/CHEM 9011- Seminar in Scientific Research (Spring 2017)
- SCED/CHEM/BIOL 7012 - All that Matters (Lowell School District Grant, Spring 2017)
- CHEM 8008- Got Milk? The Science of Lactose (Summer 2018 & 2020)
- CHEM 8001- Science Sleuths: Using Models and Data (Spring 2018)
- BIOL/CHEM 800X- Environmental Chemistry (Fall 2019)
- BIOL/CHEM 800X Proteomics (Summer 2021)

5. Internal demand of the program or department

a. Service courses

There is significant internal demand for chemistry classes on campus. The chemistry program continues to offer a number of critical courses for many disciplines. Several of the core chemistry courses are required courses for all of the Biology majors seeking a BS. These include General Chemistry I & II (CHEM 1300 &1400), and Organic Chemistry I & II (CHEM 2000 &2100). All of these courses are also taken by the biology majors seeking the BA degree, except for Organic Chemistry II. Additionally, the biochemistry sequence of courses (Biochemistry I (BIOL/CHEM 3030) & II (BIOL/CHEM 3040) and Biochemical Techniques (BIOL/CHEM

3060)) are cross-listed as biology and chemistry courses and can be taken by both majors. Biochemistry I is a required course for students in the Biology major concentrating in Health Sciences. This concentration actually makes up over half of all biology majors. These courses are currently taught by both chemistry and biology faculty, Billy Samulak and Michael Nosek, respectively. Similarly, another advanced elective course, Medicinal Chemistry, is also cross-listed in both programs and is taken by both biology and chemistry majors.

General Chemistry I and II are required courses for Environmental and Earth Science majors (Earth and Geographic Science Department), and within the Clinical Exercise Physiology major of the Exercise and Sports Sciences Department (for Pre-Physician Assistant, Pre-Physical Therapy, and Pre-Athletic Training).

General Chemistry I is required for two concentrations in the Engineering Technology Program (Electronic Engineering Technology and Manufacturing Engineering Technology), as well as Fitness Management majors in the Exercise and Sports Science program. We are currently working with the Dept. of Communications Media who plan to require Chemistry in a Changing World as a required course in their new Public Relations minor, given the focus this class has on climate change, new technologies, green chemistry, and reducing carbon footprints.

b. Enrollment in Service Courses

Chemistry for Health Sciences is a course that is used by the Nursing Department, one of the largest departments in the University, and for the Environmental Public Health program in the Earth and Geographic Science Department. Chemistry for a Changing World is an introductory course that is open to all university students to be used as a General Education requirement for Scientific Inquiry. And finally, chemistry faculty assist other departments with specific courses. Table 1 shows enrollment in the service courses since spring 2015. There are two courses entitled Environmental Chemistry and Introduction to Education 5-12 that are taught in the Honors Program and the Education Program, respectively, that chemistry faculty members share with other professors on an as needed basis.

Table 1: Cumulative Enrollments in Fall and Spring courses from 2015-2021 in Service Courses Provided by the Chemistry Department

Course Name & Number	FALL	SPRING	TOTALS
Chemistry in a Changing World (CHEM 1000)	96	64	120
Chemistry for Health Sciences (CHEM 1200)	400	389	789
General Chemistry I *# (CHEM 1300)	720	247	967
General Chemistry II *$ (CHEM 1400)	34	568	602
Organic Chemistry I * (CHEM 2000)	436	Not offered	436
Organic Chemistry II * (CHEM 2100)	Not offered	336	336
Biochemistry I *% (BIOL/CHEM 3030)	190	74	264
Total Students (Contacts) in Chemistry Services Courses 2015-2021			3514

***** Majority of the students enrolled in these classes are from majors such as Biology and Exercise and Sport Sciences, Chemistry majors make up less than 10% of students in these classes, typically.
# Offered in both Fall and spring semesters in all years in this review period
$ Offered in the fall semesters of 2019, 2020 and 2021
% Was not offered in spring 2016, 2018, 2020 and 2021

c. Learning Outcomes in Service Courses

Representatives from the Department of Biology and Chemistry, including Chemistry faculty, have been active participants in both the assessment of the service courses that counted towards the old Liberal Arts and Sciences curriculum, and in the design and implementation of our new General Education Curriculum as members of the Liberal Arts and Sciences Council and the All University Committee Curriculum Committee. Assessment of the prior LA&S Outcome associated with Chemistry, Problem Solving, was last conducted in the fall of 2013 prior to the time-frame for this review. The review of the LA&S Curriculum was completed using this data in 2015. The LA&S Council, with representation from the Chemistry faculty, engaged in a 4 year process of curricular redesign that was approved by the AUC in 2019 for full implementation in Fall 2021. From 2019 to 2021 the Chemistry Faculty sought and successfully received approval from the AUC to have a number of service and major courses designated for the new Scientific

Inquiry and Analysis and Procedural and Logical Thinking designations and as building on those outcomes and the Quantitative Reasoning outcome, meaning they have to build on necessary math skills. Advanced Integrating and Applying Learning courses building on the Scientific Inquiry and Analysis and Procedural and Logical Thinking skills developed in General Chemistry I and II at a more advanced level. The University has begun to develop an assessment plan for the new General Education curriculum with assessment of Scientific Inquiry and Analysis planned to begin in 2023, Procedural and Logical Thinking and Quantitative Reasoning in 2024, and Integrative Learning by 2025. Chemistry faculty plan to be active participants in the General Education Communities of Practice that are being established in 2022 to design and implement these assessments. The Course Objectives and General Education Curriculum Guidelines for Scientific Inquiry and Analysis and Procedural and Logical Thinking can be found in **Appendix S.**

The new General Education designations for our chemistry courses as approved by the AUC (2021) are listed below:

Scientific Inquiry and Analysis (SI):
-CHEM 1000 (Chemistry in a Changing World)
-CHEM 1200 (Chemistry for Health Sciences)
-CHEM 1300 (General Chemistry I)
-CHEM 1400 (General Chemistry II)

Procedural and Logical Thinking (PL):
-CHEM 1300 (General Chemistry I)
-CHEM 1400 (General Chemistry II)

Advanced Integrating and Applying Learning (AIA):
-CHEM 2000 (Organic Chemistry I)
-CHEM 2100 (Organic Chemistry II)
--CHEM 4900 (Independent study in chemistry)

6. Departmental and Program Initiatives

Because this is our first program review as a stand alone Chemistry Program, we do not have any action items to incorporate from a previous review. The newly approved Chemistry major officially began in AY14/15 with two degrees in the program. These included the Chemistry B.S. and Chemistry Secondary Education with Initial Teacher Licensure, B.S. Over the intervening years, numerous changes have been made to the program. Additionally, In AY19/20 the Biochemistry concentration B.S. was added. In AY20/21, the education degree was revised to the Chemistry with Initial Teacher Licensure in Secondary Education (with a Minor in Middle School and Secondary Education). This coincided with the university's change to the General Education curriculum from the former LA&S curriculum.

Several new courses were introduced and existing courses were modified to better serve the needs of our students. Significant curricular changes were required to be made by submitting proposals to the All

University Committee (AUC). Proposals also get reviewed by the Curriculum Committee (a subcommittee of the AUC). A recommendation is made to the full AUC who forwards the proposal to the President for a final decision on approval or disapproval.

Here is a list of new courses that were developed :

1. Foundations of Biochemistry (CHEM 3030 and cross listed as BIOL 3030) - created in AY 14/15
2. Introductory Research (CHEM 1600) - created in AY 15/16
3. Biochemistry II (CHEM 3040 and cross listed as BIOL 3040) - created in AY 18/19
4. Biochemical techniques (CHEM 3060 and cross listed as BIOL 3060) - created in AY 18/19
5. First Year Experience (FYE) course - created in AY 18/19
6. Environmental Chemistry - Offered as a topics course and currently seeking AUC approval

The department initiated several measures to identify and correct deficiencies in the freshman year itself, so that students will successfully graduate in a timely manner. These measures necessitated modifications to several existing courses. In addition, new courses were added to existing concentrations. The courses/concentrations that were modified are listed in Table 2.

Table 2: Chemistry Course and Program Modifications made through AUC Approval

Name of the course/concentration and year modified	Modification
Physical Chemistry I (2015)	Adding Calculus I and II prerequisites and minimum grade of 1.7 in Gen Chem II and removal of Organic Chemistry II as a prerequisite
Chemistry Secondary education with initial licensure (2015)	Addition of Sheltered English Immersion (SEI) course
Foundations of Biochemistry (2016)	Change prerequisites from General Biology I and Organic Chemistry II to General Biology I and Organic Chemistry I
General Chemistry II(2017)	Addition of Basic Mathematics II as a prerequisite
General Chemistry II (2019)	Minimum grade of 2.0 must be achieved in this course to continue as a CHEM major
Foundations of Biochemistry (2019)	Name change to Biochemistry I; Required course for all chemistry majors
Chemistry Secondary education with initial licensure (2020)	All students must complete a minor in middle school and secondary education and complete 15

	credits of licensure courses (including practicum as well as sheltered english immersion courses)
Methods of teaching Science	Name change to Methods of teaching Chemistry; Course content has been modified to address select biology, chemistry and general science subject matter knowledge required by ESE

a. Interdisciplinary Courses

Several faculty in our department offer interdisciplinary courses: Biochemistry I and II, Biochemical Techniques, Medicinal Chemistry, Environmental Chemistry, along with topics courses such as “Got Milk?” and Proteomics. Our faculty have taught some of these at the graduate level for teachers, along with courses such as Science Sleuths: Using Models and Data. Many of these courses combine biology and chemistry, and some combine earth science and chemistry. These classes emphasize real-world applications, as examples the Flint water crisis, the use of lactase in lactose intolerant individuals, and drug design and discovery. Many of these classes have been taught for current chemistry and biology teachers, providing them relevant content to proceed with their professional teaching licenses, and provide content for use in their classrooms. Our faculty have participated in federally funded projects such as the Lowell Public School’s grant to provide these types of interdisciplinary classes in public schools for local teachers as well. We also teach environmental science as an Honors seminar for all majors, including nonscience majors.

The department participates in interdisciplinary research, particularly with the Nashua River project. The this externally funded project combined biology, chemistry, math, and earth and geographic science faculty to study the health of the Nashua river watershed. Each faculty member worked with students using their own individual expertise to provide a comprehensive picture of the health of the river. Collaborations occur across disciplines with collaborators both on and off campus. The department also sponsors a Biology and Chemistry club with students from several majors participating in events.

The nature of our biochemistry concentration is a very interdisciplinary program with required courses in math (12 credits), biology (8 credits) as well as courses that are cross listed as biology and chemistry (9 credits). We have begun initial investigations into further interdisciplinary programs with computer science.

b. Course Delivery Mechanisms

Prior to the COVID pandemic, the majority of our chemistry courses were taught in a traditional manner with face-to-face lectures and labs. In the General Chemistry sequence, all professors use the same textbook, Sapling / Achieve on-line homework and do the same set of laboratory experiments. Instructors mix traditional lecture with in-class problem solving. In the Organic Chemistry sequence, instructors have switched from a traditional textbook to using the Top Hat platform and a semi-flipped classroom. From 2015

- 2019, General Chemistry I and II have been taught as hybrid courses in the summer (on-line lectures and in-person labs).

Faculty adapted well to on-line delivery of their courses in Spring 2020. Some lab-intensive higher-level courses such as Physical Chemistry and General Analytical Chemistry were difficult to adapt, but instructors strove to give students a lab experience, even if it was not optimum. Summer 2020 and 2021 courses (General Chemistry and Organic Chemistry sequences) were taught exclusively on-line. The General Chemistry lab sequence was delivered using the Beyond Labz and other lab simulators. In Fall 2020 and Spring 2021, classes were taught in a variety of modes; fully face-to-face, hybrid and fully on-line with a return to all face-to-face classes in Fall 2021.

c. Service Learning and Outreach

Faculty in the Chemistry program are also actively involved in community outreach and service learning. Some of the projects and programs that our faculty are involved in are listed under the "faculty" section of this document.

III. Assessment

1. Program Inputs

a. Program reputation

One of the main distinguishing characteristics of the chemistry program at FSU is that we enjoy the shared advantage of all public universities: affordable tuition. Besides affordability, the program serves a student population that is drawn mainly from the North Central MA area. Most of the chemistry majors, just like their counterparts in biology, are commuters coming from towns within a 15 mile radius of Fitchburg. One of the biggest strengths of our program is our small class size, which promotes better faculty-student relationships. Students gain hands-on experience using a variety of instruments in our chemistry labs, which again is feasible due to our small class size.

The Bachelor of Science degree in Chemistry is congruent with the curricular recommendations of the American Chemical Society (ACS) and provides a strong background in the modern areas of chemistry including biochemistry with emphasis on hands-on laboratory work. The program is designed for pre-professional students who intend to pursue graduate studies, secondary school teaching, or a professional career in the chemical, pharmaceutical, biotechnology or related industry. It also provides opportunities for students to conduct independent research under the guidance of the faculty. Students also develop good communication and leadership skills. In addition, the degree program prepares students for further education in health sciences, such as medicine, dentistry, pharmacy, veterinary medicine, optometry and other health professions provided they take the necessary prerequisite courses for professional schools.

During the last two decades Massachusetts has seen an increase in chemical, biotechnology, and pharmaceutical industry and the demand for qualified chemists to accept professional positions. Graduate chemistry departments of the universities in the New England area are increasingly looking for qualified students to enter their M.S. and Ph.D. programs. Additionally, the demand for teachers certified to teach chemistry and other physical science subjects is also increasing and has been exacerbated by the COVID pandemic. The chemistry degree program at Fitchburg State University is designed primarily to meet these demands by having a curriculum that is based on the recommendations of the ACS. Expected learning outcomes include competencies in the five primary areas of chemistry - analytical, inorganic, organic, physical chemistry and biochemistry. Additional competencies will also be gained in (1) laboratory safety and green chemistry, (2) chemical literature and information retrieval, (3) developing effective written and oral communications skills, and (4) professional ethics. Students will also receive training in related fields, such as mathematics and physics.

The ACS Committee on Professional Training (CPT) has provided detailed curricular expectations for the foundation courses in the five sub-fields of chemistry and for the advanced course work and laboratory experience (see **Appendix D**). The chemistry courses we teach follow these guidelines and are scrutinized by the departmental curriculum and assessment committees to ensure that we are meeting our objectives and maintaining high expectations for our students.
Furthermore, the curricular plan followed by the Chemistry Program's B.S. Degree with Initial Licensure meets all Subject Matter Knowledge (SMKs) standards for High School Chemistry teachers as established by the Massachusetts Department of Elementary and Secondary Education (DESE). The mapped out SMKs that align with specific Chemistry courses can be seen in **Appendix E.** The concepts covered in the core chemistry curriculum allow students to successfully prepare for the Chemistry MTEL (Massachusetts Test for Educator Licensure) by meeting and addressing concepts outlined in the Massachusetts STEM Frameworks for 9-12 science education.

In our classes, both undergraduate and graduate students are assessed in multiple ways. Although we use more traditional methods like homework, quizzes, exams, and lab reports, we also use creative assignments such as designing games around biochemistry topics, formal debates on current environmental chemistry issues, in-house poster presentations of student research. Because of our small class sizes, students have the opportunity to visit regional chemistry companies, tour academic labs, and use equipment not available at FSU in our upper level classes.

Chemistry majors and minors are employed as chemists in biotechnology, chemical, and pharmaceutical firms and as high school teachers. Both Chemistry majors and minors in our program could assume many of these positions. Projections for Massachusetts estimate that Chemist positions will grow 3.83% per decade (Table 3). The data in Tables 3 & 4 show a need for chemists in Massachusetts that our program and help to fulfill.

Table 3. Massachusetts Department of Unemployment Assistance Labor Market Information 10 year forecast (2018 – 2028).

Position	Number of positions 2018	Annual openings	Percent change per decade	Annual mean income
Chemist	**3,864**	**369**	**3.83%**	**$100,480**
Post-secondary chemistry teacher	**893**	**80**	**4.03%**	**$109,600**
https://lmi.dua.eol.mass.gov/lmi/STEMOccupationalProjections				

A quick search of job advertisements in Monster.com showed that there have been over 175 job postings for chemists in the biotechnology, chemical, and pharmaceutical firms, and 26 postings for chemistry secondary education teachers just in the state of Massachusetts on School Spring high school just within the last 2 months (Since 11/17/21). This demonstrates a need for trained chemists and biomedical scientists to support the growing pharmaceutical and biotechnology industry and research in the Commonwealth. Furthermore, it is common knowledge that we are experiencing a STEM teacher shortage across the state which has been worsened by the pandemic. A great majority of the students attending Fitchburg State are residents of the Commonwealth and, therefore, we will be training MA residents for jobs within the state. This number is even greater across the country and employment numbers for Chemists in 2020 nationwide are outlined in Table 4.

Table 4: 2020 National Employment Matrix	**Chemists**
Employment, 2020	85,400
Employment, 2030	91,100
Employment change 2020-2030	5700
Percent employment change 2020-2030	6700
Percent self employed, 2020	300
Occupational openings, 2020–30 annual average	8400
Median annual wage, 2020(1)	$79,300
Typical education needed for entry	Bachelor's degree
Work experience in a related occupation	None
Typical on-the-job training needed to attain competency in the occupation	None
https://www.bls.gov/emp/tables/occupational-projections-and-characteristics.htm	

b. Students by program

Trend data for the Chemistry program since 2013 can be seen in Table 5.

Chemistry Trend Data										
Undergraduate Day										
	AY 13	AY 14	AY 15	AY 16	AY 17	AY 18	AY 19	AY 20	AY 21	Trend
Total Enrollment in CHEM classes	**838**	**904**	**1,015**	**1,187**	**1,226**	**1,146**	**1,109**	**961**	**714**	
Total Enrollment in All Classes	32,683	33,952	34,081	34,062	34,169	34,257	33,695	31,983	27,479	
Percentage of total enrollment: Biology/Chem classes	**2.56%**	**2.66%**	**2.98%**	**3.48%**	**3.59%**	**3.35%**	**3.29%**	**3.00%**	**2.60%**	
Graduates in the Major										
Chemistry, B.S.	0	0	0	0	2	5	4	6	2	
Graduates in the Minor										
Chemistry Minor	18	10	14	13	18	9	11	11	6	
Number of Majors[2]	**0**	**3**	**11**	**18**	**31**	**29**	**30**	**25**	**15**	
Chemistry B.S.	0	3	10	18	31	28	27	24	13	
Chemistry with Initial Teacher Licensure (8-12), B.S.	0	0	1	0	0	1	3	1	2	
Overall declared majors[3]	3,748	3,824	3,806	3,840	3,862	3,837	3,805	3,604	3,287	
Percentage of overall declared majors	**0.00%**	**0.08%**	**0.29%**	**0.47%**	**0.80%**	**0.76%**	**0.79%**	**0.69%**	**0.46%**	
Number of incoming freshmen majors	0	2	3	3	6	4	5	3	2	
Number of incoming transfer majors	0	0	5	1	3	2	7	4	2	
Number of Minors										
Chemistry Minor	46	36	40	51	36	30	31	22	23	
Retention Rates[5]										
Number in the Cohort	0	0	0	2	3	6	4	5	3	
Retention Rate in Major				50.00%	100.00%	100.00%	25.00%	80.00%	66.67%	
Retention Rate Changed Major				0.00%			25.00%	20.00%	0.00%	
Retention Rate in Major Institutional	57.91%	62.52%	62.15%	58.75%	62.36%	65.17%	61.38%	61.71%	62.99%	
Retention Rate Changed Major Institutional	16.11%	15.56%	15.19%	16.11%	12.55%	12.80%	11.98%	11.78%	13.58%	
Undergraduate Evening										
	AY 13	AY 14	AY 15	AY 16	AY 17	AY 18	AY 19	AY 20	AY 21	Trend
Total Enrollment in CHEM classes	**39**	**18**	**101**	**83**	**78**	**55**	**35**	**45**	**36**	
Total Enrollment in All Classes	3,879	4,015	4,103	3,750	3,510	3,759	3,798	4,454	4,406	
Percentage of total enrollment: CHEM classes	**1.01%**	**0.45%**	**2.46%**	**2.21%**	**2.22%**	**1.46%**	**0.92%**	**1.01%**	0.82%	

The number of majors in our program peaked at 31 in AY2017 and stayed steady for a few years until COVID hit in 2020. We still remain a low percentage for majors across the university. For a number of reasons, students dropped out of classes and many programs during the pandemic, including Chemistry. The number of chemistry minors peaked at 51 in AY2016, but has been in a steady decline. Faculty in our department have increased our efforts to recruit Chemistry minors within the last year or two.

The Chemistry student graduation rates in 2021 were 100% while the overall institutional graduate rates for Fitchburg State were 57%. We had 0% in 2020 possibly due to delays caused by online learning and the pandemic. For reference, Fitchburg State's institutional graduation rates for 2017, 2018, 2019, and 2020 were 60%, 61%, 58%, and 58%, respectively. Our graduation rates are calculated based on the incoming freshman cohort that take less than six years to complete.

According to Fitchburg State University enrollment data, on average, there were 3.5 incoming freshman majors and 3.0 incoming transfer majors into the major each academic year can be seen in Figure 1.

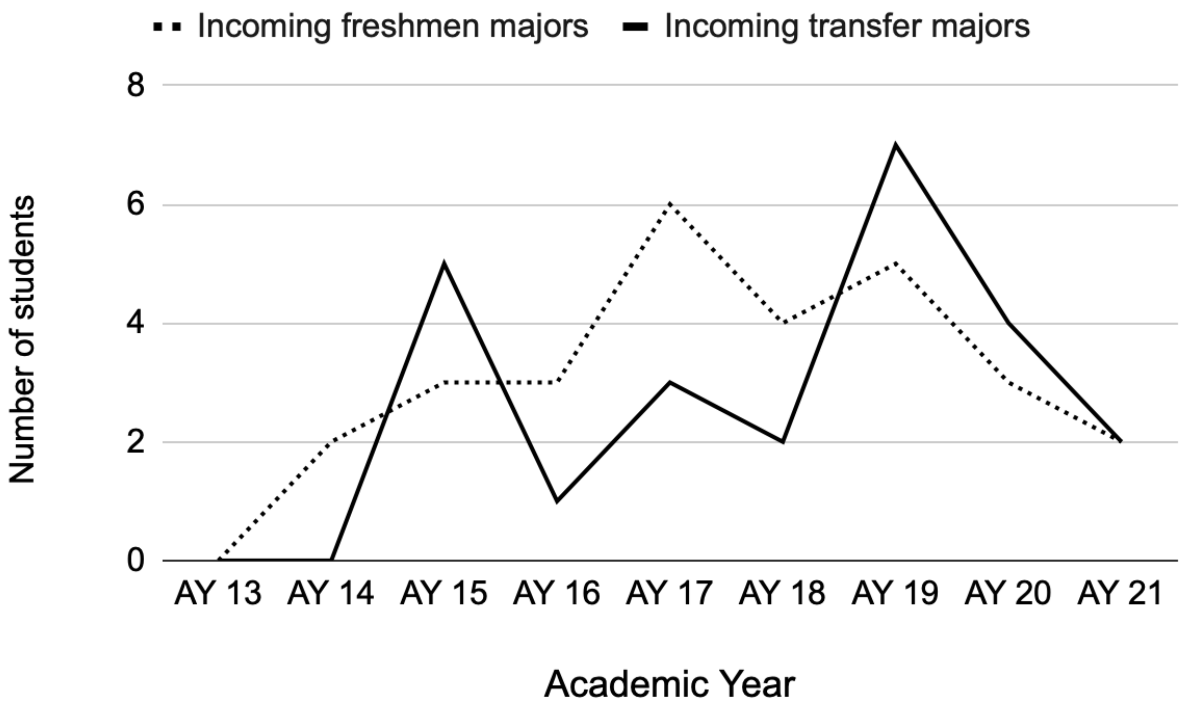

Figure 1. Number of incoming freshmen and transfer chemistry majors by academic year.
CHEM Trend Data 10_14_21.xlsx (Source: FSU Office of Institutional Research and Planning)

In 2016, faculty in our department looked at trend data and found that students who did not pass General Chemistry I with a 1.7 or higher tended to linger in the program without being successful. To improve retention and graduation rates, we implemented several policy changes within our program. These were meant to serve as early intervention strategies to "retrack" students into other majors vs. letting them fail out. For example in AY16/17, the minimum grade that students were required to achieve in General Biology I and General Chemistry I was changed from a 1.7 to a 2.0 before moving on to other courses. Additionally, we have also limited the number of times a student may take General Biology I and General Chemistry I to two attempts. Failure to achieve a 2.0 in their second attempt (or withdrawing from the course) now results in the student being removed from the major. However, we ensure that they advised on viable options for majors in other departments.

We also did this due to changes in enrollment and admission requirements of the university. We no longer require SAT scores to get into Fitchburg State. Furthermore, our department has no high school GPA requirement for enrollment in our major. Because of this, we often find that some students are not as prepared for college science (including biology and chemistry) as they should be. Our goal at Fitchburg State is to "meet students where they are". Strategies on how we try to build student math skills and preparedness for classes so that we can retain the student we have is discussed later in this document.

However, if students struggle to pass even with our interventions in place, then we advise them on a different major.

We currently have 20 students listed as chemistry minors. Figure 2 shows an overall decrease in both Chemistry majors and all majors across the university since 2013.

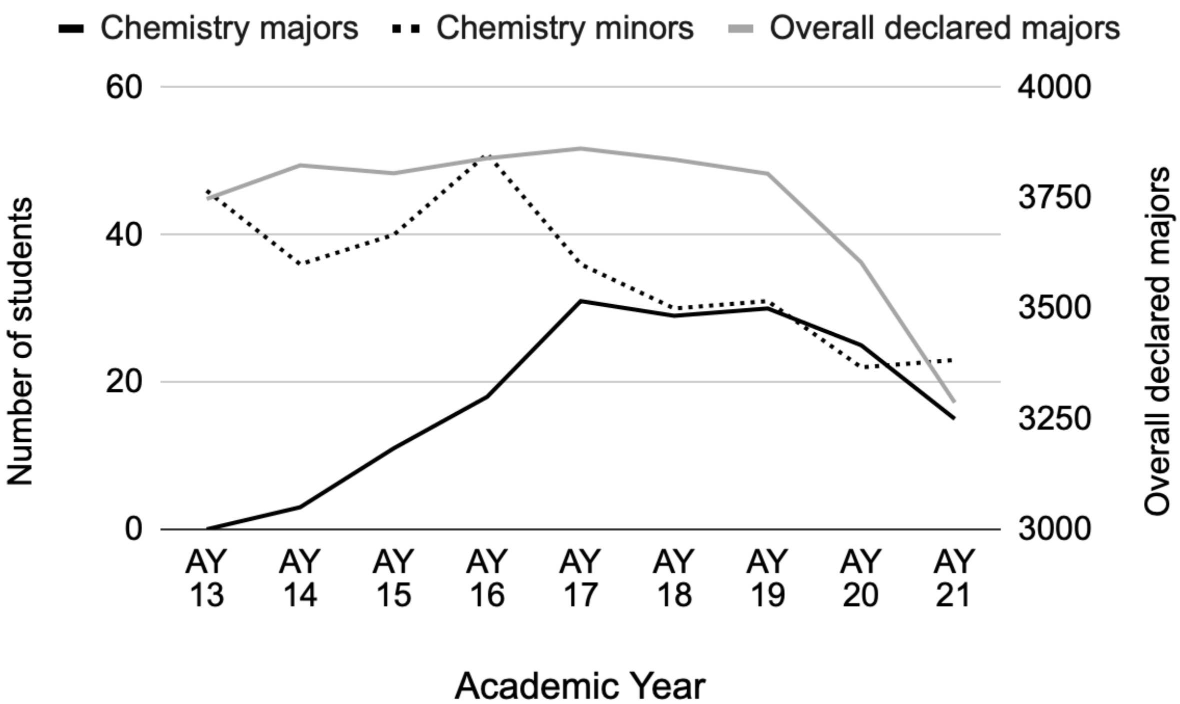

Figure 2. Number of Chemistry majors and minors by academic year.

These data were collected by the Office of Institutional Research at Fitchburg State. Like many other universities, we are experiencing an enrollment decline with a loss of almost 600 full time students over the last 7 years across all university departments. Nationwide, this enrollment “cliff” has already started and is the result of the early 2000’s recession and will likely continue well into 2035 according to the Education Advisory Board (EAB) and other sources. (https://eab.com/insights/expert-insight/enrollment/the-demographic-cliff-is-already-here-and-its-about-to-get-worse/). Many of our students also come as transfer students from local community colleges, which are experiencing even higher drops in enrollments than 4-year institutions. According to a recent Boston Globe article, community colleges across Massachusets have seen the lowest enrollments in over 20 years (https://www.bostonglobe.com/2021/11/29/metro/community-college-students-struggle-return-their-studies/#:~:text=Community%20college%20enrollment%20nationwide%20has,students%2C%20which%20fell%208%20percent.).

Low enrollments call for increased retention and recruitment efforts. Our faculty have been involved with recruitment events, such as high school visits, open houses, and outreach events such as workshops and seminars. Although these events may help bring in a few interested students, a dramatic shift in recruitment is needed. Recently, Fitchburg State hired its first Associate Vice President for Enrollment Management, Dr. Richard Toomey. The Department of Biology and Chemistry has already met with Dr. Toomey to discuss recruitment strategies that will require out-of-the-box thinking to entice and retain students. For example, we will begin giving department tours this semester which include inviting students to sit in on a science lecture while visiting campus. Furthermore, we have begun "twilight" tours in the evening and will continue to engage in new and exciting recruitment efforts for both traditional and non-traditional students. We are trying to expand our early college and dual enrollment high school programs across the university. Efforts and discussions to implement new strategies are still underway.

According to our enrollment data, the Chemistry program accepts a diverse population of students. Currently, there are 13 chemistry majors enrolled in Spring 2022 classes. Four students are in the biochemistry concentration and 1 student is enrolled in the secondary education degree program. .

Race and ethnicity data for AY 17 and AY 21 showed that 45% of chemistry majors were non-white and 55% were white. In 2017 there were 14 men vs. 3 women in the chemistry major. In 2021, male and female students made up similar proportions of chemistry majors (55% and 45% respectively). These data can be seen in Table 6. Fitchburg has a relatively large traditionally underserved undergraduate student population. In 2021, 40.5% of students identified as first generation and 34.8% were Pell grant recipients.

Table 6: Majors by Gender Race & Ethnicity in the Day Program

	Majors by Gender and Race/Ethnicity (Day)					
	AY 17			AY 21		
	Male	Female	Total	Male	Female	Total
American Indian or Alaskan Native	0	0	0	1	0	1
Asian	2	2	4	0	0	0
Black or African American	1	4	5	0	3	3
Hispanic	4	0	4	1	1	2
More than one	0	0	0	0	0	0
Native Hawaiian or Pacific Islander	0	0	0	0	0	0
Unknown	0	1	1	0	0	0
White	14	3	17	5	4	9
Total	**21**	**10**	**31**	**7**	**8**	**15**

c. Faculty

There are currently 6 full-time chemistry faculty members. No part time or adjunct faculty were needed for AY20/21. A faculty diversity and FTE committee by program can be seen in **Appendix F.** Since 2015, we have used the services of 8 different adjunct faculty to teach mostly non-majors courses like Chemistry in a

Changing world and Chemistry for Health Sciences. Eight adjuncts also assisted in teaching some General Chemistry I and II courses. We do not have comprehensive CVs for our adjunct faculty, however, requirements include a Ph.D. in chemistry or related field. A list of adjunct faculty can be found in **Appendix G.**

The Chemistry faculty members at Fitchburg State are highly qualified individuals committed to the primary mission of helping students develop a strong working knowledge of all the chemistry subdisciplines and the use of appropriate laboratory skills and instrumentation. In order to achieve this overarching goal, the faculty remain committed to a strong curriculum that will prepare students for careers and advanced study, remain active in their disciplines, provide curricular offerings appropriate for other majors on campus, and are active participants in not only the university community but the larger community as well. As a group, the faculty members remain committed to student learning and willingly integrate new pedagogical approaches and technology into their teaching. The size of our program allows for close relationships with students and advisees within our program, which generates a nurturing supportive environment.

The Biology and Chemistry faculty are active members of the university community as documented by the extensive active service on committees, participation in both on-campus as well as outreach programs, and appointments to active leadership roles. Intradepartmental committees include Curriculum, Assessment, Student Affairs, Peer Evaluation, Equipment and Facilities, and various search committees. The participation and contributions of the faculty members to both the university and greater community are too numerous to review in detail, but should be noted that the faculty members are in general, engaged and active members of both communities. Of particular note is our faculty's participation in the Nashua River Project, Discovery Museum Science Communication Fellow program, FSU- Mount Wachusett Community College Summer STEM programs, 3rd grader chemistry program at the McKay school, Science Symposium, and numerous outreach activities associated with the American Chemical Society (e.g. Chair of Central MA ACS, National Chemistry Week Coordinator, Earth Week Coordinator, Science Coach, Chemistry Olympiad Coordinator). Active research programs are also ongoing as reflected in publications, papers presented, grant writing, and student research.

Our former colleague and Department Chair, Dr. Govindan (who retired in Spring 2020) informally served as the health professions advisor from 2006 to 2020. He developed the Pre-Medical Advising Program and created our Introduction to Health Professional Seminar Course. He also developed an advising handbook and was instrumental in the development and signing of early admission agreements for medical, pharmacy, and dental programs with the Lake Erie College of Osteopathic Medicine (LECOM) and Husson University. Dr. Govindan was department chair from 2014 to 2020.

d. Staff Support

The Biology/Chemistry department has full-time support staff and one part-time that assist in the daily operation of the department as shown in Table 7. Our administrative assistant is a full time employee, but also serves the Biology & Earth & Geographic Studies Depts. The first of the support staff is the full-time administrative assistant (shared with the Earth and Geographical Sciences department) whose duties include providing administrative support to all members of both departments, organizing schedules, coordinating meetings, assigning advisees, monitoring and processing department budgets, evaluations, scheduled appointments and other duties as assigned by the chairs. The administrative assistant's duties also include assisting students with concerns such as registrations, add/drop processes and assisting advisors and students with academic forms. The Administrative Assistant also works with the Graduate and Continuing Education evening, summer, intersession, fall, and spring scheduling. Melissa Barrette was a longtime administrative assistant for the department, but retired in 2018. Her position was filled by our current administrative assistant, Lindsey Babineau.

Table 7. Support staff for the Biology/Chemistry Department.

Staff	Title	Status
Lindsey Babineau	Administrative Assistant (12 month shared with Earth & Geographic Science)	Current
Karen Kowlzan	Lab Technician (10 month)	Current
Melissa Legare	Lab Technician (12 month)	Current
Ian Murray	Lab Technician (~10%) Moved to Nursing, assists with chemical waste	Reassigned to the Nursing Dept. on 9/1/21
Melissa Barrette	Administrative Assistant (12 month, shared with Earth & Geographic Science)	Retired in 2018

Until recently (Fall 2021), there was one 10-month technician (Karen Kowlzan) in chemistry and (Ian Murray) who split his time between Biology and Chemistry and the Earth and Geographic Sciences Department. Since 2014, Ian also worked with the university's Environmental Safety office while he served as the half-time chemistry technician. He was recently reassigned by the Dean of Health and Natural Sciences to the Nursing Department to support their Simulation (SIM) Center. Currently, Karen currently serves as the only technician for chemistry. Ian still assists with chemical safety and hazardous waste.

The duties of the lab technicians include setting up labs, checking safety equipment, stocking lab supplies, ordering chemicals, inventorying, and arranging for yearly maintenance of lab equipment. Since the inception of the Chemistry major, both Karen and Ian collaborated together and provided first-class lab support for the chemistry teaching and research labs. Melissa Legare, who is the only full-time technician, has similar duties as those of the chemistry technicians. Her major duties are related to the biology part of our department. The contributions of the three technicians extend beyond their roles in the department.

They are all engaged in university wide committees. For example, Karen and Ian have been active members of the University's Safety Community. Melissa Legare also contributes significantly to the University's Institutional Biosafety Committee (IBC).

Our talented support staff significantly contributed to our major since its inception, and especially in the last two years during the COVID-19 pandemic. They assisted faculty in creative ways that far exceeded expectations. Together they helped provide safe working conditions both in the labs and in the classrooms.

e. Resources

The Chemistry Department receives funding through 5 sources, 3 operating budgets, Extra-Budgetary Requests (EBRQs), which are now called Strategic Fund Requests, and travel. This is shown in Tables 8 & 9. The base-operating budgets, Chemistry, and Condike Science Center, support the purchase of laboratory, classroom and laboratory supplies, equipment and equipment repair, and hazardous waste removal on a routine basis. The tables below contains the base budgets for biology & chemistry for the last eight years. We are showing both biology and chemistry because often supplies to support chemistry faculty could come out of the Biology budget, which is significantly larger.

Table 8: Approved Budget for Chemistry

Chemistry	FY-21	FY-20	FY-19	FY-18	FY-17	FY-16	FY-15	FY-14
Travel Budget	$0	$2,660	$2,800	$2,800	$4,700	$4,398	$4,247	$3,750
Operating Budget	$37,041*	$39,275	$42,275	$42,175	$42,275	$56,015	$54,953	$40,562
Strategic Funds				$1,500	$7,938	$6,590		

*Originally awarded $39,275, but was reduced mid-year by Finance

Table 9: Approved Budget for Biology

Biology	FY-21	FY-20	FY-19	FY-18	FY-17	FY-16	FY-15	FY-14
Travel Budget	$0	$4,940	$5,200	$5,200	$5,300	$6,514	$6,045	$4,900
Operating	$90,459*	$91,214	$98,610	$103,610	$107,910	$117,042	$108,815	$90,074

Budget								
Strategic Funds	$6,000	6,100	22,315	$5,834	$4,046			

*Originally awarded $91,214, but was reduced mid-year by Finance

The operating budgets are administered through the Department Chair. In addition to the operating budgets, the University supports the administrative costs of the Department. These items include administrative support, departmental technicians, office supplies, postage, phone usage, faculty computers and technical support, duplicating costs, and faculty salaries. Overall, our budgets have decreased over the last five years. The Department received additional equipment funding from the University through the EBRQ and Strategic Funding Requests. These University-wide funds are allocated for purchases that often represent a large one-time purchase of equipment. The Department's Equipment and Facilities Committee solicits input from the faculty and compiles a list of equipment needs based upon curricular needs that are driven by the Department's mission. The request is submitted to the University during the normal budget process.

Faculty travel funds are allocated per faculty member from the University and have remained around $400 per year per full-time member due to the MSCA Contract; faculty must apply for these funds. During COVID, there was no travel money. The Department has always maintained a policy of assigning funds according to need thereby covering the majority of costs when faculty travel. If travel requests exceed available funding, priority is given to junior faculty or to those faculty who are presenting at meetings. Faculty also have an annual professional development stipend that may be used for travel although that has been reduced over the last fiscal year due to budget restrictions brought on by COVID. Faculty can also apply for additional funding for travel through the Academic Affair's Professional Development Grants.

Purchasing of supplies and equipment for the Department is coordinated by the support staff. General lab supplies are monitored and purchased by the technicians on an as needed basis. Each semester, specific course needs are submitted to the lab technicians by individual faculty members. Because the supply needs for each course varies, there is no specific allotment of funds on a per course basis. Rather there is a single pool for all courses within each discipline. Additionally, all chemical purchases are reviewed and approved by the campus Environmental Safety officer in accordance with the University's Chemical Hygiene Plan.

The purchase of equipment, equipment repair, and hazardous waste removal are centralized under the supervision of the technical support staff. The system is effective and fairly efficient. In recent years the Department Chair has worked with support staff to set up regular equipment maintenance schedules (e.g. GC-MS instrument, IR spectrophotometer, microscopes, pipet aids). We now have a rotating schedule for the replacement of some of the standard equipment items (e.g. microscopes, balances, vortexes, pH meter, etc.). Routine maintenance, which includes cleaning and calibration of analytical balances, is carried out by our lab technician. This has been a very effective innovation and makes the budget request process much more efficient and predictable.

Technology and Equipment

The Department possesses a diverse and very extensive array of equipment for all of the courses. The new Science Complex has provided a lot of new or upgraded equipment. Some of the new pieces of equipment have service contracts which we deem essential for ensuring proper functioning of the equipment and extending their lifespan. In addition to equipment needed in the teaching laboratories, we have an extensive range of research grade equipment which are summarized in the paragraphs below.

One of the strategic goals of the university is to modernize and improve the science facilities and programs. The approval of the chemistry major coincided with the construction of a new science building with brand new lecture areas and laboratories. Over the last seven years, the program has acquired several new equipment such as Atomic absorption spectrophotometer, UHPLC, potentiostat/Galvanostat, UV-Vis spectrophotometers and upgraded the IR spectrophotometer for teaching and research use.

There are several spectrophotometers: UV-vis, NMR, IR, Vis, Atomic absorption which are generally used for teaching and research. Other research grade equipment include a GC-MS spectrometer, several GC instruments, HPLC, UHPLC and a potentiostat/Galvanostat. All the lab instruments are accessible by faculty and students for both classroom and independent studies. The biology teaching and research labs are equipped with several research equipment that chemistry faculty and chemistry students have used in collaborative research. Some of the equipment include: a plant growth chamber, fraction collectors, platform rocker, automated cell counters (2 different types), three research grade fluorescent microscopes, (inverted, upright, and dissecting), plate reader, plate washer and motorized cryostat. There is a microscope suite that houses three research-grade microscopes - inverted, upright, and dissecting. Each has fluorescence capabilities, with dedicated digital cameras and computer-based software for data collection and image analysis.

The department is well appointed in terms of field equipment, with a wide-range of research-grade meters for accessing water quality (e.g. Salinity Meter, pH Probe, Turbidity Meter and Dissolved Oxygen Meter).

Although we have access to the equipment, many of our machines are not under service contract or and are getting old and unreliable. For example, the only piece of equipment that is currently under contract is our FTIR and our NMR machine was used (demo model) when we purchased it in November of 2008. The software for our EFT Spectrometer has not been updated since 2016 and our Agilent GC-MS literally died last week (Feb 20, 2022).   Getting a new GC-MS is now our highest priority and we have already requested funds for that through an extra budgetary request.

As stated above, extra budgetary requests (EBRQs) can be used to purchase supplies and equipment to support teaching and research activities. These “open up” yearly around mid-February and typically require departments to prioritize large purchases. Our department has sent numerous requests through the EBRQ/ Strategic Funding pipeline over the last few years. Some of the requests have been approved, and while others were not recommended for funding even though they were needed.

In AY 2014-2015 Dr. Steven Fiedler was awarded an EBRQ award of $6,590 for the purchase of the Evolution 201 LC UV-Vis spectrometer. In AY2015-2016, Dr. Fiedler was awarded a Strategic Funding of $7995 and $625 for the purchase of the Gamry Interface 1000B Potentiostat and Electrochemical cell kit, respectively. These equipment were used for teaching his physical chemistry class. Other faculty in the department have utilized them for their research. In AY 2016-2017 Dr. Fiedler was awarded another Strategic Funding of $3,325 for the purchase of an HP Workstation Z840 (2x) E5-2620 v3 2.4 Hz, 1 TB SATA drive, 500 GB SSD. This supported his research.

In 2017-2018 and 2018-2019, Dr. Awasabisah submitted two separate proposals for funding for the purchase of an Anasazi EFT-60 NMR Wideband Probe under the Strategic Fund requests. The purpose was to obtain funds to upgrade the department's EFT-60 NMR instrument to allow analysis of other nuclei such as F-19 and P-31. This proposal similarly made it to the needs category, but it was not approved for funding.

In AY 2018-2019, Dr. O'Connor and a team of chemistry and biology faculty submitted a proposal for funding to purchase a Graphite Furnace Atomic Absorption spectrometer to support teaching and research activities. The proposal made it to the needs category, however, it was not recommended for funding. For next fiscal year, (FY2023), we requested a new GC-MS to replace our old, unusable machine. Our quote exceeded $75K but we strategically made this our only departmental request for this year, We have a very strong argument about how this machine is needed for our Organic & Analytical labs and for faculty/student research. We are hopeful that this will be approved. All proposals for EBRQs can be seen in **Appendix H.**

The department continues to explore future Strategic Funding requests and other grant opportunities to purchase these and other research equipment.

Fitchburg State University's Department of Information Technology has continued to be aggressive in introducing and supporting new technologies such as Zoom Web Conferencing, Google Meet, Hoonuit Learning (on-line technology training) and SelectSurvey. Technology has become a very important resource for us, especially during the COVID-19 lockdowns. We were provided Wacom tablets to make annotations on presentations and specialized microphones and recording devices to help with online instruction. In order to meet some course goals of providing students with practical knowledge, we had to be creative. During this period several faculty adopted a variety of virtual lab resources such as Beyond Labz, and other simulation programs. We were fortunate to receive supplemental funds from the university to purchase licences for the virtual resources. In addition, the IT department has employed an Instructional Technologist, Allison Bunnel, who provides regular training sessions for faculty and students on various technologies. She has been an invaluable resource person especially in the last two years when many of our classes were moved online due to the COVID-19 pandemic.

All faculty members are provided with a new laptop or tablet every 3 years. Students in the department now have increased access to laptops for class use as the department has 4 carts containing 8 – 10 laptops each. There is support for emergency-type problems that occur in the classroom. Faculty can call the IT helpdesk if they have a classroom emergency and a member of the IT staff will immediately come to the classroom to provide assistance.

Spaces

The Antonucci Science Complex was opened in AY13/14 and consists of the Irving Wing and the renovated Condike Wing. This building houses all of the Chemistry and Biology laboratories, instrument rooms, preparation rooms, and research labs as well as lecture classrooms, faculty offices, conference rooms, student lounges, and common areas. Also occupying this complex is the Earth and Geographic Sciences Department, facilitating interactions across our closely related Disciplines. The Science Complex is LEED Silver certified and also meets all laboratory and classroom standards for OSHA and ADA. The Irving Wing has 3 Chemistry teaching labs, 6 faculty research labs, 8 Biology teaching labs, various research facilities (chemistry instrumentation room, and a room housing an NMR and an IR spectrophotometer) and preparation rooms with chemical storage spaces on each floor to support the facilities. The Condike Wing has 28 offices (including chairs, faculty, and technician offices), 3 Physics labs, 2 Geoscience labs, Geo/Physical Science research areas, 4 classrooms, a large lecture hall, a computer lab, numerous meeting rooms, and student lounges.

The impact of the Science Complex on the ability of the Department to carry out its mission is incalculable. Its effects are far-reaching, impacting faculty and students alike. Increased technology in the lecture and lab classrooms has enhanced teaching and learning opportunities. In addition, the new equipment has provided increased opportunities for students to conduct research with faculty members. Lastly, students can frequently be seen utilizing the lounge spaces as study areas and to interact with their peers and several faculty offices have small “common areas” outside of their office. All of this creates a more collaborative and welcoming atmosphere for all the occupants of the building.

Environment and Safety

The Antonucci Science Complex building meets all OSHA guidelines and fulfills the requirements of the American with Disabilities Act, therefore all labs and research spaces are accessible to all students. Due to the sophistication of the research that can now be done in the new building, members of our faculty, including Dean of Health and Natural Sciences, Dr. Meg Hoey and the Biosafety Committee, in consultation with an outside consulting firm, have written a University-wide Biosafety Policy and an Exposure Control Plan. This certifies us to use materials and equipment with biosafety levels 1 or 2. To ensure that this policy is enforced, it is overseen by a University-wide Biosafety committee. Established safety procedures are now routinely followed and faculty receive yearly training on topics such as lab safety, hazard communication and blood-borne pathogens. We also have a fully effective Chemical Hygiene Plan, an online chemical inventory system, and a full-time Environmental Safety Officer.

In each lab class, faculty train students on lab safety before they engage in any lab activities. Throughout the term, they are expected to practice the lab safety procedures. Additionally, students who conduct independent research receive similar lab safety training. Some independent research students are allowed into research spaces using swipe cards which open lab doors and can be carefully monitored and managed administratively. Faculty generally supervise all students' research, and they ensure that their students follow the safety protocols.

We have designated benches in most teaching labs to help students with disabilities perform experiments at a lower, but safe, height in the lab. Some labs have portable wheelchair accessible benches that can be moved around each semester to accommodate needs of different students. We have also received help from the office of disability services in providing customized hood settings in our Organic chemistry lab for wheelchair bound students

Library Resources
Fitchburg State's Amelia V. Gallucci-Cirio Library offers access to over 134,000 online journals in 183 databases. Specifically, for the Chemistry major and classes, the focus is more on academic journals and monographs. The library has several core databases such as SciFinder, PubChem, Academic Search Ultimate, SpringerLink Package, etc. (**Appendix I**). Faculty and students are able to utilize their robust InterLibrary Loan Services. The library also offers in-person chemistry instruction sessions, and more recently, embedded chemistry courses. They offer a one-to-one reference service for students and faculty. Additionally, the library has several print books in call numbers associated with chemistry. In 2019, the library subscribed to EBSCO Academic Complete eBook package, the JSTOR's DDA and EBA packages. In 2020, the library subscribed to the ProQuest eBook Central DDA collection. All these e-text support our program, especially during the pandemic.

2. Program Processes

a. Curriculum

The curriculum of the Chemistry Program was designed using guidelines from the American Chemistry Society, although we are not ACS accredited for reasons explained earlier. All of our students must complete the requisite number of General Education courses and supporting coursework math, biology, geology, and and physics. As explained earlier, we have updated existing courses to incorporate them better into our overall four-year plans and added additional electives to help students broaden their knowledge in chemistry. Four-year plans for the chemistry program can be found in **Appendix J**. Furthermore, our Curriculum Committee has been tasked with going through our University Catalog to remove and update course listings that have not been offered recently. This will be completed in the next academic year. We also keep a student handbook for all majors in the Department of Biology and Chemistry as a reference to help them navigate through our programs, which can be found in **Appendix R.** The handbook appendix letter is *non sequitur* due to the length of the document, which had to be attached to this report as a PDF.

Changes to the Chemistry Curriculum are often data-driven and arise from multiple anecdotal issues. Once faculty notice a trend or issue with students in our classes or as advisees, we design a way to assess the problem. These issues are then discussed at our department meetings or at retreat with the goal of finding solutions to the issues. If the problem requires a policy change, the new policy is brought to our Department's Curriculum committee for approval before it it sent to the AUC for change. A list of all the AUC proposals which changed policies or procedures in the Chemistry Program can be seen in Table 2.

Course delivery methods:

Courses such as General Chemistry I and II, Organic Chemistry I and II and Biochemistry are offered to both chemistry and biology majors. In addition, Analytical chemistry and several chemistry electives such as Forensic chemistry, Medicinal Chemistry, Inorganic chemistry and Environmental chemistry are taken by chemistry and biology majors with chemistry minors. Many courses have the traditional lecture component that is taught in person and some of the courses have accompanying lab components.

In spring 2020, due to the COVID pandemic, the program had to make a sudden switch from conventional teaching to a fully online modality. This necessitated development of new course delivery methods. Lectures were taught in either synchronous or asynchronous formats. In the synchronous format, students and instructors met online at designated lecture times in Google Meet sessions. The Google Meet session was used to teach lectures in the traditional format. In asynchronous lectures, instructors posted videos or screencast lectures for the various topics online. Students were required to listen to these lectures before coming to online lectures, which were primarily used for solving problems and answering questions.

While the transition to online lecturing was more straightforward, teaching labs in the online format was more challenging. For General Chemistry labs, an online lab instruction portal called Beyond Labz, was used to give students the required experiential learning. This portal was well suited not only for General Chemistry I and II, but also for teaching Organic Chemistry II labs. However, the labs in this online system were not well suited for Organic Chemistry I. Two different approaches were used to teach Organic Chemistry I labs. Faculty members posted lab video demonstrations available on sites such as OrganicERs (Organic Education Resources) that were developed by a group of chemistry faculty members from various universities such as Dartmouth College, Georgia Tech, IUPUI and Centre College in Kentucky. For some of the experiments where videos were not available, faculty members recorded their own videos in our chemistry labs and posted them online for students to watch and learn how to set up experiments in the laboratory.

The same teaching modality was followed for all courses taught in the summer sessions of 2020.
In the academic year 2020-2021, the program offered courses in a hybrid format having some face-to-face sessions and some online instruction. Lectures were taught online using the synchronous format, while face-to-face sessions were used for instructing labs. This was the most logical way to ensure quality pedagogy in labs but limit close contact interactions during the pandemic.

The chemistry faculty provide a large number of specialized learning opportunities for our students. Within this review period chemistry faculty sponsored 46 student projects. 37 students performed independent research projects, 4 students were enrolled in introduction to research courses, and 5 students participated in internships. The topics for these projects were quite varied. Some major themes include silver nanoparticles, heme, cross-linked proteins, DNA intercalators, heavy metals, and nanoparticles. In addition to the projects listed above, a number of chemistry faculty sponsored students participating in the Nashua River Project, an interdisciplinary program funded by the Lloyd G. Balfour Foundation. This was a 3-year project involving the evaluation of the health of the Nashua River watershed as well as the public health of the Fitchburg community. A table showing a list of independent studies and internships in the Chemistry Program can be seen in **Appendix K.**

Before his retirement in 2021, Dr. Mel Govindan, our former department chair, devoted much effort to increasing study abroad programs and learning experiences for students in Chemistry. He developed a course that was taught twice for our students in Verona, Italy. He also devoted his sabbatical time on endeavoring to increase opportunities for our students by establishing connections by visiting and teaching courses or classes in China, Germany, and India. A list of Dr. Govindan's contributions to the Study Abroad program can be found in **Appendix L.**

b. Students

Helping students succeed is our top priority. To do this, we help them prepare for the rigor of the program by "meeting them where they are". For example, we have begun to offer math skills competencies integrated into our classes, work closely with the tutoring centers, and implement Universal Design Strategies (such as posting notes ahead of time, offering review sessions, flipping our classrooms, and recording lectures).

To ensure high expectations and rigor within the major, incoming majors must maintain a 2.0 in prerequisite courses to move into upper-level courses and must maintain an GPA of 2.0 or higher, both overall and in the major, to stay in the chemistry program. Due to the challenging nature of chemistry courses, we work closely with our Tutoring Center on campus to ensure students have access to additional out-of-class assistance. As seen in Table 10, since 2016, there have been 2361 contacts with Chemistry Tutors through Fitchburg State's Academic Coaching and Tutoring Center. This service is free to students and can be found in our Student Union Building (Hammond Hall) on campus. Students are able to sign up for tutors online or can drop in during open tutoring hours offered for specific classes. Typically, tutors are students who have taken the class previously and have done well (3.5 or above). Over half (51.6%) of our tutoring contact hours have been with CHEM 1200, which is Chemistry for Health Sciences, otherwise known as "Nursing Chem." This is a required course taken by all Nursing students and is often viewed as a challenging course. Students in the Nursing major must maintain a 2.7 or higher to remain in the program, thus keeping grades up through the use of study groups, office hours, and student tutors is commonplace. CHEM 1300 (General Chemistry I) has the second most contacts with 443, followed by CHEM2000 (Organic Chemistry I) with 326. This was surprising to us as CHEM 1400 (General Chemistry II) is a more challenging course due to its content. However, biology majors and chemistry majors must receive at least a 1.7 or 2.0 in CHEM 1300, respectively, to stay in their major. Fewer students take CHEM 1400 and CHEM 2100 (Organic Chemistry II) overall, as a result of changing majors or not doing well in prerequisite courses. Furthermore, students in the B.A. in Biology program do not have to take Organic II thus reducing the number of students enrolled in that course. Only one student sought tutoring for Physical Chemistry (CHEM 3200), which has only been offered 5 times since 2016 and is typically taken by upperclassmen.

Table 10: Tutor Contacts for Chemistry Courses since 2016

Row Labels	Count of Student ID

CHEM-1000	1
CHEM-1200	1219
CHEM-1300	443
CHEM-1400	280
CHEM-2000	326
CHEM-2100	91
CHEM-3200	1
Grand Total	**2361**

The Chemistry major has implemented three specific strategies to improve success in the major and retention in college. First, weekly review sessions were held for Organic I and Organic II starting from Fall 2016 (but discontinued in Spring 2020 due to COVID). Worksheets were prepared to help students with concepts covered in the lectures. These sessions were attended by about 10-15 students on a regular basis and comprised a mix of students, both academically strong as well as weak. Students who attended these sessions managed to earn grades of C or higher and successfully completed the Organic Chemistry sequence. These sessions were time intensive and difficult to coordinate. Thus, it is unclear whether regular weekly sessions can continue due to the amount of faculty and student time and effort they require.

Second, Chemistry faculty have joined other STEM faculty in planning initiatives around diversity, equity and inclusion (DEI). The increase in the number of minority students in the Biology and Chemistry majors has outpaced growth at FSU as a whole. In an effort to improve student retention, we have been devising ways to identify unique barriers that minority students experience in our STEM programs, and ways to train faculty to better address DEI. We have begun gathering input from a STEM student focus group, and have applied for grants from the Howard Hughes Medical Institute (2020), and the Balfour Foundation (2021) for faculty training. While these large grants have not yet been funded, they were helpful to start faculty discussions around DEI.

Third, the Chemistry faculty, along with some Biology faculty, have increased opportunities for student research in the last few years. Studies on retention show that independent work is a high-impact practice that greatly improves retention and completion, particularly among minority students. See **Appendix K** for the complete list of student projects offered by the Chemistry faculty. As part of this effort, from 2017-2019 a team of STEM faculty led a summer program studying the Nashua River watershed, including Chemistry projects on microplastics, salts and water quality. This Nashua River Project was funded by the Balfour Foundation.

Finally, beginning in 2016 Chemistry majors are required to earn at least a 2.0 in General Chemistry I, and are limited to two attempts before being counseled out of the major. While this initiative may seem counterintuitive for improving retention, the larger goal was to help students succeed in college. We based this policy on data from the Student Success Collaborative: students who earned below a 2.0 in General Chemistry I did not complete the Biology major, and the same should apply to the newly reinstated Chemistry major. In the past, too many poor-performing students lingered in a Biology major that was not a good fit for their skills. They wasted tuition on courses they did not complete and many eventually dropped out of college. In response, we started this 2.0 minimum policy in 2016 in an attempt to catch Biology and Chemistry students early so we could counsel them into other majors before they dropped out of college altogether.

We had also hoped that the 2.0 requirement would be an incentive to improve performance in General Chemistry I, but there has been no change. Figure 3 shows the DFW (D grade, fail, and withdrawal) rates for General Chemistry I for 2013-2015 (just prior to starting the 2.0 policy) with failing grades (0.0, squares); withdrawal rates (W, triangles), and D grades (sum of grades 1.0-1.7, in circles). The new 2.0 requirement has not resulted in any consistent change in student performance. However, this has affected such a small percentage of students, that it can't be fully assessed yet.

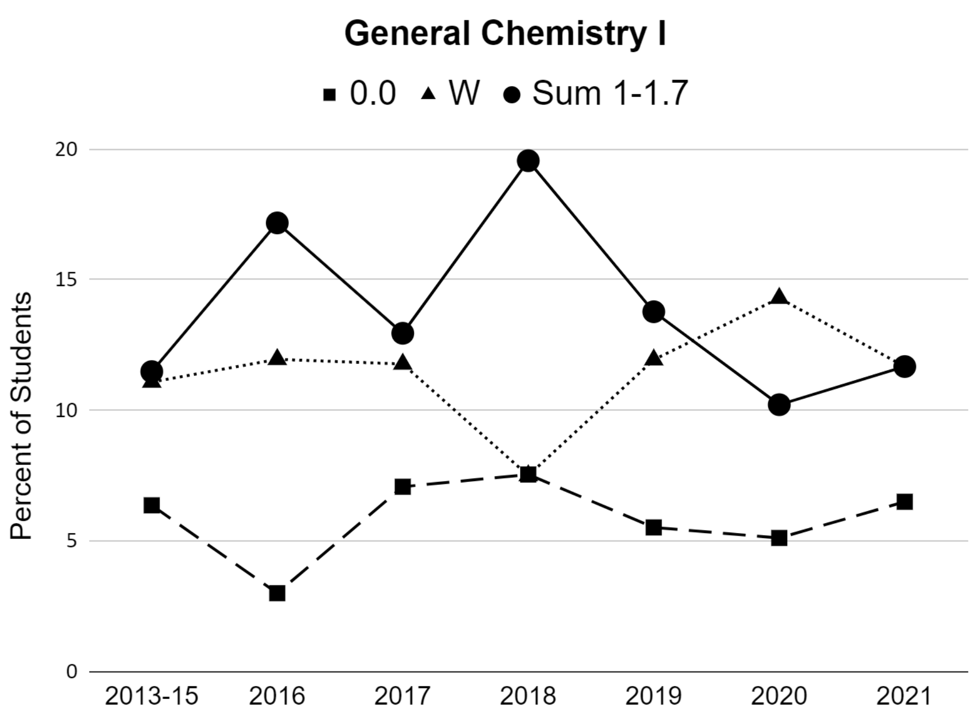

Figure 3. Percent of failing, withdrawals, and D grades in General Chemistry I from 2013-2022

C. Faculty

Each faculty member is responsible for teaching a 4/4 teaching load (12 credits) every semester unless they are awarded release time for other professional responsibilities. A list of Chemistry courses taught by tenure-track faculty over the last 7 years can be seen in **Appendix M.** Also found in Appendix M is a list of

2-year rotation of chemistry courses that we try to follow to make schedules predictable for faculty and students.

Advising is also an important area of the faculty responsibilities. It is one of four major performance categories that faculty are evaluated on for any job actions as part of the MSCA union contract. Each student is assigned a faculty advisor when they enter the program. An effort is made by the Administrative Assistant to assign students to an advisor whose area of expertise is most closely aligned with the students concentration or general area of interest. However, because there are more biology majors than chemistry majors, chemists are often assigned biology majors as well as some of the chemistry majors.

We try to maintain parity across the faculty members regarding numbers of advisees. In the current academic year the department has approximately 150 biology majors, 15 chemistry majors, and 20 chemistry minors. Students in the minor are usually assigned to the department chair for advising, although sometimes a faculty member takes on one of these students because of an interest by the student in the faculty member's area of interest. The students in the biology and chemistry majors are divided up as close to equally as possible. In the current academic year, each faculty member has between 8 and 11 advisees. Differences occur as students enter and leave the program. When a faculty member goes on sabbatical, their advisees are re-assigned to the chair or other faculty members if necessary.

When assigned a new advisee, faculty reach out to students as soon as possible and encourage them to meet often during the semester. At the start of each academic year, the University provides a time for each department to meet with their new advisees in a meet-and-greet session.

One of the major responsibilities of faculty is to meet with all advisees during the 3-week advising period held in the middle of each semester. Faculty set up an advising calendar in SSC (Student Success Collaborative) platform and meet with each advisee one or more times. During these sessions, there are discussions focused on 1) student academic progress (mid-term warnings are available at that time), 2) setting up a schedule for the next semester, and 3) discuss other business (e.g. navigating University workings for new students, and career pathways for upperclassmen). Faculty can access student records through the Web4, DegreeWorks, and SSC platforms. Faculty maintain notes of meetings in Degreeworks that are available to others who have access to student records (e.g. other faculty, and administrators, especially the Registrar). Some faculty have starting doing remote advising sessions and keeping Google Sheets for advising records so students can access their information and progress at any time. This also helps faculty who have been assigned a new advisee from a different department or when a faculty member has been on sabbatical. An example of an advising sheet created by our Teaching and Learning Center and used by our faculty to help students with advising can be found in **Appendix N.**

Several of our faculty have also been given Alternative Professional Responsibilities (APRs) for course releases (typically 3 credits) by Academic Affairs. APRs are used to support academic scholarship and service. Steven Fiedler was granted two APRs for research over the last 7 years and Dennis Awasabisah was given one for conducting research. Billy Samulak received one APR in Spring of 2020 to be coordinator of the General Science and Chemistry Secondary Education majors as the program was undergoing a review.

3. Program Outcomes

a. Program

Twenty-two students have graduated from our program with a major in chemistry. Year of graduation and number of graduates is as follows: 2017 (4), 2018 (6), 2019 (4), 2020 (6) and 2021 (2). We know details of the careers of almost 70% of our graduates and are not aware of any alumni are currently pursuing graduate degrees.   Of these, fourteen are employed in Massachusetts and one in New Hampshire. Table 11 summarizes the careers of our alumni. We currently do not have access to the Graduate/Alumni surveys of our recent graduates' ratings of our program.

Table 11 Chemistry Graduate's Career & Employment Placements

Industry	# Alumni	Company Name	Job Title
Pharma/Biotech	6	-Charles River Labs -Vivetide -Albany Molecular Research -Masy's Bioservices -Chemistry Serve Labs	-Project /Account Manager -Associate Scientist 2 -Lab Assistant -Account Manager -Business Operations Specialist -Calibration Technician -Environmental Chemist
Chemical / Fine Chemical	3	-Banzan Inc. -Aspen Aerogels -Johnson Matthey	-Lab Technician -Lab Technician -Chemist
Food	1	Mega Food	Sr. Quality Specialist
Construction Services	1	Eurovia	Environmental Specialist
Local Government	1	City Of Lowell	Staff Engineer
Research	1	Brigham & Womens'	Research Assistant
Medical Marijuana	1	Revolutionary Clinics	Business Analyst
Medical Device	1	Werfen	Scientist 1

d. Students

The Chemistry faculty established its Program Learning Outcomes (PLOs) delineated in Table 12 at a department retreat in Fall 2019. Prior to Fall 2019, PLOs were defined by the Department Assessment Committee. The PLOs were adapted from learning outcomes developed by the American Chemical Society

(ACS). Full descriptions of the PLOs are given in **Appendix O.** All PLOs are published in the program assessment plan. The curriculum map shown in **Table 13** was correspondingly developed by the Chemistry faculty at the same retreat in Fall 2019.

Table 12: Program Learning Outcomes implemented in Fall 2019

PLO #	Learning Outcome	Assessment method	Frequency	Rubric
1.	Disciplinary knowledge of topics in foundational chemistry (General Chemistry and Organic Chemistry)	Exit exam	Annual	**Appendix O1**
2.	Demonstration of, and application of laboratory skills	Analytical exam	Annual	**Appendix O_2**
3.	Demonstration and application of the concepts of lab safety practices	Organic – embedded questions in prelab Seminar/Analytical – Chemical hygiene plan assignment	Annual	**Appendix O_3** **Appendix O4**
4.	Presentation of scientific information in clear and organized manner through written or oral communications	Capstone Written report Poster presentation Oral presentation	Annual	Poster presentation rubric: **Appendix O5** Oral presentation rubric: **Appendix O6**

Table 13: Curriculum map of Program Learning Outcomes implemented in Fall 2019

	PLO 1 Disciplinary Knowledge	PLO 2 Laboratory Skills	PLO 3 Safety	PLO 4 Science Presentation
CHEM 1300 *G-Chem I*	I	I	I	
CHEM 1400 *G-Chem II*	I	I	I	
CHEM 2000 *O-Chem I*	I	B	B*	I
CHEM 2100 *O-Chem II*	I	B*	F*	I
CHEM 2400 *Analytical*	B	F*	F	F
CHEM 3030 *Biochem*	B			F
CHEM 3200 *P-Chem*	F	F	F	B
CHEM 3600 *Inorganic*	F			B
CHEM 4750 *Seminar*	F*		F*	B*

Key: (I)ntroduced, (B)roadening, (F)ulfilling, (*) Assessed for program

As customary with most programs at Fitchburg State, the Chemistry Program is assessed annually by the Departmental Assessment Committee and reported to the Office of Institutional Research and Planning. The report is itself peer-reviewed by the University Assessment Research Committee (UARC). Evaluation and comments from the UARC are then returned to the Department.

The rubrics applied to PlO 1 and PLO 4 have undergone iterative revision since their initial deployment in AY16/17. The outcomes specified by PLO 2 and PLO 3 were introduced in AY19/20. However, the results from PLO 4 can be tracked over a five-year span (Figure 5) by selecting a subset of categories that were evaluated in the Chemistry Seminar oral presentations (**Appendix O6)** that did not undergo appreciable revision over the course of this duration. Student presentations were not evaluated in AY19/20 due to the onset of the pandemic.

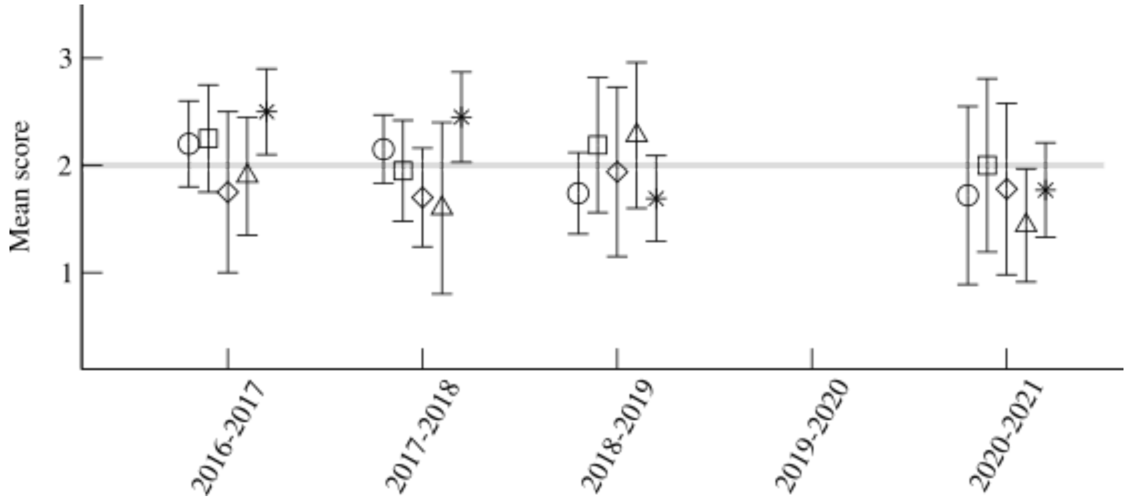

Figure 4: Mean scores from student oral presentations in Chemistry Seminar. Presentations were evaluated by members of the Departmental Assessment Committee with respect to the following rubric categories: ○ - Define problems clearly, □ - Information presented in a clear and organized manner, ◇ - Ability to retrieve information by searching the chemical literature, △ - Proper citation of others' work, and * - Evaluate technical articles critically. A gray horizontal line indicates the target threshold for PLO 4 as specified in **Table 13.**

The rubric and the delivery of the Capstone exit exam (PLO 1) has been monitored and improved accordingly since its first issuance in the Spring 2017. A copy of the current exam is provided in **Appendix O_2.** Below is a set of the applied changes; a histogram of the results from the Spring 2019 Capstone Exit Exam is provided in Figure F2.

- The date of the exam delivery has been moved from the final exam week to an earlier point in the semester to combat student apathy.
- Low scoring questions, such as questions 16 in 17 in Figure 5, were discussed by all the Chemistry faculty. These questions were subsequently either edited for clarity and/or additional emphasis were provided in the introductory courses on the referenced topics.
- A consistent delivery medium is sought in order to provide the exam in Capstone courses that are being taught online.

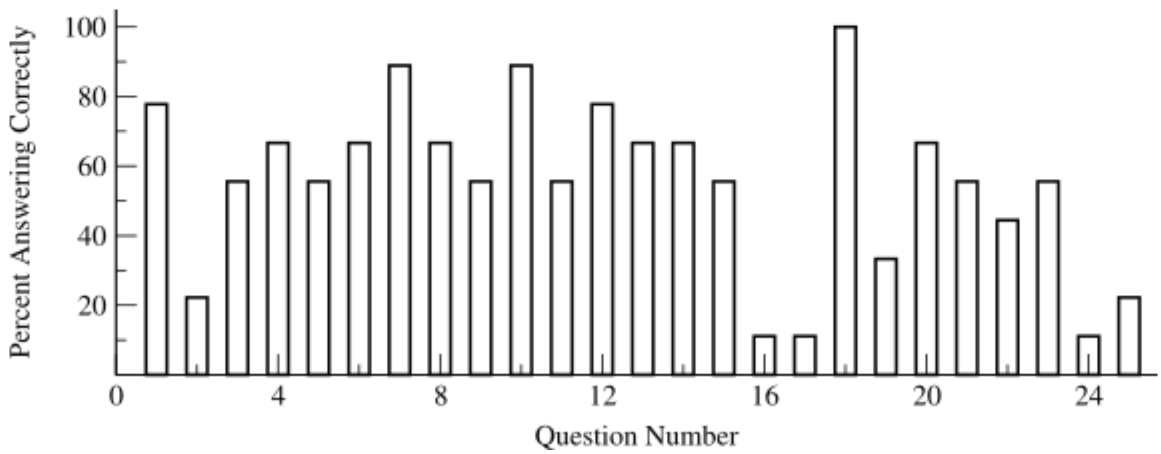

Figure 5: Student Success by Question - Results from the Chemistry Seminar exit exam (**Appendix S2**), in Spring 2019. These data comprise the aggregated results from nine students.

Two measures were employed to assess the outcome of PLO 3: *Demonstration and application of the concepts of lab safety practices*.

- Questions were embedded in the pre-laboratory report for Organic Chemistry I and II (**Appendix O_3**). Despite a low sample size, it was found that nearly all students surpassed the target of a 70% average for the course: see Figure 6. During the Fall 2020 and Spring 2021 semester, two of the three chemistry majors that were assessed on PLO 3 obtained a perfect score, well above the 70% average bench mark. The third student who was only assessed in Fall 2020 was deficient in this PLO. We speculate that this student may have struggled due to the COVID-19 situation.

- A chemical hygiene assignment was assigned to chemistry majors in the Chemistry Seminar Capstone course **(Appendix O4)**. Nearly all students surpassed a target of 90% score for the assignment: see **Figure F4**. Two students did not complete the assignment in Spring 2021.

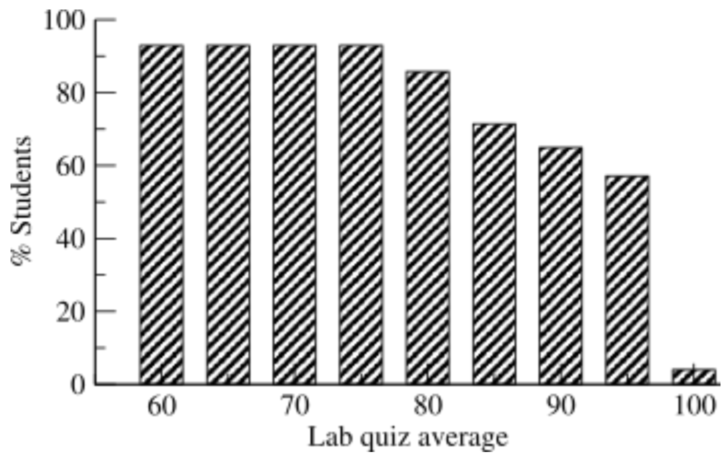

Figure 6: Percentage of students achieving a given average on lab safety quizzes (**Appendix O4**) over the course of a semester in Organic Chemistry I and Organic Chemistry II. The sample size consisted of fourteen students, with five, four, three, and two students in Fall 2019, Spring 2020, Fall 2020, and Spring 2021, respectively.

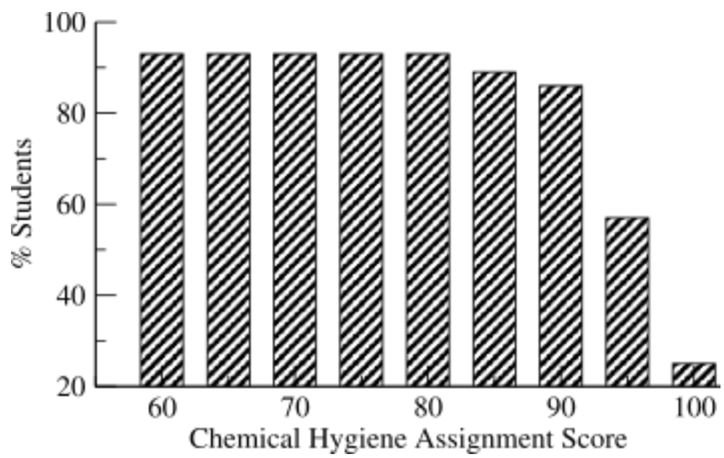

Figure 7: Percentage of students achieving a given average on the Chemical Hygiene Assignment **(Appendix O4)** in Chemistry Seminar. The sample size consisted of twenty-eight students, with seven, five, nine, and seven students in 2017, 2018, 2019, and 2021.

Table 12 contains the direct methods used to collect information for assessing students' core sets of knowledge, skills, and attitude. All students in the major are required to participate in the listed assessment activities.

Table 12. Direct Methods for Assessing Student's Core Knowledge

PLO #	Assessment description (written project, oral presentation with rubric, etc.)	Point of assessment	What is the target set for the PLO? (criteria for success)
1	Capstone exam	Junior or senior year	90% of students to score > 50% 80% of students to score > 70% Aggregate student performance in subject areas monitored.
2	Embedded exam questions	Sophomore and junior years	90% of students to score > 70%
3	I. Embedded pre-lab questions II. Chemical hygiene assignment*	Sophomore and senior year	I. 90% of students to score >70% II. 95% of students to score > 90%
4	Oral presentations	Junior/senior year	A majority of students should demonstrate a proficiency on oral presentations by attaining a score > 2 (sufficient)

*Note: I and II are independent assessments; i.e., not a pre-/post-test combination

The Chemistry program uses the results from an annual Student feedback survey as an indirect method to assess PLO 1 (Disciplinary knowledge of topics in foundational chemistry). The survey is developed and issued through the Department Student Affairs committee.

IV. Analysis and Action Plan for Future

1. Comparative strengths and distinctiveness, and areas of improvement across all program levels

The biggest strength of the chemistry program is its highly qualified and caring faculty who focus on teaching and student success. All faculty members have a terminal degree and experience doing professional activities and research. A list of faculty CVs can be seen in **Appendix P.** Additionally, our small class sizes help foster effective communication between the faculty and students. Close faculty-student interactions have resulted in several students pursuing research opportunities in the form of independent studies and internships. The chemistry program is well funded by the administration, despite its small size, and has state-of-the art equipment in dedicated instrumentation rooms and several teaching and research lab spaces. Every student gets hands-on experience using all the instrumentation in the labs, which again is a desirable outcome of the small class size.

The program offers several courses that are considered core courses for both Chemistry as well as the Biology major. One such course that is taken by students in both the majors is General Chemistry I. This course is considered a gateway course for both majors and students are required to get a minimum grade of 2.0 in this course to continue in the major. The program offers the General Chemistry I course in fall as well as spring semesters to help freshman students successfully complete this important course in their first year and ultimately graduate in a timely manner. In addition, the program also offers both the general chemistry (General Chemistry I and II) as well as Organic Chemistry (Organic chemistry I and II) sequences in the summer sessions to help existing as well as transfer students complete their course requirements. It is one of the few programs in the area that offers a Physical Chemistry lab as part of the curriculum. Besides courses for the chemistry and biology majors, the program also offers courses for students in other disciplines such as Nursing , Exercise and Sports Sciences, Communications media and Political science.

Faculty in the chemistry program conduct interdisciplinary research that involves students from both majors (Biology and Chemistry). These research experiences have helped students (both Chemistry as well as Biology majors) find employment in local chemical industries. Some faculty members are also involved in collaborative research projects involving students from local community colleges as well as high schools. Our faculty have gone to the Fitchburg High School Fairs to advertise our program. The department has made efforts to engage faculty in our feeder schools (MWCC and Quinsigamond Community College. Faculty and students from these community colleges have been invited to participate in our department’s yearly Science Research Symposium. We have also reciprocated visits to their department. In the Spring 2017 semester for example, Dr. Govindan led a group of faculty to visit the new Science Center at MWCC and to network with the STEM faculty. These were all efforts geared to strengthening our commitment in ensuring that students who transfer from their school have the support they need to succeed in our program.

We have also offered to engage the students in our feeder schools in research activities. In Summer 2019, Dr. Awasabisah hosted and supervised two students from MWCC for a Summer STEM Scholars (S^3) Program – a joint FSU-MWCC program designed to help promote introductory research opportunities for freshmen-sophomore in STEM.

These collaborative efforts will hopefully help recruiting new students as well as transfer students from the local high schools and community colleges respectively.

The chemistry program benefits immensely from its geographical location with graduates being able to secure jobs locally in companies in the central and western Massachusetts area as well as tap into the career opportunities available in the Greater Boston area. Several recent graduates (both chemistry majors as well as minors) have been successful in getting jobs at local chemical industries. The recently approved Biochemistry concentration is anticipated to further boost the career prospects of graduating majors. FSU is one the few state schools in the region offering students a Bachelor of Science degree in Chemistry with initial licensure and a minor in middle school and secondary education. This is particularly important considering the ever increasing need for trained science teachers nationwide.

2. Opportunities to extend existing strengths and resources in place or needed

Despite the attractive career choices available for chemistry graduates, there has been a steady fall in the number of new students being admitted to the program. This is an issue that needs to be addressed immediately and requires targeted and sustained recruitment efforts.

There is clearly a need to increase enrollment in the Chemistry major. One of the ways to promote the program is through the extensive connections in the community and local industries. In the past few years, chemistry and biology graduates (with minor in chemistry) have been successful in securing jobs in local chemical companies and have played a significant role in establishing connections with industry. While these connections can be utilized to market the program in the area, they have also been helpful in attracting students to some of our initiatives such as the new one-year post baccalaureate teaching program.

3. Weaknesses found during the self-study

Recruitment of new students to the program is by far the biggest challenge. This has been complicated by lower retention rates amongst existing students. While the recruitment issue can be addressed through effective marketing of the program, the low retention rates are reflective of deficient Math skills. For example, Dr. Steven Fielder has done some assessments to gauge algebra skills in General Chemistry I and found that many students needed significant remediation in math. To address this problem, faculty members teaching the general chemistry sequence review basic mathematical concepts with incoming freshmen in the first two weeks of the fall semester and also provide worksheets to further reinforce these concepts. Besides general chemistry, the next hurdle that students face is the organic chemistry sequence in their sophomore year. Weekly review sessions were held to help students with concepts covered in each week of lectures and worksheets were prepared for each session to reinforce the concepts taught. Unfortunately, these review sessions had to be suspended due to the COVID pandemic.

4. **Opportunities for addressing weaknesses**

The chemistry program, like so many other programs on campus, has been sustained by a healthy influx of transfer students from local community colleges through our well-established articulation agreements and transfer pathways. The enrollment challenge presents new opportunities for developing closer ties with local community colleges such as Mount Wachusett community college and Quinsigamond community college. Some of the faculty in the department are already engaged in collaborative research with faculty in these community colleges and these efforts need to be strengthened further. In addition, measures such as effective advising and conducive course scheduling should be implemented to assist these transfer students.

5. **Positioning of program to address future direction of the discipline in the next five years**

There has been an increase in demand for chemistry graduates to take up entry level positions in local chemical companies. The program is equipped to meet this demand and has produced graduates, who have been successful in getting these jobs. In addition, there is a nationwide need for science teachers. The chemistry program with its teacher preparation concentration, is well positioned to address this need for school teachers. The newly approved Biochemistry concentration would further strengthen the program to meet the needs of local Biotechnology companies.

6. **Action Plan for next five years**

    a. **Key objectives, and strategies actions to achieve each objective**

The most important objective is to increase enrollment in the major. One way in which faculty could help tackle this problem is by reaching out to local high schools by offering college level chemistry courses to these high school students. Another way to attract students would be offering financial incentives in the form of student financial aid or scholarships. A key element in the new student recruitment strategy would also involve offering courses at local community colleges. Besides offering courses at local high schools and community colleges, our collaborative research and outreach efforts with local community colleges and high schools would also be pivotal in increasing enrollment. The chemistry program has been able to attract several transfer students from the regional community colleges such as Mount Wachusett Community college and Quinsigamond community college as a result of these partnerships. Our collaborative partnership with the Sizer school in Fitchburg, has also helped in recruiting new students into various programs across the university, including chemistry. Hence, strengthening our partnerships with local high schools and community colleges should be an integral part of our recruitment strategy.

    b. **Timeline, with milestones and measurable outcomes to determine progress and measure success**

The program would like to set a timeline of 5 years to obtain a total of 50 chemistry majors (all years of study). This number would include a minimum of two students per year seeking the Secondary education option in the chemistry major. In order to support the needs of the chemistry majors, the program will strive to offer electives and upper level courses consistently. We look forward to working with our new VP of Enrollment Management, Dr. Richard Toomey, to devise and implement strategies for increasing visibility and enrollments in our chemistry program.

c. Method of achieving objectives

Several programs at FSU, including chemistry, have faced a decline in new student enrollment over the past three years. This decline in enrollment was further exacerbated by the COVID pandemic. While resumption of regular face to face instruction from fall of 2021 is a welcome change after the COVID lockdown, more proactive measures are needed to achieve our enrollment goals.

d. Resources necessary to achieve the plan

In 2017, the Chemistry Department submitted a proposal for funding to increase retention and success rates in General Chemistry courses by hiring and training embedded tutors into the courses as Supplemental Instruction leaders. This proposal was rejected by the administration and we are hopeful moving forward that initiatives such as this are funded. This proposal can be seen in **Appendix Q**. We now have a Vice President for Institutional Advancement, Jeffrey Wolfman, who is tasked with finding funding sources for University programs that would enhance and enrich student experiences on campus.

V. Appendices

1. Appendix A: Biology and Chemistry Department Procedures

The department holds monthly meetings of the full-time faculty. Departmental committee procedures are detailed in a procedural manual below. This document was developed previous to an earlier program review. The Department holds annual "retreats." before each semester and during these sessions, held before the beginning of each semester and lasting for most of a day, and these include detailed and lengthy discussions that take place concerning initiatives important to the Department. We use this time to establish key priorities for the department for the upcoming semester.

Department Meetings

1. The Department Chair is the presiding officer. If the Chair is unavailable and the meeting must be held, the members present should elect a chair *pro tem.* It is the responsibility of the presiding officer to maintain order at the meeting, including adherence to the agenda, use of proper motions and establishment of a speaker's order for all discussions.

2. A schedule of department meetings for the semester should be established by the chair at the beginning of each semester and distributed to all department members. Meetings should take place between the hours of 8:00am and 4:30pm, Monday through Friday. Meetings should be scheduled to maximize participation (*i.e.* avoid days and times when a large number of members have a scheduled class). If there is insufficient business or the Chair knows a quorum cannot be attained, the meeting may be canceled at the discretion of the Chair.

3. At the Chair's discretion, special meetings of the department may be called in order to make decisions that cannot be postponed until a regularly scheduled department meeting. The specific agenda and the reason for the special meeting must be given to all members of the department. Notification must be given at least two (2) working days in advance of the special meeting. Department members should be contacted via their home telephone number; additional notification via email, office telephone numbers and written memorandum may also occur.

4. A written agenda, with all items and proposals to be considered, shall be distributed to all members of the department at least three (3) working days in advance of the meeting. The members present at the meeting may vote to change the order of the agenda items. Members of the department may submit items for the agenda to the Chair at least five (5) working days prior to the meeting or from the floor at the meeting.

5. A quorum is a majority of the eligible voting members of the department. Part-time faculty and faculty on any leave of absence on a full-time basis are not eligible to attend department meetings. If a quorum is not present, discussion may occur but no votes may be taken.

6. Everyone has the opportunity to be heard on a subject under discussion. The Chair is not required to allow participants to repeat the same points or address themselves to extraneous matters.

7. Voting is by a show of hands or a voice vote. Secret ballots shall be used when individuals are being elected to a position (chair, committee appointments, *etc.*). Votes by mail or email may be allowed

when proposals have been submitted to all department members ahead of time. Proxy voting is not permitted under any circumstances.

8. In accordance with Robert's Rules, a majority vote is a majority of the votes cast when a quorum is present; abstentions are not votes.

Summary of Departmental Meeting Attendance, Committee Service and Voting Rights

Type of Appointment	May Attend Meetings?	May Serve on Committees?	May Vote in Elections?	May Vote on Non-Election Matters?
Tenure Track	Yes	Yes	Yes	Yes
Full-Time Temporary	Yes	Yes	No	Yes
Other Part-Time Faculty	At Department's Discretion	No	No	No

9. Minutes shall be taken by a secretary *pro tem* appointed by the Chair for the term of a meeting and such appointments should rotate among department members. Minutes will include the names of members present, motions adopted or not adopted, and report announcements. Unless points are made in discussion that clarify the motion or actions to be taken, discussion of motions are not summarized in the minutes. Minutes shall be signed by the secretary *pro tem* and distributed to all department members within ten (10) working days after the meeting. Minutes must be approved and subsequent department meeting.

10. If the Chair deems it necessary, and no member of the department objects, voting on a specific issue that would otherwise need to be handled via a special departmental meeting may be conducted via email or telephone so long as the issue is not one in respect of which confidentiality is a concern.

11. The Chair is authorized to make decisions on an emergency basis. The Chair should notify the department members of any such emergency decisions as soon as practicable. Such notice might appropriately be given via home telephone.

12. Non-voting guests (including part-time and full-time faculty and faculty on a leave of absence on a full-time basis, such as a sabbatical leave) may attend meetings at the invitation of the chair or by majority vote of the members present at any meeting.

Recruitment of Full-Time Faculty

I. General Provisions

1. The procedures for the recruitment of all faculty in the Department shall conform to applicable Affirmative Action/Equal Employment Opportunity guidelines of the University, state and federal law and the BHE/MTA collective bargaining agreement.

2. These procedures shall only apply to the recruitment of full-time faculty, whether tenure- track or temporary, when either the Vice President for Academic Affairs or the department Chair has requested that the department assist in the recruitment for the position.

3. The hiring of part-time faculty is conducted under the auspices of the department chair. The Chair may request assistance in the hiring of part-time faculty.

II. Job Descriptions

1. The department chair shall call a meeting of the department to discuss the job description. The department chair shall then submit a written proposed job description for the approval of the department members at least ten (10) working days prior to the deadline for submission to the administration.

2. If the department fails to approve a job description at the end of the meeting, the chair may call further meetings for the purpose of discussing the job description or submit his/her own job description to the administration. Copies of any such submission shall be provided to the members of the department.

III. Search Committees

1. Once the job description has been approved for advertisement by the administration, a search committee shall be formed, the size of which shall be determined by standard university policy. Members of the department may submit their names for nomination to search committees. If more members are nominated than are required on the committee, then an election shall take place. Members of the department shall vote by secret ballot and the department chair shall tally the votes.

Note: While the contract requires a secret ballot in this instance it is agreed that if a verbal resolution may be reached we will not require a secret ballot.

2. Once constituted, the search committee shall elect its' own chair. The search committee chair shall be responsible for communication with the members of the department, the department chair and the administration. The search committee chair shall ensure that the committee adheres to all university procedures.

3. In compliance with appropriate university and collective bargaining requirements, the search committee shall devise its own method of reviewing job applicants, identifying those applicants to be interviewed, and gathering feedback regarding interviewed candidates from members of the department.

IV. Interviewing Candidates

All members of the department, including the department chair, shall be invited to participate in on-campus interviews with all candidates to be interviewed. Copies of applicant materials shall be made available to members of the department prior to the interview.

V. The Role of the Department Chair

1. The search committee shall recommend, simultaneously and in writing, the names of finalists to the department chair and the Affirmative Action/Equal Employment Opportunity Officer, in accordance with college procedures. The department chair shall then meet with the search committee to discuss the relative strengths and weaknesses of each finalist.
2. When the department chair has prepared his/her recommendation regarding which candidate(s) should be offered the position, the department chair shall communicate that recommendation, in writing, to all members of the search committee at least five (5) working days prior to submitting the chair's and committee's recommendation(s) to the administration.
3. At the request of either the search committee or the department chair, another meeting shall be held to discuss the Chair's and/or committee's recommendation(s).

VI. Notification Procedures

1. After the administration has informed the department chair that an applicant has accepted an offer of employment, then, within ten (10) working days thereafter, he/she shall inform the members of the department in writing of the name of the successful candidate.
2. Upon the conclusion of the search, the search committee chair or designee shall notify all other candidates that the search has concluded. If for any reason a search fails, then the department chair shall notify the members of the department in writing as soon as practicable.

Departmental Committees General Provisions

I. Eligibility

Unless precluded from serving by contractual or statutory provisions, all full-time members of the department who are not on a leave of absence on a full-time basis are eligible to serve on departmental committees. All full-time faculty members are expected to serve on at least one committee within the Department.

II. Nominations and Membership

1. Unless otherwise specified by contractual or statutory provisions, the department chair shall determine the number of members to serve on a committee and, if applicable, the number of student members.
2. The department chair shall request faculty nominations for all committees in writing at least

five (5) working days before nominations are to close. Members may nominate themselves; members shall not nominate others without the express consent of the other person.

3. Proposed committee composition will be presented at a departmental meeting for review by all faculty. Once agreement has been reached committee membership, each committee then meets to nominate a chair and to select student members.

4. Whenever appropriate or required contractually, students shall be appointed to serve on departmental committees. Unless otherwise specified, student nominees shall be full-time, matriculated students majoring in a major offered by the department. In all cases, student members must be in good academic standing.

5. The chair shall solicit from members of the department the names of student nominees. Members may submit names of student nominees after obtaining permission from the student to be nominated; such nominations shall be in writing. The chair shall then appoint the requisite number of students to the appropriate committee and inform all members of the department of these appointments in writing.

Composition, Duties, and Responsibilities of Department Committees

I. A. Departmental Undergraduate Curriculum Committee

1. The membership of the committee is composed of full-time faculty, the Department Chair, and two eligible students. The committee is composed of at least three but not more than five faculty (excluding the Chair in the faculty count).
2. Faculty and student members are selected according to the General Provisions outlined above and serve for one academic year. The committee is reconstituted in the fall of each academic year.
3. Once constituted, the committee shall elect its' own chair.

B. Duties and Responsibilities

1. The committee shall review and make recommendations concerning the undergraduate curriculum of the department.
2. The committee shall from time to time review the long-range educational objectives of the department as those may relate to its academic curriculum and to the goals and objectives of the University.
3. The committee shall also make recommendations concerning the quality of student academic advising in the department and the manner of its most effective delivery to students, interdisciplinary cooperation, innovative instructional techniques, career opportunities for students, or such other related matters as the committee shall deem appropriate.
4. In respect of all of the foregoing matters, the committee shall consider such recommendations and proposals as the Vice President may from time to time submit to the committee. The Vice President may also meet with the committee from time to time

to discuss matters of mutual concern.

5. The committee shall transmit its recommendations to the Department Chair who shall transmit the committee's recommendation to the Vice President.

6. In considering and making its recommendations on the quality of academic advising in the department and its most effective delivery to students, the committee shall solicit recommendations and comments from those students who are advisees assigned to members of the department, and shall do so using Appendix H (refer to MSCA contract for this form).

II. A. Departmental Graduate Committee

Membership consists of graduate faculty (as determined by the College President) within the department is selected by the same process as for other committees; the chair of the committee is selected by majority vote of the committee members. The number of committee members is at least 3 but no more than 5 graduate faculty. The Graduate Program Chair is automatically on this committee.

B. Duties and Responsibilities

1. The Departmental Graduate Committee shall review and make Recommendations concerning graduate curriculum, admissions, the criteria for appointment to membership on the graduate faculty and other related matters.

2. From time to time, the committee shall also review the long-range Educational objectives of the department in relation to the department 's graduate curriculum and make recommendations concerning interdisciplinary cooperation, career opportunities for students or such other matters as the committee shall deem appropriate.

3. The committee shall transmit its recommendations to the Department Chair, who shall transmit the committee's recommendation to the Graduate Dean.

III. A. Peer Evaluation Committee

1. The Department shall constitute a Peer Evaluation Committee as necessary. If the department has twelve or more full-time members and the Peer Evaluation Committee must conduct eight or more evaluations, then the department may, at its discretion, establish a second Peer Evaluation Committee.

2. The Department Chair is responsible for ensuring that the Peer Evaluation Committee is annually established no later than September 30th.

3. Two tenured members are be elected by the department from within the department; a third member may be selected in each case by the candidate from the department or from a cognate department (the selected member can serve on more than one Peer Evaluation Committee).

4. Elected members may be drawn from cognate department(s) when needed. Cognate departments are designated as such by the Vice President.

B. Duties and Responsibilities

Members conduct the duties and shall meet contractual calendar deadlines as outlined in the MSCA Contract.

IV. A. Student Affairs

1. The membership of the committee is composed of full-time faculty. The committee is composed of at least 3 but not more than 5 faculty.
2. Faculty members are selected according to the General Provisions outlined above and serve for one academic year. The committee is reconstituted in the fall of each academic Year.
3. Once constituted, the committee shall elect its' own chair.

B. Duties and Responsibilities

1. Ensure that students are integrated into departmental committees, advise the Biology and Chemistry Club, and help coordinate social activities between students and faculty.
2. Work to improve student/faculty communication by writing and maintaining a student Handbook.
3. Determine which students will be awarded the Outstanding Senior Awards annually.
4. Review and update departmental publications or marketing materials on a regular basis; PowerPoint, Open House board, web pages. Interface with Admissions so that they may better recruit students.
5. Update enrollment data annually including retention and diversity which should be broken down by majors, tracks, non-majors, and by courses. Develop a system to identify those students that will need particular courses in any given year to help in course scheduling.
6. Update post-graduate student records, develop a method of surveying former students as to their post-graduate employment. Make recommendations on how to improve career advising.
7. Compile an annual summary of Independent Study/Internships completed by students.
8. Any student appeals concerning the student's removal from the major for a science GPA below 2.0 will be directed to and decided by this committee.

V. A. Assessment

1. The membership of the committee is composed of full-time faculty. The committee is composed of at least 3 but not more than 5 faculty.
2. Faculty members are selected according to the General Provisions outlined above and serve for one academic year. The committee is reconstituted in the fall of each academic Year.
3. Once constituted, the committee shall elect its' own chair.

B. Duties and Responsibilities

1. Compile assessment data, review assessment action items on an annual basis.

2. Evaluate course content, work to increase and maintain coordination and integration among courses, especially core courses.

3. Develop and implement an exit survey for majors as well as a post-graduate survey in order to assess the effectiveness of our program.

4. Interface with campus on the incorporation of our assessment and survey documents into the campus-wide system.

VI. A. Equipment and Facilities

1. The membership of the committee is composed of full-time faculty. The committee is composed of at least 3 but not more than 5faculty.

2. Faculty members are selected according to the General Provisions outlined above and serve for 1 academic year. The committee is reconstituted in the fall of each academic year.

3. Once constituted, the committee shall elect its' own chair.

B. Duties and Responsibilities

1. Develop and annually update a comprehensive plan on facility use. Propose space reallocations.

2. Identify and develop justifications for capital expenditures (must be ready to submit in December on budget as EBRQ (extraordinary budget requests) as relating to vision statement action items.

3. Compile an annual summary of equipment, technology, and facility changes, purchases or improvements.

4. Coordinate with staff support and campus community on safety procedures. Interface with other campus departments about new building.

VII. A. Departmental Ad Hoc Committees

1. The membership of the committee is composed of full-time faculty. The committee is composed of at least 3 but not more than 5 faculty.

2. Faculty members are selected according to the General Provisions outlined above and serve for 1 academic year. The committee is reconstituted in the fall of each academic Year.

3. Once constituted, the committee shall elect its' own chair.

VIII. A. Search Committees

See Recruitment of Full Time Faculty

Selection Process for a Department Chair Nominee

The appointment of a Chair follows those procedures stated in the MSCA Contract. The single nominee put forth by the department for consideration of the President is selected according to the following procedure:

1. Candidates are selected by nomination. A candidate is nominated by a tenure-track faculty member or may self-nominate for the position.

2. All candidates will express their willingness to serve at an open departmental

meeting. If more than one faculty member wishes to serve, the faculty are given a chance to consider the merits of all candidates.

3. If necessary, a vote is taken to decide on the nominee that will be put forth to the President. Voting is by secret ballot and will take place within a defined time period.
4. The name of the nominee is put forward to the President according to the time frame outlined in the MSCA Contract.

2. Appendix B: Departmental Committees and Their Current Memberships (2021/2022)

All department documents such as meeting minutes or procedural manuals are stored on a departmental Google Drive. All department members have access to this drive. Department decisions are made by majority vote of faculty in attendance at the meetings after motions have been introduced, discussed, and recommended for a vote. The department and its committees informally follow Robert's Rules of Order.

Departmental subcommittees meet on a monthly basis or on an as needed basis to handle their respective responsibilities. The subcommittees are: Equipment, Student Affairs, Curriculum, Assessment and PEC (for promotion & evaluation). The Equipment Committee handles all proposals for the proper utilization of department space as well as the care and purchase of departmental equipment. Each academic year the university puts out a call for Strategic Funding Requests (formerly known as EBRQ, Extraordinary Budgetary Request, which provide departments with funds to purchase materials that cannot be funded through the annual department operational budget. For our department, this often includes large pieces of equipment to enhance educational delivery. In recent years, these funds are focused on several of the goals outlined in the University's 5-year Strategic Plan. The Equipment Committee collects these requests and prioritizes them, forwarding them to the Chair for submission to the university as part of the annual budgeting process. The Student Affairs Committee is responsible for formal student/faculty interactions such as department sponsored social activities and student awards. The Peer Evaluation Committee, in conjunction with the Chair, oversees the evaluation of faculty in accordance with the guidelines set forth in the Massachusetts State College Association (MSCA) union contract. The Assessment Committee develops strategies and collects samples of student work, and other data and collects samples of student work, and other data to assess student achievement of learning outcomes. The Curriculum Committee and the Graduate Curriculum Committee are responsible for new course proposals or other changes to the curriculum or the majors. These committees make recommendations to the Department and Graduate Chairs. It should be noted that several of the departmental committees have student representatives who volunteer for the positions and serve as voting members.

***Denotes Chemistry Faculty**

Curriculum Committee

Sean Rollins, Erin Rehrig, Michael Nosek, *Billy Samulak, *Steven Fiedler, *Aisling O'Connor, Ron Kreiser

Assessment

*Dennis Awasabisah, *Mathangi Krishnamurthy, Chris Picone, John Ludlam, Eric Williams

Equipment and Facilities

*Dennis Awasabisah, *Mathangi Krishnamurthy, Daniel Welsh

Biology/Chemistry Club

*Billy Samulak

Peer Evaluation Committee

John Ludlam, Daniel Welsh

Student Affairs

Lisa Grimm, *Emma Downs, Elizabeth Kilpatrick

3. Appendix C: Membership by Chemistry Faculty on University Committees (2014-2021)

The University has a governance structure that is composed of an All University Committee (AUC) and three subcommittees, the Academic Policies Committee (APC), the Student Affairs Committee (SAC), and the Curriculum Committee (CC). Proposals are submitted to the AUC which then refers them to the appropriate subcommittees for review. Recommendations are made to the AUC which will then make recommendations for approval or disapproval to the President who makes the final decisions on governance matters. These committees have administrators, faculty, and student representation. In addition to the governance committees, the University has numerous other standing and *ad hoc* committees that are populated with faculty members, administrators, and student representatives at the beginning of each academic year. Our department encourages that we have at least one, if not several, members of our department on these crucial, University-wide committees.

The Department follows all established campus-wide policies and procedures as described in the university catalog, and the faculty contract.   These include the policies outlined by the Institutional Review Board (IRB), the Institutional Animal Care and Use (IACUC), The Chemical Hygiene Plan, the Exposure Control Plan, and the Biosafety Committee. Training for compliance with these and other university policies is provided by the university via the Collaborative Institutional Training Initiative (CITI) program, and Velocity EHS.

Faculty	University Committee	Past (5) Years	Title
Dennis Awasabisah	Student Affairs	2019-2022	Member
	Parking	2017-2019	Member
	Technology Advisory	2016-2017	Member
Emma Downs	LA&S Council	2016-2019	Member
	FYE Committee	2016-2021	Member
	Sustainability	2015-2016	Member
	Stem Working Group	2016-2017	Member
	Honors Advisory Committee	2019-2020	Member
Steven Fiedler	AUC	2021-2022	Member
	AUC Curriculum	2017-2018	Member

		2018-2019 2019-2020	Secretary Chair
	UARC	2016-2018	Member
	Technology Advisory	2014-2017	Member
	LA&S Council	2014-2015	Member
	Parking	2014-2015	Member
	Interdisciplinary Learning Working Group	Summer 2015	Member
Meledath Govindan	Vincent J Mara Award Committee	2016-2018	Member
	Environmental Public Health Degree Program Group	2016-2018	Member
	Harrold Lecture Committee	2016-2017	Member
	Emeritus Faculty Selection Committee	2016-2017	Member
	Faculty Scholarship Forum	2016-2017	Member
	International Advisory Committee	2016-2017	Member
	Dean Search Committee	2014	Member
	University Committee on Promotions	2012-2014	Member
Aisling O'Connor	AUC	2017-2019	Member
	AUC Curriculum	2015-2016 2020-2022	Member Co-secretary

	International Advisory	2014-2015	Member
	Undergraduate Conference	2013-2014	Member
Mathangi Krishnamurthy	Student Affairs	2011-2013	Member
	AUC Policy	2013-2016	Member
	AUC Curriculum	2016-2018	Member & Secretary
	OER	2019-2020	Member
	AUC Policy	2021-2022	Member
Billy Samulak	AUC Policy	2014-2018	Member & Secretary
	STEM Working Group	2016-2017	Member
	PreMajor Advising Committee	2015-2017	Member

4. Appendix D: ACS Curricular Guidelines

Due to the size of this PDF document created by the American Chemical Society, this has been moved to the end of the Appendices for pagination purposes.

Here is a link to the ACS Undergraduate Professional Education in Chemistry: Guidelines and Evaluation Procedures for Bachelor Degree Programs

5. Appendix E: Subject Matter Knowledge (SMK) Required for Secondary Chemistry Teachers

Chemistry Standard (Massachusetts STEM Frameworks 2016)	FSU Chemistry Course
HS-PS1-1.	General Chemistry I
HS-PS1-2.	General Chemistry I
HS-PS1-3.	General Chemistry II
HS-PS1-4.	General Chemistry II & Physical Chemistry I
HS-PS1-5.	General Chemistry II & Physical Chemistry I
HS-PS1-6.	General Chemistry II
HS-PS1-7.	General Chemistry I
HS-PS1-9(MA)	General Chemistry II
HS-PS1-10(MA)	General Chemistry I & II
HS-PS1-11(MA)	General Analytical Chemistry & Organic Chemistry I
HS-PS2-6.0	General Chemistry I, Organic Chemistry I & Descriptive Inorganic Chemistry
HS-PS2-7(MA)	General Chemistry I & II
HS-PS2-8(MA)	General Chemistry I & II
HS-PS3-4b	General Chemistry II

6. Appendix F: Full Time Information and Diversity Tables

Name	Rank	Type of Appointment TT, T, NTT	FT or PT	Highest Degree	FTE by Program	Very Brief description of Activity		
						Teaching	Scholarship	Service
Aisling O'Conner	Associate Professor	T	FT	PhD	1.0	General & Analytical Chemistry	Environmental Chemical Analysis	AUC
Billy Samulak	Associate Professor	T	FT	PhD	1.0	Service courses (Chemistry for Health Sciences) and Biochemistry	Mass Spectrometry of Protein Complexes	Organized science symposium (6 years), sponsored bio/chem club, served on committees
Dennis Awasabisah	Assistant Professor	TT	FT	PhD	1.0	General Chemistry Organic Chemistry, and Chemistry for the Health Sciences	Heme model complexes as synthetic models for the active sites of heme and related biomolecules	AUC Student Affairs Search Committee for the Director for Student Diversity, Equity, and Belonging Programs; Strategic Planning Sub-Committee member; University Parking Committee member; University Technology Assessment Committee member; Dept. Assessment Committee; Dept. Student Affairs Committee; Equipment Committee; Dept Administrative Assistant Search Committee
Emma Downs	Associate Professor	T	FT	PhD	1.0	General Chemistry, Inorganic Chemistry, Environmental Chemistry	Silver nanoparticles and the environment	LAS, FYE, Student Affairs, Inclusive Excellence (Student Success and Inclusiveness)
Mathangi Krishnamurthy	Associate Professor	T	FT	PhD	1.0	Organic Chemistry, Medicinal Chemistry, Chemistry in a changing world and Biochemistry	Synthesis of small molecule drug compounds; Synthesis of delta-8 tetrahydrocannabinol based drug molecules as antineoplastic agents	National Chemistry week coordinator, Central MA American Chemical Society section; Chemistry Celebrate Earth Week coordinator, Central MA American Chemical Society section; Chemistry Olympiad coordinator, Central MA American Chemical Society section

Steven Fielder	Associate Professor	T	FT	PhD	1.0	General Chemistry, Physical Chemistry, Chemistry in a Changing World	Theoretical Chemistry	AUC member, former Chair of the Central MA section of ACS, former chair of the FSU Curriculum Committee

Faculty Demographic Table

Demographic Faculty Summary	No. of Full Time Assigned to Unit	No. of Part Time Assigned to Unit
Women	4	
Men	2	
Ethnicity		
White/Caucasian	4	
Asian	1	
Hispanic/Latino		
Black/African American	1	
American Indian		
International or Other		
Credentials – highest degree held		
Bachelor’s Degree		
Master’s Degree		
Doctorate	6	
Experience		
0-3 years		
4-7 years	4	
8-11 years	1	
12-15 years	1	
16-24 years		
25+ years		

7. Appendix G: Chemistry Adjunct Faculty since 2015

Semester	Adjunct Professor	Course Taught (# Sections Taught)
Spring 2021	Dr. Madhira Gamanna	General Chemistry I (1) General Chemistry I Lab (2)
Fall 2020	Dr. Madhira Gamanna	General Chemistry II Lab
Spring 2019	Dr. Madhira Gamanna Dr. Pamela Ruiz Martinez	General Chemistry I Lab (1) General Chemistry II Lab (1) General Chemistry II Lab (2)
Fall 2018	Dr. Priti Tiwari	Chemistry for the Health Sciences (1) Chemistry for the Health Sciences Lab (2)
Spring 2018	Ms. Donna Lee LaMura	Chemistry for the Health Sciences (1) Chemistry for the Health Sciences Lab (3)
Spring 2017	Dr. Richard Boucher Ms. Donna Lee LaMura Dr. Vanina Guidi	Chemistry in a Changing World (1) Chemistry in a Changing World Lab (1) General Chemistry II Lab (1) Organic Chemistry II Lab (2) General Chemistry II Lab (1)
Fall 2016	Ms. Donna Lee LaMura	Chemistry in a Changing World (1) Chemistry in a Changing World Lab (1)
Spring 2016	Dr. Richard Boucher Dr. Timothy Lauer Ms. Alissa Lando Dr. Madhira Gamanna Ms. Donna Lee LaMura	Chemistry in a Changing World (1) Chemistry in a Changing World Lab (1) Chemistry for the Health Sciences (2) Chemistry for the Health Sciences Lab (1) General Chemistry I (1) General Chemistry I Lab (1) General Chemistry I Lab (1) General Chemistry II Lab (1)
Fall 2015	Dr. Madhira Gamanna	General Chemistry I Lab (1)

8. Appendix H: Extra Budgetary Requests for Equipment (EBRQs)

Strategic Funding Request
Department of Biology and Chemistry
Steven Fiedler
February 14, 2016

Request Overview
Gamry Interface 1000B Potentiostat and Electrochemical Cell Kit
$7,937.50

Facilitating Instruction of a Core-Concept
Physical Chemistry is a required course in the new Chemistry major at Fitchburg State University (FSU), and will be offered starting in the Spring of 2017. The course curriculum and scope was approved by the FSU Chemistry faculty and aligned with the Physical Chemistry Course Content (PCCC) Guidelines as issued by the American Chemical Society (ACS), the preeminent national accreditation organization for academic Chemistry programs. The topics of electrochemistry and reduction/oxidation (redox) reactions are typically covered in Physical Chemistry and the ACS PCCC Guidelines specify that the "thermodynamics of electrochemical cells" is a core conceptual topic. The concepts can be taught in the laboratory setting with experiments based on voltammetry, an analytical technique that investigates the composition of a solution in an electrochemical cell by measuring electrical current as as a function of applied voltage. These laboratory experiments reinforce the lecture material on electron transfer reactions and provide students hands-on experience. Presently, this experiment can not be offered at Fitchburg State. The requested potentiostat will enable FSU students to gain hands-on experience in this core Chemistry concept. At California State University, Northridge, an institution which served a similar student demographic, I instructed a lab for two academic years using a potentiostat similar to the model being requested, and am familiar with its use.

Departmental Asset
In addition to providing valuable instruction for students in the Physical Chemistry laboratory, the requested potentiostat can also serve as a relatively inexpensive way to include students in faculty research. Below is a statement of support provided by incoming tenure-track faculty member, Dr. Dennis Awasabisah.

> *My research program is based on the synthesis of chemical models of enzyme active sites. Since most of the enzyme action is determined by electron-transfer events, it is critical that we understand the redox behavior of these models that students will prepare. Cyclic voltammetry is an excellent tool for this purpose. The students will thus be trained, not only in chemical synthesis, but also in electrochemistry using the requested equipment. The intent is to obtain data of sufficient quality for publication in peer-reviewed journals.*

Alignment with Strategic Plan
Pursuant with Goal 1, Action 1A of the FSU 2015-2020 Strategic Plan to "Align Liberal Arts and Sciences core curriculum with skills and aptitudes valued in the workforce," the ultimate objective of the new Chemistry major is to prepare our students for successful future careers. To this end, the requested instrument will allow FSU students gain an understanding and proficiency in electrochemical concepts that pertain to many fast-growing fields including the development of fuel-cells and the exploration of alternative energy sources. The recent proliferation of electric and hybrid vehicles, solar panels, and wind turbines exemplify the demand for these skills for many years to come.

Extraordinary Budget Request Department of Biology and Chemistry
Steven L. Fiedler
December 19, 2014

1. Vacuum Manifold Infrastructure Agilent: Rotary Vane Pump, DS 42: $1,979

A reliable mechanical pump with sufficient pumping speed is necessary to bring pressures down to required values in a vacuum manifold. A vacuum manifold, or Schlenk line, is an apparatus commonly used to handle chemicals in the gaseous state. While the Biology and Chemistry Department previously purchased two glass vacuum manifolds, a dedicated mechanical pump with specifications such as those possessed by the requested model, will facilitate its operation. I (SLF) have instructed multiple Physical Chemistry laboratory experiments that employ a vacuum manifold, including an experiment where students measure the temperature dependence of the vapor pressure of water. This experiment is particularly insightful, as it correlates with multiple topics in the lecture that include gas laws and enthalpy. To allow sufficient time to build the apparatus and ensure its proper operational order, e.g., order auxiliary connections, leak check, etc., it would be helpful to receive the pump by May 2015.

2. Agilent Cary 60 UV-Vis Spectrophotometer $10,362

UV-VIS absorption spectroscopy instigates the excitation of electron(s) in atoms and molecules to electronic states of higher energy. In a practical sense, this allows experimental investigations in termodynamics, quantum mechanics and kinetics - all areas of fundamental study in Physical Chemistry. By exploring the electronic excitations of the ground (X singlet Sigma) to the excited (B triplet Pi) states of the iodine molecule, for example, the Gibbs free energy of dissociation can be derived. In the process, topics of entropy, enthalpy, heat capacity, and basic spectroscopy concepts are illustrated. I (SLF) have experience instructing this lab to undergraduate students, as well as a lab that evaluates the kinetics of a reversible, first order consecutive reaction. In that experiment, the oxidation of a tripeptide, gluthatione-γ-L-glutamyl-L-cysteinylglycine (GSH) by Cr(VI) is monitored in real time by recording the absorbance of Cr(VI) in the form of CrO42- at 370 nm and the absorbance of the CrO42--GSH intermediate complex at 430 nm. Based on data analysis, the value of the three pertinent rate constants can be calculated, as exemplified by undergraduate students in the Physical Chemistry course at California State University, Northridge. While the Department of Biology and Chemistry at Fitchburg State University, owns UV-Vis spectrometers, the current instruments *cannot monitor more than one wavelength as a function of time*. This capability is essential to extract out the kinetics for a multi-step reaction mechanism as described above.

Dr. Mathangi Krishnamurthy has interest in use of the requested instrument, as well, for Organic Chemistry laboratory instruction. Additionally, Dr. Krishnamurthy cited use of this UV-Vis spectrometer as an important component in the upcoming Synthetic Techniques course. To allow sufficient time to develop instructional material, particularly for use in the Organic Chemistry Laboratory course, it would be helpful to receive the instrument by May, 2015.

3. Basi EC Epsilon Potentiostat and Stand $15,780

The topics of electrochemistry and reduction/oxidation (redox) reactions are commonly covered in Physical Chemistry. The American Chemical Society, Physical Chemistry Course Content Guidelines, specify the “thermodynamics of electrochemical cells” as a core conceptual topic. The concepts can be instructed in the laboratory setting with experiments based on voltammetry, an analytical technique that investigates the composition of a solution in an electrochemical cell by measurement of electrical current upon the application of a potential (voltage). These laboratory experiments reinforce the lecture material on electron transfer reactions and provide students hands-on experience. At California State University, Northridge, an institution which served a similar student demographic, I (SLF) instructed a lab using the requested instrument and am familiar with its use. There, students monitored the redox reactions of a quinone compound to study solvent bonding effects and the influence of hydrogen bonding. This requested instrument will also likely be of interest to the incoming Inorganic faculty member as it can probe the reactivity of organometallic compounds in a variety of conditions, including the effect of ligands on the redox potential of a central metal atom. To allow sufficient time to develop instructional material, it would be helpful to receive the instrument by Fall, 2015.

4. Perkin Elmer LS 55 Fluorescence Spectrometer $22,479

As a counterpart to the UV-VIS spectrometer, which measures molecular absorbance of electromagnetic (EM) radiation, a fluorescence spectrometer can allow for sensitive detection of molecular EM emissions as molecules relax from excited electronic states to electronic states of lower energy. Both absorption and emission spectroscopy are useful experimental techniques used to demonstrate concepts in quantum mechanics, thermodynamics and rate equations in kinetics, all core topics in Physical Chemistry. At California State University, Northridge, an institution which served a similar student demographic, I instructed a laboratory experiment using the requested instrument and am familiar with its use. There, students determined the forward and reverse rate constants associated with the deprotonation a fluorescent organic compound, 2-naphthol, in an excited state. Additionally, this experiment reinforced understanding on the lecture topic of reaction mechanisms.

Dr. John Ludlam has expressed support for this request. This instrument would allow the measurement of algal chlorophyll at much lower concentrations than a standard spectrophotometer. These measurements are an important part of his on-going work on stream metabolism in collaboration with Allison Roy (University of Massachusetts Amherst), and the purchase of a fluorometer would support student independent research projects. To allow Dr. Ludlam use of this instrument for Summer research, and to develop instructional material, it would be helpful to receive the instrument by May 2015.

Strategic Funding Request
Department of Biology and Chemistry
Steven Fiedler
February 22, 2018

Request Overview
HP Workstation Z8G3 4108, 32 GB RAM, 1 TB SATA drive, 250 GB SSD
$4,119.38

Number of Students Impacted Annually: 3-5, with the higher values pertaining to ongoing discussions for collaborative projects.

Facilitating Meaningful Student Research
The academic performance and retention of students belonging to disadvantaged demographics improves with their participation in undergraduate student research. I have been fortunate to serve as a research advisor to talented and enthusiastic Fitchburg State University (FSU) students who remain highly engaged throughout the course of their projects. These students have presented their findings at regional conferences offered by the Central Massachusetts division of the American Chemical Society and Bridgewater State University and the FSU Undergraduate Research Conference. I have also successfully mentored a student through the application process to compete nationally for an NSF award to conduct summer research at a tier-1 institution.

Throughout the course of the year, these research advisees assist on all phases of an interdisciplinary project centered at the intersection of Biology and Chemistry. By leveraging my background in scientific computing, they are able to explore the impact of nanoparticle pollutants on cell membranes through computational modeling and simulation. This is an extension of a study that I developed at the University of Michigan and is designed to lead to peer-reviewed publication with student authorship. Although it is often not a trivial task, the students' continual dedication has allowed for systematic progress. For example, to maintain this necessary momentum, one student took it upon himself to implement a method for the server to send a SMS text message to notify him when a job was completed or terminated.

Students now have the expertise to run production-level calculations. This will require greater computational resources. To this end, as a temporary measure, I obtained:

- A start-up award of supercomputer time through the NSF-funded XSEDE program.
- A month of use of an additional computational server of a collaborator.
- A quote for computer time through the Massachusetts Green High Performance Computer Center (MGHPCC). In the summer of 2016, I provided support for a NSF proposal to the MGHPCC program. This proposal was subsequently funded.

However, the first two resources have been consumed, and the third option is prohibitively expensive. This Strategic Fund Request seeks a comparable server comparable to that currently employed to both support and increase the number of students involved with this project.

Alignment with Strategic Plan
Pursuant with Objective 2A of the FSU 2015-2020 Strategic Plan to improve student retention and completion, the ultimate objective of such activity is to prepare our students for successful future careers. Participation in research has been shown to improve student performance, increase aspiration and ultimately result in improved retention.[1,2] To this end, the requested instrument will allow FSU, students to gain an understanding and proficiency in scientific exploration and provide a framework for them to learn and improve their technical communication skills.

1. Mitchell J. Chang, Jessica Sharkness, Sylvia Hurtado, and Christopher B. Newman. What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups. Journal of Research in Science Teaching, 51(5):555-580, 2014.
2. Ivelitza Garcia. Just-in-Time Approach to Undergraduate Biochemistry Research, chapter 8, pages 91-120.

Petition for Strategic Funding: Submitted 2017 & 2019

Faculty Requesting: **Dennis Awasabisah**
Department Name: Biology and Chemistry (Submitted by Dennis Awasabisah)
Department Head: Dr. Michael Nosek
Amount requested: $16,500.00
FOAPAL(Expenditure Account Code):
Number of Students Impacted Annually: 96. This number is expected to increase in the next year.

Brief description and main objective of request:
The petition being submitted is for funds for the upgrade of our department's 9-year-old Anasazi EFT-60 Nuclear Magnetic Spectrometer from a C13/H1 system to a *Wideband Probe* that would allow for the observation of C13, H1, F19, P31, B11, Na23, Co59, Si29, Sn117, S119, etc. nuclei. The upgrade also includes an installation visit from the manufacturer, service of the air-handling system, optimization of the magnetic field and the software, as well as training for users of the instrument.

Comprehensive outline supporting request:

The characterization of compounds is central to the field of chemistry. One standard characterization technique is Nuclear Magnetic Spectroscopy (NMR), which reveals specific placement and connectivity of atoms in a given compound. When applied to organic compounds, for example, this technique not only gives information about the carbon skeleton, it also provides information about the three-dimensional structure of the compound. The type and quality of data provided by an NMR instrument is determined by the *Nuclei Probe* installed on the instrument.

The current EFT-60 C13/H1 system in the department is equipped with a *Nuclei Probe* that provides signals for carbon and hydrogen nuclei only. Due to its limited capabilities, the instrument is currently used in our organic chemistry I and organic II classes for characterizing simple organic compounds only. In addition, Dr. Krishnamurthy and I use this instrument in our student-focused research. We would like to upgrade the instrument to expand its applications, particularly in the detection of other important nuclei such as F19, P31, B11, Na23, etc. In our organic chemistry class, we would like to develop spectroscopy experiments so students can observe heteronuclear coupling, and interpret the NMR data from experiments performed on complex molecules. These are learning goals we would like our students to attain in the organic chemistry class. In addition, the upgrade could allow us to use the instrument to study reaction kinetics[1] and the measurement of isotopic ratio of nuclei such as B10/B11,[2] even in our general chemistry classes. The overall goal is to give our students hands-on experience on using the NMR instrument and interpreting more challenging data, thus, helping them meet the skill set they need to be successful in the workforce.

In my research with students, one of our ongoing projects involve the synthesis and characterization of fluorine-containing molecules. Such molecules have applications in different fields; for example, as feedstock for pharmaceuticals, agrochemicals and other industrial chemicals. As part of the learning outcome in this project, students will learn about the applications of chemistry in real life, thus, arousing their interest in the subject of chemistry. This consequently, answers students' questions such as, "why do we learn chemistry?", and as such leads to high retention in the field. Furthermore, in this project, students will learn to detect fluorine atoms in a compound using F19 spectroscopy, and then investigate the roles of fluorine on the electronics and structural properties of organic compounds using those spectroscopic data they collected.

Proposed outcome:

The proposed outcome is high retention and graduation rate. It is reported that undergraduate student-faculty research promote retention; more so for students at greater risk for college attrition and those with low GPAs.[3] By involving students in research activities using the upgraded NMR instrument, students will be prepared to succeed as chemists in the workforce. The research activities will also be a source of motivation for students to further their studies in graduate schools.

Identify which strategic plan goal and objective the request relates to:

The strategic plan goal and objective the request relates is Objective 2A – improvement of student retention and completion.

Attached additional pages as needed to support your request.

Please see attached for a quote for the upgrade.

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References

1 Werner, R. M.; Johnson, A. *Biochem. Mol. Biol. Edu*. 2017, *45*, 509-514.
2 Zanger, M.; Moyna, G. *J. Chem Edu.* 2005, *82*, 1390 - 1392.
3 Gregerman, S. R; Lerner, J. S.; Hippel, W.; Jonides, J.; Nagda, B. A. *l. Rev. Higher Edu*. 1998, *22*, 55-72.

FY 2019 Petition for Strategic Funding (Aisling O'Connor)
Department Name: Biology & Chemistry
Department Head: Dr. Michael Nosek (acting)
Amount requested: $38,000
FOAPAL(Expenditure Account Code): T65-1230-K02-0000-D01

Brief description and main objective of request:

The requested funds will be used to purchase a graphite furnace atomic absorption spectrometer (GF-AAS). This is an instrument used to measure the concentration of metals at very low levels (parts per billion). The instrument would be used for both teaching and research in the Biology and Chemistry & Earth and Geographic Sciences Departments. Specifically, the instrument will be used extensively in the biology capstone Plant Physiology class, for at least one experiment in the General Analytical Chemistry laboratory class, in upper level chemistry electives and perhaps in future courses offered by the Earth and Geographic Sciences Department especially with the introduction of the concentration in Environmental Public Health. At least six faculty members will use the instrument extensively, while conducting research projects with undergraduate students. A number of research projects have already been identified and many are already in progress.

Comprehensive outline supporting request:

The section below describes in detail, the classes and research projects in which the GF-AAS instrument will be used:

1. *Health of the Nashua River (Interdisciplinary Research Project, Drs. Emma Downs, Elizabeth Gordon, Jane Huang, Aisling O'Connor & Daniel Welsh)*
Five faculty members from the Biology & Chemistry and Earth & Geographic Sciences Department are currently involved in the FSU Student-Faculty Collaborative Summer Research Experience. They are working on a project assessing the health of the Nashua River in the Fitchburg area. The faculty involved in this project are very interested in analyzing the heavy metal content of water, fish and sediment samples collected from the river. Heavy metals pose significant adverse health effects for invertebrates, fish, and humans and the environment. The results of these analyses would provide information regarding the current and past health of the river. This cannot be done with the instrumentation currently available at FSU, but the GF-AAS would be sensitive enough to detect these metals at the concentrations likely to be found [1].

Chemists, Drs. Emma Downs and Aisling O'Connor are planning on using the GF-AAS to analyze the heavy metal content of water sampled from various sites along the Nashua River. It is expected that the concentrations of heavy metals such as lead, cadmium, chromium, manganese, iron and copper will be sub to low ppb level [2]. Levels obtained will be compared to those in place for drinking water in order to ensure the water is suitable for recreational purposes.

The examination of heavy metal concentrations in fish is cited as an even better indicator of water quality than that of the results obtained from water grab samples [3]. Many heavy metals have a tendency to bioaccumulaute in various fish tissues. Dr. Daniel Welsh is interested in analyzing the heavy metal content of fish muscles, liver and gills obtained from fish sampled from various sites in the Nashua River.

Dr. Elizabeth Gordon is interested in using the GF-AAS to investigate the imprint of anthropogenic activities as observed in aquatic sediments collected from the river. In particular, she is interested in how the concentrations of heavy metals such as lead, cadmium, manganese, iron and copper vary depending on the age of the sediment. Sediments would be sampled using a corer and sediment depth used to section it according to the age of the sediment deposition. Thus, it will be possible to get hundreds of years worth of information regarding the heavy metal content of the sediment and the results could be linked to the past industrial uses of the Nashua River [4]. It is expected that higher levels of metals will be found in sediment layers dating to the time period when untreated effluent was discharged into the river by the paper and textile mills.

2. Leaching of Silver Nanoparticles from Commercially Available Products (Research Project, Dr. Emma Downs, Assistant Professor, Chemistry)

Nanoparticles are clusters of material in the nanometer range (10-9 m). The small size of these particles creates a very high surface to volume ratio, leading to properties that differ from larger (bulk) samples of the same materials. For this reason, nanoparticles are a part of many emerging technologies. Silver nanoparticles have excellent antimicrobial properties, and are often used as anti-odor agents in clothing, sports gear, and even food storage. Despite the current and historic uses of silver and silver nanoparticles, there are risks associated with elevated levels of silver, both at the individual and environmental level. Long term exposure to silver may cause permanent discoloration of the skin and eyes. Additionally, while bulk and nano silver are potent antimicrobials they have been seen to cause the formation of reactive oxygen species in humans leading to cell damage. In other animals such as fish, it was seen that nanoparticles themselves damaged membrane integrity and led to lower mitochondrial activity [5]. Unfortunately, the threat is not limited to animals as many microbes, including nitrogen-fixing bacteria are negatively impacted by higher levels of silver. The growth of these bacteria in particular is important as they provide nitrogen in a usable form for plants. However, bacteria that convert nitrates into nitrogen gas are also harmed, leading to higher levels of nitrates in the soil, which may also lower plant productivity [6].

Due to these risks, further study on the leaching of silver nanoparticles from commercial products is necessary. The real world applications of this project are very interesting to students, and one student has worked on the project already. Additionally, there is a natural connection to the studies on silver nanoparticle effects on plants also being undertaken in the department.
For consistency, we focused on one type of commercial product. Several different brands of athletic socks that were advertised as containing silver nanoparticles were obtained and tested for leaching. The fabrics were exposed to various conditions that might be encountered during washing, including heat, detergent, and mild acids. The resulting washes were analyzed in two ways, with UV-visible spectrometry (UV-vis) and with Atomic Absorption Spectroscopy (AA). UV-vis is used to detect silver nanoparticles. The surface plasmon resonance of silver nanoparticles gives a clear spectroscopic handle to confirm the presence of nanoparticles, while AA is used to quantify the amount of silver present.

Three brands of athletic socks labeled as containing silver and silver nanoparticles were tested. They were subjected to multiple washes under various conditions including heat, acid, detergent, bleach, and reducing agents. The fabric was also digested with acid to determine total silver content. The effluent from each of the washes was examined with both AA and UV-vis to test for overall silver content and the presence of nanoparticles. In all samples, the effluent from the nanoparticle containing socks showed the presence of Ag nanoparticles by UV-vis, but the amount of silver in the water was below the limit of detection for the AA. Conversely, the socks containing other forms of silver had much higher amounts of metal present in the effluent, although no nanoparticles were detected. Bleach, reducing agents, and heat increased the amount of leaching, while detergent actually decreased the amount of leaching.

A major roadblock to continuing this project is that many of the effluent samples contained silver concentrations below the limit of detection for the AA we currently have. Other studies of silver nanoparticle treated athletic gear have shown concentrations of silver ranging from 3 to 1300 ppb [7]. Our current instrument does not have this level of sensitivity. A graphite furnace instrument with a lower limit of detection would enable us to look at the leaching of silver nanoparticles from more products. These lower levels are still within a range that could be harmful to the environment.

3. *Silver Nanoparticle Accumulation in Plants and Insects & Plant Physiology (Research Project and Capstone Biology Course, Dr. Erin Rehrig, Associate Professor, Biology)*

Silver nanoparticle accumulation in plants has been well-documented. Uptake and accumulation varies depending on species and soil ecotoxicity [8]. The limited number of studies that have been conducted on the model plant species Arabidopsis thaliana [9, 10] suggest that these plants can accumulate concentrations of AgNPs that are in the range of ug/g of dried weight. This small concentration has been detectable using an Elan 9000 AA Apparatus which can detect levels well below ppb.

Plant Physiology students, will measure the effect of silver nanoparticles on seed germination, growth, and insect herbivory by lepidopterans. Knowing the concentrations of AgNP will be important to determine whether any differences in material eaten by insects is due to overall poor plant health or the insect’s non-presence/preference for plants contaminated with higher concentrations of silver nanoparticle. Furthermore, we may be able to determine whether there is a bioaccumulation effect in insects fed on AgNP-laden plants. To date, there are no known studies published on the effect of silver nanoparticle on insect herbivory in plants. This project would be part of a capstone Plant Physiology class as well as a source of research of undergraduate independent studies.

It is suspected that low ppm concentrations of silver can be found in plants based on the literature citing detections of ug/g dried plant weight. However, insects might have significant less than this with concentrations in the ppb range. The GF-AAS would be sensitive enough to detect silver in both plant and insect samples. Some lepidopteran insects have the ability to exterminate ingested silver nanoparticles in the feces [11]. Students will also collect insect feces (frass) to be dried and assayed.

4. *General Analytical Chemistry (Required Course Chemistry Major & Minor)*

This course if offered every spring semester and has a lab component. It is a very hands-on practical course in which students learn about and use a wide variety of chemical analysis techniques. The lab curriculum would be strengthened by the addition of a 2 – lab session experiment involving the analysis of heavy metals in sediment samples taken from the Nashua River. This experiment would complement the work being conducted by the Health of the Nashua River team and provide a local, "real world" application of an analysis technique. Different lab groups in the class would prepare and analyze sediment samples from different time periods and class data shared to provide a cohesive snapshot of the historical anthropogenic activities of the local area.

5. <u>Electrochemical Behavior of Heme Macrocycles and Related Complexes (Dr.Dennis Awasabisah, Assistant Professor, Chemistry)</u>

The redox properties of compounds generally provide insight on the chemical and the structural behavior of complex molecules. One of the widely used electrochemical techniques is cyclic voltammetry (CV), which is also used to study electron-initiated chemical reactions such as catalysis. My research objective is to engage our diverse students in projects involving the investigation of the mechanism of action of heme-related enzymes via electrochemical techniques. In particular, my lab is interested in understanding the role of the heme group as a target for antimalarial drugs; a process that involves redox chemistry.

Although CV is a powerful technique for probing redox reactions, there are several reports in the literature of misinterpreted data from CV experiments, partly due to failure to detect redox processes resulting from trace impurities in the solvent and/or the analyte [12]. Since most CV experiments require analyte samples of at least ~1mM, the presence of trace redox-active impurities in the experiments often yield redox waves that either interfere with those of the analyte, or overshadow the "true" waves of the analyte altogether; thus yielding inconclusive data. As a result, conclusions from electrochemical experiments have to be verified by careful experimental controls. Some of the controls include:

1. Ensuring that solvents for electrochemical investigations are devoid of redox-active substances
2. Ensuring that chemically and electrochemically inert supporting electrolytes are used
3. Purifying the analyte and removing any metal and redox active by-products

Unfortunately, solvents from commercial sources often contain stabilizers and other trace redox-active metals, some of which produce redox waves that interfere with the redox wave from the analyte. Such solvents need to be re-purified and retested for impurities via special techniques prior to use. In addition, complexes and other analytes obtained via metal catalyzed reactions sometimes contain other redox-active metals that tend to interfere with the analyte's CV data. Such trace metals cannot be detected by available spectroscopic techniques such as IR, UV-vis and NMR. For our work, we need a technique that is sensitive, selective for metals, and one that does not require complex sample preparation or lengthy analysis time. The GAAFS instrument being requested will be used to prescreen catalysts (and analytes) for metal impurities and solvent contaminants prior to their use in the electrochemical experiment and catalysis reactions. This will help reduce experiment time and cost, and produce publishable data.

6. *Analysis of Lead and Cadmium in Makeup & Face Paint (Dr. Aisling O'Connor, Associate Professor, Chemistry)*

Cosmetics are used by millions of people around the world on a daily basis. Many cosmetic products contain chemicals which may be hazardous to human health. In the case of heavy metals, many countries, including the U.S. do not regulate the concentration of these elements in cosmetic products. In general, heavy metals are found at low ppm to ppb levels in cosmetics, but even low levels of elements such as lead or cadmium can cause health problems, in particular in women and children [13].

The goal of this study is to develop an analytical method to measure the levels of heavy metals such as lead and cadmium in lipstick, lip gloss and face paint using Atomic Absorption Spectrometry (AAS). Cosmetics which are applied to the lips were selected for this study as they are more likely to be ingested than other products. The focus will be on inexpensive products (< $5) which are likely purchased by / for young children, tweens and teenagers.

This project was conducted as an independent study with an undergraduate student in the Fall 2015 semester. Although cadmium was detected in some of the samples, it was below the limit of quantification of our current instrument. It would be very interesting to continue this project and the GF-AAS would have low enough detection limits for lead, cadmium and other metals of interest in personal care products.

Proposed outcome:

Inclusion of labs conducting using the GF-AAS instrument will strengthen our curriculum. In particular, it will allow meaningful research to be conducted in the capstone Plant Physiology class. Many of our chemistry major and minors go on to work as analytical chemists and providing them with an opportunity to use GF-AAS will strengthen their knowledge and be an addition to their resumes. This addition of this instrument to our chemical analysis arsenal will provide many additional research opportunities for our faculty and undergraduate students. It will strengthen the interdisciplinary "Health of the Nashua River" summer research project which serves at least 8 students / year as well as support other research projects headed by Drs. Awasabisah, Downs, O'Connor and Rehrig.

Identify which strategic plan goal and objective the request relates to:

We believe engaging our students in these research projects using the GAAFS instrument will improve student retention and completion in pursuant of Objective 2A of the University Strategic Plan. The Health of Nashua River team are planning on working more closely with the Nashua River Watershed Association (NRWA) in future years and the heavy metal data we obtain will be shared with them. NRWA is a local non-profit organization with a mission to restore and protect the water quality of the Nashua River watershed. This aligns with Objective 3A of the strategic plan. The Health of the Nashua River project also aligns with Objective 3B of the Strategic Plan as we are striving to provide information regarding the wellbeing of the river in the city of Fitchburg with a view to its use for recreational purposes.

References

[1] Gupta, A., Rai, D.K., Pandey, R.S. et al., Environ Monit Assess (2009) 157: 449.

[2] Tchounwou P.B. et al., Molecular, Clinical and Environmental Toxicology, (2012) 133:164

[3] Öztürk et al., Iran. J. Environ. Health. Sci. Eng., (2009), Vol. 6, No. 2, 73:80

[4] Maanan M. et al., International Journal of Sediment Research, (2014) Vol. 29, No. 1, 1:10

[5] Yu et al., (2013) Emma

[6] Panyala et al., (2008) Emma

[7] Benn and Westerhoff, (2008) Emma

[8] Navarro E. et al., Ecotoxicology (2008), Vol. 17, 372:386

[9] Wang J. et al., Sci. Total Environ. (2013), Vol 47, 5442:5449

[10] Ma X., at al., Sci. Total Environ. (2010), Vol. 408, 3053:3061

[11] Yasur I. & Pathipati, U.P., Chemosphere (2015), Vol. 124, 92:102

[12] Pumera, M., Chem. Rec. (2012), Vol. 12, 201:213

[13] http://www.safecosmetics.org/wp-content/uploads/2015/02/Pretty-Scary.pdf

FY2023 Extraordinary Budget Request
Funding requests for one-time expenses.
Department Name: Department Org Code: 1210/1230 Submitter Name: Erin Rehrig

ITEM #1 Short Description: Gas Chromatograph/ Mass Spectrometer for Organic & Analytical Chemistry Labs and Faculty research

Total Amount $ 79,195.57
Ranking 1
Funding: One-Time

Please answer Yes or No to the following questions:
1. Will the area require any modifications to accommodate equipment (i.e. utilities)? NO
2. Does the item require special handling to install (i.e. heavy equipment, etc.)? NO
3. If the cost exceeds $10,000 - is the product/service available from MHEC or CommBuys contract? YES
4. Will this item require IT to be involved in the operation, installation, or maintenance, etc.? NO

Additional Supporting Material
This proposal is to request funds to replace a Gas Chromatography – Mass Spectrometry (GC-MS) equipment. The purchase comes with a one-year warranty and a five-year renewable service contract. Attached is a quote for this purchase.

The GC-MS is a standard laboratory technology that is used heavily in the chemical and pharmaceutical industry, and is also a technique we emphasize in our organic chemistry and analytical chemistry laboratory courses. Additionally, the GC-MS is an integral technology in chemistry research, and it is a crucial instrument we need to fulfill our Chemistry Program Learning Objectives (PLO) 1 and 2. PLO 1 and PLO 2 provide students with 'Disciplinary Knowledge in Chemistry' and 'Lab Skills', respectively. The GC-MS will also help us meet Goal One of the university's new Strategic Plan, by allowing us to create a learning environment in which our academic program works to offer applied learning experiences that prepare students for purposeful professional lives.

Our current GC-MS was purchased in 2006 (at a cost of over $65K, obtained through EBRQ funds) from Varian, Inc. Varian was bought by Bruker, which had been providing us with yearly equipment servicing and other warranties through a service contract. We had the circuit board for our instrument fail a few times in the past and these were covered by the service contract. We obtained an extended warranty contract and we were able to get them repaired each time. However, in the last two years Bruker Instruments stopped providing the service contract and even turned down a request from us for a per diem maintenance/repairs. As a result, we were responsible for all repairs and maintenance for the instrument in the last year. Last Summer, the instrument broke down yet again, and we were unable to find and purchase replacement parts for the instrument. One of the service technicians who had retired, had an old spare part with him, which he came and replaced in our instrument free of cost. Unfortunately, as of February 15, 2022, the GC-MS is now completely nonfunctional, and efforts to get it back to operational status have failed. This has made it quite challenging for us as a department in our teaching and scholarly efforts. Dr. Krishnamurthy who uses it heavily in the spring semester for her Organic Chemistry II class is unable to provide her students with this important learning goal in a scheduled lab. Similarly, Dr. O'Connor who uses this equipment in her Analytical Chemistry class will not be able to provide her students with this lab experience. Without a new GC-MS, student learning will suffer and their post-graduate preparedness will be impaired as well.

Application of GC-MS in Organic Chemistry I and Organic Chemistry II:
Organic Chemistry I and II are taken by Biology and Chemistry majors and are core courses in both majors. In Organic Chemistry I, students are introduced to the use of GC (gas chromatograph) with a flame ionization detector. They use the instruments to analyze samples in two separate experiments. In Organic Chemistry II, they will gain further experience in GC alone and then are exposed to GC-MS for analyzing the components of essential oils they isolate from herbs, such as cloves, nutmeg, cumin, rosemary, lavender, etc. Each pair of students works on a particular herb and their task is to isolate the oil and then identify the compounds in the oil. This gives them hands-on experience with the operation of the instrument and in analyzing the mass spectra generated. Later in the semester they are asked to use GC-MS to analyze the product(s) of a multi-step organic synthesis (a standard experiment in Organic II) in conjunction with proton and carbon NMR spectrum. Drs. Mathangi Krishnamurthy and Dennis Awasabisah use the GC-MS for teaching purposes both in the regular semesters and the summer semesters.

Application in General Analytical Chemistry
Analytical Chemistry is taken by all Chemistry majors, as it is a requirement of the major, and is also taken by many Biology majors, as it is one of the requirements for the Chemistry minor. In General Analytical Chemistry, the instrument is used for quantitative analysis of a drug in an environmental sample. Here, the students gain practical, hands-on training in making standard solutions, standard curve and then quantitate the amount of drug in the test sample they produce. They use the GC-MS instrument to analyze samples, including organic samples contained in the dollar bill.

Application in Student-Faculty Collaborative Research
The GC-MS instrument is also used in research in our department. Drs. Krishnamurthy and Awasabisah, who have research projects in organic chemistry use this technique in analyzing their samples. Dr. Awasabisah is an untenured faculty who does research with students on the synthesis of organofluorine compounds, which serve as building blocks for pharmaceutical compounds. He and his students perform regular analysis of compounds they make and use the GC-MS technique to ascertain them. His students have presented data from the GC-MS instrument at the FSU Undergraduate Research Conference and have received an award and positive feedback for their efforts. Dr. Krishnamurthy uses this technique for her organic and medicinal chemistry projects as well. In the past few years when the instrument gave us problems, we gave usage priority to our classes. Independent research is a "high impact" practice that has been shown to not only increase retention of students but also help ensure students are prepared for life after graduation and are successful in their future jobs and/or graduate school.

Other Potential Applications of the GC-MS Instrument
Since we started to have technical issues with our current GC-MS instrument, we had to cut back on its use in order to extend its longevity. There are several other experiments we would like to conduct using the GC-MS in order to provide students with a diversity of practical laboratory experience. Further, the replacement of the instrument will open up several other scholarly activities for students and faculty, including a course in forensic science. Forensic science will be offered as an interdisciplinary course. As a result, we anticipate that this instrument will benefit many students outside our major.

Number of Students Impacted

As stated above, the students in our Organic Chemistry course sequence, General Analytical Chemistry as well as students in our independent study benefit immensely from the GC-MS instrument. We estimate that about 70-80 students from our majors/concentrations in our department will benefit from this instrument every year. This number does not include nonmajors that would potentially benefit through the interdisciplinary forensic science course. Several of our students work for chemical companies in the New England area after they graduate, and we believe the GC-MS will provide them with some of the requisite skills they need to secure and succeed in their careers.

9. Appendix I : Library Information

Researchers in Chemistry generally focus on the use of academic journals and monographs (books).

Journals and Databases

The Amelia V. Gallucci-Cirio Library offers access to over 134,000 online journals in 183 databases. Specifically, for the Chemistry major and classes, the library has the following core databases:

1. Academic Search Ultimate (EBSCO)
2. Applied Science & Technology Source
3. SciTech Premium (ProQuest)
4. PubChem (National library of Medicine)
5. Science & Technology Collection (EBSCO)
6. Science Full Text Select (H.W. Wilson)
7. SciFinder (American Chemical Society)
8. SpringerLink Package

Chemistry related journal titles in the following sub-categories may be viewed online by subject using the Library's "Journal Locator" tool (items in parenthesis are # of journals):

- Chemical Engineering (371)
- Analytical Chemistry (51)
- Biochemistry (115)
- Chemistry - General (190)
- Crystallography (10)
- Inorganic Chemistry (27)
- Organic Chemistry (74)
- Photochemistry (5)
- Physical & Theoretical Chemistry (72)

Library Supplemental Table 1 (see below) shows the full-text Journal Databases by Disciplines related to Chemistry. Usage statistics show the overall usage numbers are good.

In fall 2018, the Library conducted a journal review project. It looked at the approximately 400 print and online journals to which the Library subscribes (outside of the journals available through the databases). The Library determined the annual cost per usage by dividing the annual cost for the journal title by the number of times the journal was used in a year. Criteria was established and applied that allowed the Library to cancel journals that were not being effectively used. No journals in Chemistry were cancelled during this review.

This journal review project allowed the Library to increase journal offerings in needed areas as determined by InterLibrary loan data, as well as to purchase large, multi-disciplinary eBook collections. More information about the new eBook collection is below.

The Library collection development policy has been, and continues to be, to provide the core journals and databases appropriate for each discipline. Reviews of databases and journals are consulted, peer comparisons are conducted, and faculty input on the effectiveness of the resource is critical when considering new databases. Funds for new databases and/or journals are then requested, and if granted, they are purchased.

Books

A review of our print collection in the Library of Congress call number ranges specifically associated with Chemistry shows 384 print books in our collection. This is an inadequate depth of collection. See Library Supplemental Table 2: Monograph Collection Description and Analysis.

Prior to FY19, almost all of our books were in the print collection as the Library offered few eBooks. It was our recommendation that eBook packages that include Chemistry books be acquired to meet the needs of the undergraduate and graduate researchers and the faculty. This would not only increase the number of volumes available; it would also increase the number of books published in the past 5 years. Therefore, effective in FY19, the EBSCO Academic Complete eBook package and JSTOR EBA and DDA eBook collections were subscribed to. In addition to these packages, in FY21 the Library subscribed to the ProQuest eBook Central DDA Collection. Through these 4 eBook packages we have added approximately 6,085 titles in Chemistry and related areas (1,846 of these titles were published in the last 5 years and 4,142 were published in the last 10 years). This increases the number of books associated with Chemistry in total to 6,469 books while providing on and off-campus access. This total number is adequate to support undergraduate level research and course work, especially since Chemistry students and faculty tend to use other resources, such as databases and journals, more than books to do research.

Films and other Media

In 2018, the Library purchased a subscription to the academic streaming film database Kanopy. Over 3,000 videos are available with subjects aligned with Chemistry (this does include some duplicates). See Library Supplemental Table 3: Films and Other Media Collection for a breakdown by category.

Services for Chemistry

Technology

Starting in Fall 2020, the Library offers a robust Technology Lending Library to ensure that all students, regardless of their financial means, are able to access the technology needed to do their course work, including digital cameras and camcorders. The equipment is available for checkout. Students also have access to a range of technology available in the Library building.

Library Instruction

For all academic departments in the 2021 academic year, faculty librarians taught 111 research sessions and were embedded into 97 courses. Through these efforts, the Library reached over 4,000 students during the last academic year. With only 7 faculty librarians on staff, the number of classes with research sessions and/or an embedded librarian is impressive and requests continue to increase. Since students in our major take classes in other majors, we believe that they also benefited from these research sessions.

Since FY19, Chemistry faculty members have collaborated with librarians seven times to teach the research process. Librarians have visited and embedded in sections of the First Year Experience course and in a section of the Senior Seminar.

Library Instruction	FY2019	FY2020	FY2021
Total Embedded Courses	72	68	97
Embedded Chemistry Courses	0	0	1
Total In-person/Onsync Sessions	194	177	111
In-person Chemistry Sessions	2	0	4

See Library Supplemental Table 4: Research Instruction for more information.

The Library has recently completed the Library's information literacy student learning outcomes. The Library staff welcomes the opportunity to discuss how they can support our department's information literacy and research goals.

Library Research Guides

The Library offers 35 subject research guides plus 188 course specific guides, covering all disciplines at Fitchburg State. For Chemistry, they have created one subject research guide and three course specific research guides. The usage statistics in the Chemistry research subject guide shows that the guide was accessed a total of 408 times in FY21. This is about 71% less than the usage the average subject guide receives (1417 views/guide avg.). Starting in fall 2019, the

Library's Chemistry Research Guide was made available at point-of-need within the Blackboard course management system in all courses, including Chemistry, in order to facilitate access.

The Library is interested in working with Chemistry faculty to increase course-specific use of specialized databases via our embedded research guides.

Research Help

The Library offers one-on-one reference services in a variety of modes, including dropping in at the reference desk, making a personal appointment, email, and chat instant messaging service. Over the past two years, research help questions have transitioned from primarily in-person assistance to primarily virtual assistance via our chat and video call (i.e. Google Meet) services. This medium has led to an increase in the number of research related questions received and answered by librarians. During the academic year, research help is available to students for 52 hours per week. In FY21, librarians answered over 1,500 research questions. For FY22, the Library has subscribed to 24/7 chat service, which allows students to receive research help for 24 hours per day, 7 days per week. The aggregate trends in research help appear in Library Table 5: Research Help. Statistics on the use of research help by Chemistry students only are not available.

Reserves

The Library's Reserve system is well used by the Fitchburg State community. In FY20, 98 professors put a total of 595 items on reserves. Checkouts of reserve materials by all students were more than 1,100 during FY20.

Due to COVID-19, print reserves were unavailable in FY21 and the library moved to digital reserves. In FY21, there were a total of 102 items available for digital reserves that were checked out a total of 279 times, across all disciplines. The Library hopes to discuss with the Chemistry faculty further opportunities to utilize their new Controlled Digital Lending program, a digital reserve system. In addition, the Library is currently exploring ways to increase access to materials by students, including the insertion of digital Library resources into courses, controlled digital lending, and the adoption of Open Educational Resources, which would increase student access to no or low-cost textbooks and other course materials.

InterLibrary Loan Services Request

Data shows students and professors from Biology/Chemistry have the 6th highest use of InterLibrary Loan Services based on discipline. See Library Supplemental Table 6: InterLibrary Services for details.

Facilities for Chemistry

With the Library's recent renovation, students have access to welcoming spaces designed to support individual and group work, and is more than adequate to meet the needs of students, faculty and administration. Building information is in Library Supplemental Table 7: Facilities

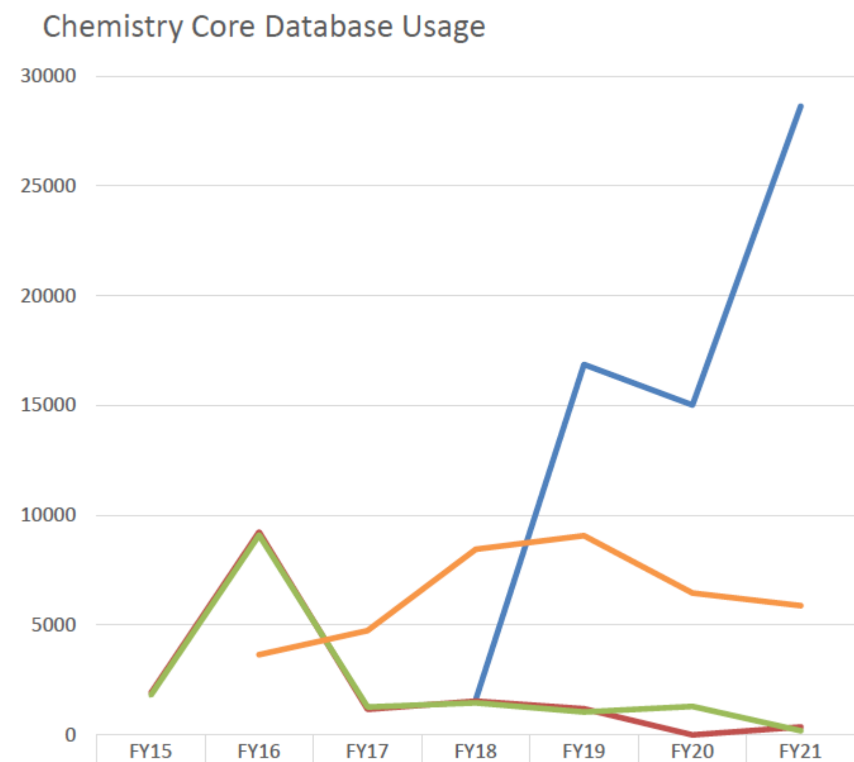
Library Supplemental Table 1:

Full-text Journal Databases by Disciplines related to Chemistry

The full complement of databases treating Chemistry can be found on the Library website (https://Library.fitchburgstate.edu/research/databases). Whereas there are 8 directly applicable full-text databases, another 10 full-text databases supplement this core collection. In addition, individual titles stretching across disciplines number in the thousands. Journals are either embedded within databases or are available through individual subscriptions, accessible through Serials Solutions.

Core Full-text Journal Databases
1. Academic Search Ultimate (EBSCO) 2. Applied Science & Technology Source 3. SciTech Premium (ProQuest) 4. PubChem (National library of Medicine) 5. Science & Technology Collection (EBSCO) 6. Science Full Text Select (H.W. Wilson) 7. SciFinder (American Chemical Society) 8. SpringerLink Package
Supplemental Full-text Journal Databases
1. Academic OneFile (Gale) 2. Academic OneFile Select (Gale) 3. Biological Abstracts/BIOSIS 4. Credo Reference 5. eBook Central (ProQuest) 6. eBook Collection (EBSCOhost) 7. Energy & Power Source 8. JSTOR 9. ProQuest SciTech Premium Collection 10. Science In Context

Chemistry Core Database Usage



	FY15	FY16	FY17	FY18	FY19	FY20	FY21
Academic Search Complete				1606	16863	15016	28620
Applied Science & Technology Source	1902	9239	1163	1540	1189	3	369
Science & Technology Collection (EBSCO)	1810	9102	1279	1458	1046	1297	193
Science Full Text Select (H.W. Wilson)							78
SciFinder (American Chemical Society)							119
SpringerLink Package		3656	4753	8452	9074	6462	5881

Notes-

Database usage data disaggregated by discipline does not exist therefore it is not possible to determine how many articles were accessed only by Chemistry faculty and students. In total for the Fitchburg State community, over 134,000 articles were accessed through the Library's 183 databases in FY21.

Academic Search Complete - *Upgraded from Academic Search Complete in June 2018.*

SciTech Premium (ProQuest) - *We upgraded to this for FY 21. Only searches (not sessions) available.*

PubChem – *Open Source (no stats available)*

Science Full Text Select - *Started 1/1/21 (stats are Jan.-July 2021 only).*

SciFinder – *Prior to FY21 stats only included searches (not sessions).*

Library Supplemental Table 2: Chemistry Books
Monograph Collection Description and Analysis

Fitchburg State University is, by Carnegie classification, a Master's granting institution. The Chemistry program offers a Bachelor's degree, and therefore the University must currently uphold at least the standard of 3b, "Intermediate Study" for its collections. (see below).

General Guidelines for Monograph Collection Depth

1. Minimal – A level that consists mostly of basic works.
2. Basic Information.
    a. A level that introduces and defines the subject and that indicates the varieties of information available elsewhere.
    b. Basic Instructional Support – A level that introduces coursework and research for undergraduate courses, including a wide range of basic monographs and reference tools pertaining to the subject and targeted to undergraduate students. 3. Study or Instructional Support.
3. Basic Study – A level that supports undergraduate courses.
    a. Intermediate Study – A level that supports upper division undergraduate courses.
    b. Advanced Instructional Support – A level that supports coursework and research for graduate and undergraduate courses, including a wide range of basic monographs and reference tools pertaining to the subject.
4. Research – A level that supports independent research and preparation of doctoral dissertations.
5. Comprehensive Inclusion – Comprised of all significant works for a defined topic.

Specific Definitions for Monograph Holdings*

1b (or less) Minimal level = less than 2,500.
2a Basic introductory level = 2,500 - 5,000 titles.
2b Basic advanced level (Community College) = 5,000 - 8,000 titles.
3a Instructional support (lower level undergraduate) = 8,000-12,000 titles representing a range of monographs.
3b Intermediate support level (advanced undergraduate) = more than 12,000 titles representing a wider range than 3a.

3c Advanced support level (Master's degree level) = more than 12,000 titles representing a wider range than 3b.

*Quantitative WLN Criteria for Determining CL (Current Collection Level) Rating

Chemistry Book Collection

LC	Subject Area	2021	2020	2019	2018	2017	2016	2015
QD 1-65	General Chemistry	100	96	94	91	87	76	64
QD 71-142	Analytical Chemistry	14	14	14	14	12	10	9
QD 146-197	Inorganic Chemistry	19	18	17	16	13	11	6
QD 241-441	Organic (Includes Biochemistry)	77	75	73	73	69	66	61
QD 450-801	Physical and Theoretical Chemistry	57	55	55	53	46	39	25
QD 901-999	Crystallography	5	5	5	5	5	3	2
TP 1-1185	Chemical Technology (Includes Chemical Engineering and Manufacture)	112	109	108	102	99	95	85
Total	General	**384**	**372**	**366**	**354**	**331**	**300**	**252**

The total number of print books in the call number ranges associated with Chemistry is 384. This is below the number expected for a collection to support advanced undergraduate coursework and research (12,000+ books). Effective in 2019, the EBSCO Academic Complete eBook package, JSTOR's DDA and EBA packages were subscribed to. In addition to these packages, in 2020 we subscribed to the ProQuest eBook Central DDA collection. Through these 4 eBook packages we have added approximately 6,085 titles in Chemistry and related areas (1,846 of these titles were published in the last 5 years and 4,142 were published in the last 10 years). This increases the number of books associated with Chemistry in total to 6,469 books while providing on and off campus access. This total number is barely adequate to support undergraduate level research and course work, especially since Chemistry students and faculty tend to use other resources, such as databases and journals, more than books to do research.

Library Supplemental Table 3:

Film and Other Media Collection

# of Streaming Films by Subject in Kanopy Database	
Applied Science	640
Biology	252
Chemistry	218
Engineering	274
Mathematics	329
Medicine	497
Science, Nature, and Technology	822
Total (includes duplicates)	**3,032**

Library Supplemental Table 4:

Research Instruction

	FY19	FY20	FY21
Total Instruction Sessions Conducted:	266	245	208
Chemistry Sessions Conducted:	2	0	5
Percentage	0.75%	0.00%	2.40%
Total Embedded:	72	68	97
No. of Chemistry Embedded:	0	0	1
Total In-person/Onsync classes:	194	177	111
No. of Chemistry In-person/Onsync classes:	2	0	4

Prior to FY20, undergraduate Library instruction was mainly provided through in-person classes. Librarians taught lessons on research in every delivery model offered as the university transitioned from all remote to hybrid learning. As the Chemistry program is revised, consideration should be given to how Library instruction will be effectively delivered, particularly if an increase in the number of online courses is anticipated.

Note: The Library offers both discipline-specific and general information literacy instruction sessions.

Library Supplemental Tables 5 & 6:

Research Help

Library Research Guides

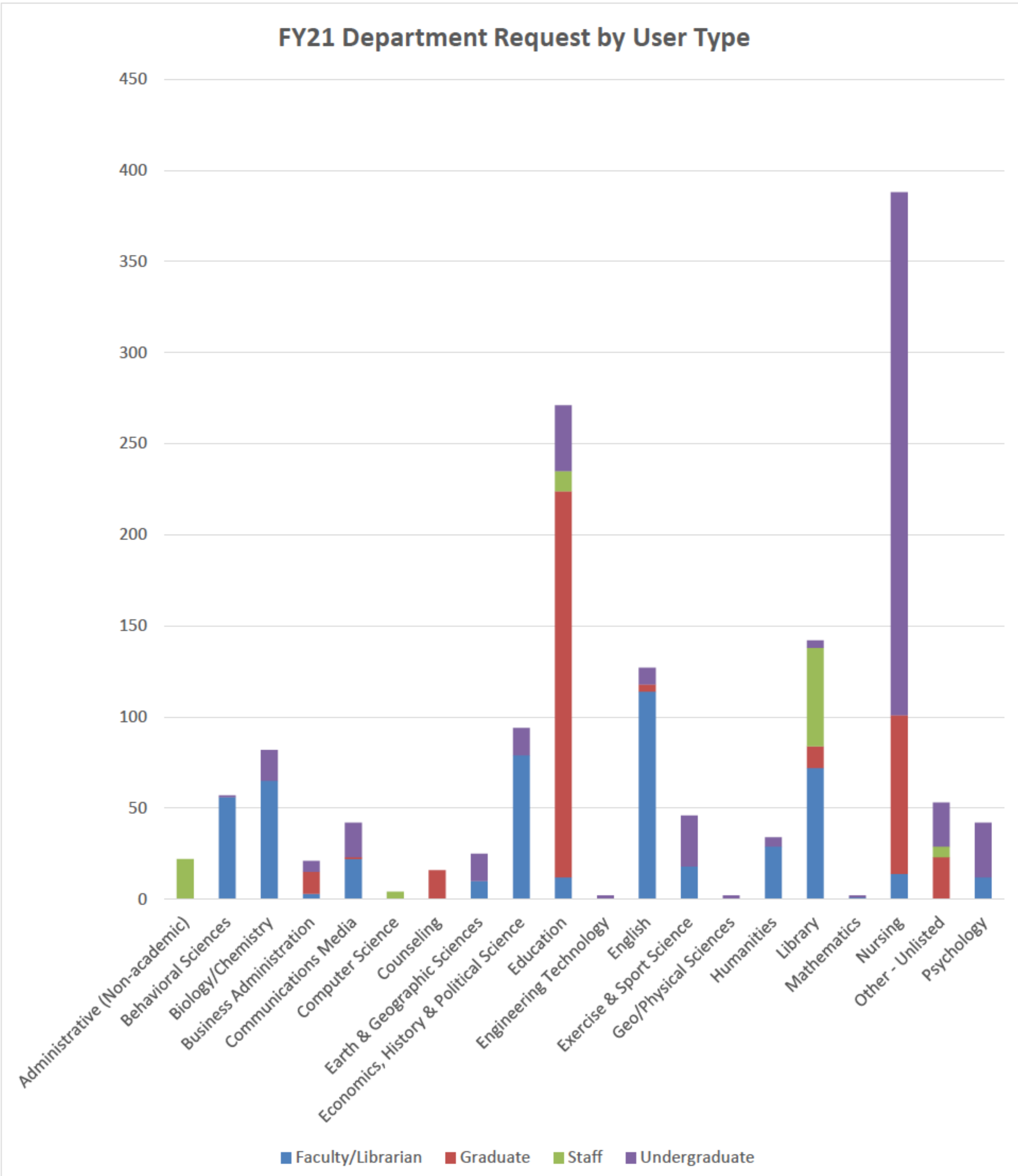
For Chemistry, we have created 1 subject research guide and three course specific research guides. The usage statistics in the Chemistry research guides show that the subject guide was accessed a total of 408 times in FY21, about 71% less than the usage the average subject guide receives (1417 views/guide avg.). Effective in summer 2019, the primary subject guide for Chemistry was embedded into all Blackboard courses; use of the guide (as indicated by page views) has since increased considerably.

Reference Statistics for University

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021
Total Records	**2642**	**2497**	**1875**	**2854**	**2803**	**2409**	**2534**
Mode of Access	**FY2015**	**FY2016**	**FY2017**	**FY2018**	**FY2019**	**FY2020**	**FY2021**
In Person	1959	1872	1386	2297	2253	1547	838
Chat	548	510	308	268	229	416	1002
Phone/Email	133	112	162	287	320	420	455
Video Call	2	3	19	11	16	42	252
Library FAQ Tickets							26
Questions by Patron	**FY2015**	**FY2016**	**FY2017**	**FY2018**	**FY2019**	**FY2020**	**FY2021**

Student	2438	2320	1674	2632	2538	2091	2286
Faculty	59	66	57	65	116	165	147
Extended Campus/DL	27	21	45	112	180	169	129
Public/Alumni/Other	111	79	89	131	123	134	69
Staff	7	11	10	8	14	29	21
Unknown	0	0	0	0	0	0	0
Duration	**FY2015**	**FY2016**	**FY2017**	**FY2018**	**FY2019**	**FY2020**	**FY2021**
0-2 minutes	1104	1006	782	1483	1418	844	666
2-5 minutes	735	683	532	689	634	644	710
5-15 minutes	509	424	327	331	350	433	551
15 minutes or longer	294	384	234	351	401	488	607

InterLibrary Loan Services



Library Supplemental Table 7:

Facilities

Space	Specifications
Total Number of Seats in Library	596
Information Commons	Research Help Desk Circulation Desk 61 public computer stations (now distributed in 4 floors due to COVID-19) 3 multi-function printers KIC Scanner
Study Rooms	9 large (up to 8 people) containing conference table, white board, media viewing equipment, and Apple TV. 8 small (2 people) containing a conference table, computer, and whiteboard.
Media Production Room	Seating up to 7 people containing a computer, Apple TV, ceiling mounted projector, DVD player, and document projector.
Quiet Space	2 floors (3rd and 4th)
Archives	47,821 items used in FY20 38 Special Collections totaling 322 boxes. 13 record groups totaling 480 boxes 20 digital collections containing 14,600 items 2,500 rare books Art collection

Study Room Statistics	FY19	FY20	FY21
Unique Users	1743	1552	472
Total Bookings	9454	6330	1849
Hours Booked	16869	11272	3456

**This decrease from FY20 to FY21 can be attributed to the limitations imposed by COVID on study room capacity and the Library's hours.*

10. Appendix J: Chemistry 4 Year Plans

Gen Chem LAS

Chemistry B.S. (Bachelor of Science)

FRESHMAN YEAR

Fall Semester — *15 Credits*

CHEM 1300	General Chemistry I*	(4)
ENGL 1100	Writing I	(3)
MATH 1300	Precalculus	(4)
BIOL 1800	General Biology I*	(4)

**General Biology I and General Chemistry I require the completion of the Math Placement test prior to enrollment. Those eligible to take Basic Math II (without co-requisite) will be accepted into Biology and Chemistry courses if they concurrently enroll in Basic Math II. To continue as a Chemistry major, students must earn a grade of 2.0 or higher in General Chemistry I and II.*

Spring Semester — *14 Credits*

CHEM 1400	General Chemistry II	(4)
ENGL 1200	Writing II	(3)
MATH 2300	Calculus I	(4)
	LA&S Elective	(3)

SOPHOMORE YEAR

Fall Semester — *14 Credits*

CHEM 2000	Organic Chemistry I	(4)
MATH 2400	Calculus II	(4)
	LA&S Elective	(3)
	LA&S Elective	(3)

Spring Semester — *15 Credits*

CHEM 2400	General Analytical Chemistry	(4)
CHEM 2100	Organic Chemistry II	(4)
PHYS 2600 **OR** PHYS 2300	Calculus-Based Physics I **OR** General Physics I	(4)
	LA&S Elective	(3)

JUNIOR YEAR

Fall Semester — *16 Credits*

CHEM 3600 **OR** CHEM 3030	Descriptive Inorganic Chemistry **OR** Biochemistry I	(3)
PHYS 2700 OR PHYS 2400	Calculus-Based Physics II OR General Physics II	(4)
	LA&S Elective	(3)
	LA&S Elective	(3)
	Free Elective	(3)

Spring Semester — *16 Credits*

CHEM 3200	Physical Chemistry I	(4)
CHEM 4750 **OR** CHEM ≥3000	Chemistry Seminar **OR** Chemistry Elective	(3)
	LA&S Elective	(3)
	Free Elective	(3)
	Free Elective	(3)

SENIOR YEAR

Fall Semester — *15-16 Credits*

CHEM 3600 **OR** CHEM 3030	Descriptive Inorganic Chemistry **OR** Biochemistry I	(3)
CHEM ≥3000	Chemistry Elective	(3-4)
	Free Elective	(3)
	Free Elective	(3)
	Free Elective	(3)

Spring Semester — *15-16 Credits*

CHEM 4750 **OR** CHEM ≥3000	Chemistry Seminar **OR** Chemistry Elective	(3-4)
	Free Elective	(3)
	Free Elective	(3)
	Free Elective	(3)

LA&S Elective List

1 AOM attribute (Art or Music)
1 ART attribute (the Arts)
1 CTW attribute (Citizenship & The World)
3 credits HAF attribute (Health/Fitness)
1 HIST subject (History)
1 HMN attribute (Human Behavior)
1 LIT attribute (Literature)

Advanced LA&S Options Area

Review the three options with your advisor and submit your decision to the Registrar's Office when you reach Junior status.

Free Electives

It is recommended that students consider their career goals in selecting their free electives by seeking advice from their academic advisor and/or the pre-health advisor. Examples of recommended electives are courses in biology, mathematics, physics, geophysical sciences, computer science and/or industrial technology.

***Chemistry Seminar** fulfills the Capstone requirement for this Major.*

Global Diversity Area

Two courses must meet the Global Diversity (GD) requirement.
The GD courses may also satisfy other LAS requirements at the same time.

Completion of 120 credits required for graduation.

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FITCHBURG STATE UNIVERSITY

Biochemistry B.S. (Bachelor of Science in Chemistry)

FRESHMAN YEAR

Fall Semester — *15 Credits*

BIOL 1800	General Biology I	(4)
CHEM 1300	General Chemistry I	(4)
ENGL 1100	Writing I	(3)
MATH 1300	Precalculus*	(4)

This assumes students place into MATH 1300 Precalculus. If students do not place into MATH 1300 Precalculus, they would have to take MATH 0200 Basic Math first.

Spring Semester — *14-15 Credits*

CHEM 1400	General Chemistry II	(4)
ENGL 1200	Writing II	(3)
MATH 2300	Calculus I	(4)
	Free Elective	(3-4)

SOPHOMORE YEAR

Fall Semester — *17 Credits*

CHEM 2000	Organic Chemistry I	(4)
MATH 2400	Calculus II	(4)
PSY 1100 **OR** SOC 1100	Introduction to Psychological Science **OR** Introduction to Sociology	(3)
	LA&S Elective (ART)	(3)
	Free Elective	(3)

Spring Semester — *14 Credits*

BIOL 2800	Genetics	(4)
CHEM 2100	Organic Chemistry II	(4)
	LA&S Elective (HAF)	(3)
	LA&S Elective (LIT)	(3)

JUNIOR YEAR

Fall Semester — *16 Credits*

CHEM 3030	Biochemistry I	(3)
PHYS 2300	General Physics I	(4)
	LA&S Elective (AOM)	(3)
	LA&S Elective (CTW)	(3)
	Free Elective	(3)

Spring Semester — *13 Credits*

CHEM 2400	Analytical Chemistry	(4)
CHEM 3040 **OR** CHEM 3060	Biochemistry II **OR** Biochemical Techniques	(3)
	Free Elective	(3)
	Free Elective	(3)

SENIOR YEAR

Fall Semester — *16 Credits*

CHEM 3600	Inorganic Chemistry	(3)
PHYS 2400	General Physics II	(4)
	LA&S Elective (HIST)	(3)
	Free Elective	(3)
	Free Elective	(3)

Spring Semester — *14 Credits*

CHEM 3200	Physical Chemistry	(4)
CHEM 3060 **OR** CHEM 3040	Biochemical Techniques **OR** Biochemistry II	(3)
CHEM 4750	Chemistry Seminar	(3)
	Free Elective	(4)

LA&S Elective List

1 AOM attribute (Art or Music)
1 ART attribute (the Arts)
1 CTW attribute (Citizenship & The World)
3 credits HAF attribute (Health/Fitness)
1 HIST subject (History)
1 HMN attribute (Human Behavior)
1 LIT attribute (Literature)

Advanced LA&S Options Area

Review the three options with your advisor and submit your decision to the Registrar's Office by completion of 60 credits.

Free Electives

It is recommended that students consider their career goals in selecting their free electives by seeking advice from their academic advisor and/or the pre-health advisor. Examples of recommended electives are courses in biology, mathematics, physics, and computer science.

Global Diversity Area

Two courses must meet the Global Diversity (GD) requirement. The GD courses may also satisfy other LAS requirements at the same time.

Completion of 120 credits required for graduation.

Rev. 10-2019

FITCHBURG STATE UNIVERSITY

Secondary Education — Chemistry (B.S.)

FRESHMAN YEAR

Fall Semester — *15 Credits*

ENGL 1100	Writing I	(3)
CHEM 1300	General Chemistry I*	(4)
MATH 1300	Precalculus	(4)
BIOL 1800	General Biology I*	(4)

**General Biology I and General Chemistry I require the completion of the Math Placement test prior to enrollment. Those eligible to take Basic Math II (without co-requisite) will be accepted into Biology and Chemistry courses if they concurrently enroll in Basic Math II. To continue as a Chemistry major, students must earn a grade of 2.0 or higher in General Chemistry I and II.*

Spring Semester — *14 Credits*

ENGL 1200	Writing II	(3)
CHEM 1400	General Chemistry II	(4)
MATH 2300	Calculus I	(4)
	LA&S Elective	(3)

SOPHOMORE YEAR

Fall Semester — *14 Credits*

CHEM 2000	Organic Chemistry I	(4)
CHEM 2860	Introduction to Secondary School Teaching	(3)
MATH 2400	Calculus II	(4)
	LA&S Elective	(3)

Spring Semester — *15 Credits*

CHEM 2400	General Analytical Chemistry	(4)
CHEM 2100	Organic Chemistry II	(4)
SPED 3800	Secondary Programs for Adolescents (14-22) with Disabilities	(3)
PHYS 2600 **OR** PHYS 2300	Calculus-Based Physics I **OR** General Physics I	(4)

JUNIOR YEAR

Fall Semester — *16-18 Credits*

CHEM 3600 **OR** CHEM 3030	Descriptive Inorganic Chemistry **OR** Biochemistry I	(3)
PHYS 2700 **OR** PHYS 2400	Calculus-Based Physics II **OR** General Physics II	(4)
CHEM≥3000	Chemistry Elective	(3-4)
	LA&S Elective	(3)
	Free Elective	(3)

Spring Semester — *15 Credits*

CHEM 4750	Chemistry Seminar	(3)
CHEM 3200	Physical Chemistry I	(4)
ENGL 4700	Teaching Reading and Writing Across the Content Area	(3)
	LA&S Elective	(3)
	Free Elective	(3)

SENIOR YEAR

Fall Semester — *15 Credits*

CHEM 3600 **OR** CHEM 3030	Descriptive Inorganic Chemistry **OR** Biochemistry I	(3)
CHEM 4850	Methods in Teaching Science	(3)
EDUC 3122	Sheltered English Immersion	(3)
	Free Elective	(3)
	Free Elective	(3)

Spring Semester — *12 Credits*

CHEM 4860	Chemistry Practicum in a Secondary School I	(4.5)
CHEM 4870	Chemistry Practicum in a Secondary School II	(4.5)
CHEM 4012	Practicum Seminar	(3)

LA&S Elective List

- 1 AOM attribute (Art or Music)
- 1 ART attribute (the Arts)
- 1 CTW attribute (Citizenship & The World)
- 3 credits HAF attribute (Health/Fitness)
- 1 HIST subject (History)
- 1 HMN attribute (Human Behavior)
- 1 LIT attribute (Literature)

Advanced LA&S Options Area

Review the three options with your advisor and submit your decision to the Registrar's Office by completion of 60 credits.

Free Electives

It is recommended that students consider their career goals in selecting their free electives by seeking advice from their academic advisor and/or the pre-health advisor. Examples of recommended electives are courses in biology, mathematics, physics, geophysical sciences, computer science and/or industrial technology.

Global Diversity Area

Two courses must meet the Global Diversity (GD) requirement. The GD courses may also satisfy other LAS requirements at the same time.

***Chemistry Seminar** fulfills the Capstone requirement for this major.*

Completion of 120 credits required for graduation.

Rev. 10-2019

Suggested Four-Year Plan of Study

BIOLOGY AND CHEMISTRY

FITCHBURG STATE UNIVERSITY

Chemistry B.S. (Bachelor of Science)

FRESHMAN YEAR

Fall Semester — 14 Credits

CHEM 1300	General Chemistry I*	4
ENGL 1100	Writing I	3
MATH 1300	Precalculus	4
FYE 1015	First Year Experience	3

** General Chemistry requires a 'passing' score on Advanced Algebra and Functions Accuplacer placement exam OR successful completion of MATH 0500. (Algebraic Preparation) prior to enrollment. To continue as a Chemical major, students must earn a grade of 2.0 or higher in General Chemistry I and II.*

Spring Semester — 15 Credits

CHEM 1400	General Chemistry II	4
BIOL 1800	General Biology I (SI)	4
ENGL 1200	Writing II	3
MATH 2300	Calculus I (QR)	4

SOPHOMORE YEAR

Fall Semester — 14 Credits

CHEM 2000	Organic Chemistry I	4
MATH 2400	Calculus II (AIA)	4
	General Education (WS)	3
	General Education/Exploration	3

Spring Semester — 14 Credits

CHEM 2100	Organic Chemistry II	4
CHEM 2400	General Analytical Chemistry	4
	General Education/Exploration	3
	General Education/Exploration	3

JUNIOR YEAR

Fall Semester — 16 Credits

CHEM 3030	Biochemistry I **OR**	
CHEM 3600	Descriptive Inorganic Chemistry	3
PHYS 2300	General Physics I (PL) **OR**	
PHYS 2600	Calculus-Based Physics I (PL)	4
	General Education/Exploration	3
	General Education/Exploration	3
	Free Elective	3

Spring Semester — 17 Credits

CHEM 3200	Physical Chemistry I	4
PHYS 2400	General Physics II (AIA) **OR**	
PHYS 2700	Calculus-Based Physics II	4
	General Education/Exploration	3
	General Education/Exploration	3
	Free Elective	3

SENIOR YEAR

Fall Semester — 15-18 Credits

CHEM 3030	Biochemistry I **OR**	
CHEM 3600	Descriptive Inorganic Chemistry	3
CHEM ≥3000	Chemistry Elective **OR**	
CHEM 4900	Independent Study	3-6
	Free Elective	3
	Free Elective	3
	Free Elective	3

Spring Semester — 15-16 Credits

CHEM ≥3000	Chemistry Elective	3-4
CHEM 4750	Chemistry Seminar (Capstone) (IHIP)	3
	Free Elective	3
	Free Elective	3
	Free Elective	3

General Education: Foundation

3 credits Reading and Information Literacy (R and IL): First Year Experience
3 credits Writing (W): Writing I
3 credits Writing and Information Literacy (W and IL): Writing II
3 credits Quantitative Reasoning (QR) (MATH)
3 credits World Languages, Speaking and Listening (WS)

Suggested 4-year plan of study.
Completion of 120 credits required for graduation.

General Education: Exploration

3 credits Civic Learning (CV)
3 credits Diverse Perspectives (DP)
3 credits Ethical Reasoning (ER)
3 credits Fine Arts Expression and Analysis (FA)
3 credits Historical Inquiry and Analysis (HI)
3 credits Literary Inquiry and Analysis (LI)
3 credits Personal Wellness (PW)
3 credits Procedural and Logical Thinking (PL)
3 credits Scientific Inquiry and Analysis (SI)

General Education: Integration

9 credits AIA (3 of which must be Integrative High Impact Practice - IHIP)
OR
Minor (professional majors completing a minor or second major must include at least 9 credits in LA&S disciplines for that minor)

General Education: MAJ

There may be major courses that have been approved to fulfill up to 3 General Education requirements (at least 9 credits). Varies by major and concentration.

Suggested Four-Year Plan of Study
BIOLOGY AND CHEMISTRY

FITCHBURG STATE UNIVERSITY

Biochemistry B.S. (Bachelor of Science in Chemistry)

FRESHMAN YEAR

Fall Semester — 14 Credits

CHEM 1300	General Chemistry I*	4
ENGL 1100	Writing I	3
MATH 1300	Precalculus	4
FYE 1015	First Year Experience	3

**General Chemistry requires a 'passing' score on Advanced Algebra and Functions Accuplacer placement exam OR successful completion of MATH 0500. (Algebraic Preperation) prior to enrollment. To continue as a Chemistry major, students must earn a grade of 2.0 or higher in General Chemistry I and II.*

Spring Semester — 15 Credits

CHEM 1400	General Chemistry II	4
BIOL 1800	General Biology I (SI)	4
ENGL 1200	Writing II	3
MATH 2300	Calculus I (QR)	4

SOPHOMORE YEAR

Fall Semester — 14 Credits

CHEM 2000	Organic Chemistry I	4
MATH 2400	Calculus II (AIA)	4
	General Education (WS)	3
	General Education/Exploration	3

Spring Semester — 14 Credits

BIOL 2800	Genetics (AIA)	4
CHEM 2100	Organic Chemistry II	4
	General Education/Exploration	3
	General Education/Exploration	3

JUNIOR YEAR

Fall Semester — 16 Credits

CHEM 3030	Biochemistry I	3
PHYS 2300	General Physics I (PL)	4
	General Education/Exploration	3
	General Education/Exploration	3
	General Education/Exploration	3

Spring Semester — 16 Credits

CHEM 2400	General Analytical Chemistry	4
CHEM 3040	Biochemistry II **OR**	
CHEM 3060	Biochemical Techniques	3
	General Education/Exploration	3
	Free Elective	3
	Free Elective	3

SENIOR YEAR

Fall Semester — 16 Credits

CHEM 3600	Descriptive Inorganic Chemistry	3
PHYS 2400	General Physics II	4
	Free Elective	3
	Free Elective	3
	Free Elective	3

Spring Semester — 15 Credits

CHEM 4750	Chemistry Seminar (Capstone) (IHIP)	3
CHEM 3040	Biochemistry II **OR**	
CHEM 3060	Biochemical Techniques	3
	Free Elective	3
	Free Elective	3
	Free Elective	3

General Education: Foundation

3 credits Reading and Information Literacy (R and IL): First Year Experience
3 credits Writing (W): Writing I
3 credits Writing and Information Literacy (W and IL): Writing II
3 credits Quantitative Reasoning (QR) (MATH)
3 credits World Languages, Speaking and Listening (WS)

General Education: Exploration

3 credits Civic Learning (CV)
3 credits Diverse Perspectives (DP)
3 credits Ethical Reasoning (ER)
3 credits Fine Arts Expression and Analysis (FA)
3 credits Historical Inquiry and Analysis (HI)
3 credits Literary Inquiry and Analysis (LI)
3 credits Personal Wellness (PW)
3 credits Procedural and Logical Thinking (PL)
3 credits Scientific Inquiry and Analysis (SI)

General Education: Integration

9 credits AIA (3 of which must be Integrative High Impact Practice - IHIP)
OR
Minor (professional majors completing a minor or second major must include at least 9 credits in LA&S disciplines for that minor)

General Education: MAJ

There may be major courses that have been approved to fulfill up to 3 General Education requirements (at least 9 credits). Varies by major and concentration.

Suggested 4-year plan of study. Completion of 120 credits required for graduation.

Suggested Four-Year Plan of Study

BIOLOGY AND CHEMISTRY

FITCHBURG STATE UNIVERSITY

Chemistry B.S. with Initial Licensure in Secondary Education (with Minor in Middle School and Secondary Education)

FRESHMAN YEAR

Fall Semester — **14 Credits**

CHEM 1300	General Chemistry I*	4
ENGL 1100	Writing I	3
MATH 1300	Precalculus	4
FYE 1015	First Year Experience	3

** General Chemistry requires a 'passing' score on Advanced Algebra and Functions Accuplacer placement exam OR successful completion of MATH 0500. (Algebraic Preparation) prior to enrollment. To continue as a Chemistry major, students must earn a grade of 2.0 or higher in General Chemistry I and II.*

Spring Semester — **17 Credits**

CHEM 1400	General Chemistry II	4
ENGL 1200	Writing II	3
MATH 2300	Calculus I (QR)	4
CHEM 1860	Introduction to Education (5-12)**	3
	Gen Ed/WS	3

SOPHMORE YEAR

Fall Semester — **15 Credits**

CHEM 2000	Organic Chemistry I	4
BIOL 1800	General Biology I (SI)	4
MATH 2400	Calculus II	4
EDUC 2011	Diversity in Education (5-12)**	3

Spring Semester — **14 Credits**

CHEM 2100	Organic Chemistry II	4
CHEM 2400	General Analytical Chemistry	4
EDUC 2012	Teaching the Adolescent Learner (5-12)**	3
	Gen Ed/Exploration	3

** These courses are required for completion of the minor in Middle School and Secondary Education. Students must complete this minor for the Initial Licensure in Secondary Education. The minor fulfills the Integration requirement for the Chemistry major.

JUNIOR YEAR

Fall Semester — **16 Credits**

CHEM 3030	Biochemistry I	3
PHYS 2300	General Physics I (PL)	4
CHEM 3600	Descriptive Inorganic Chemistry	3
SPED 3800	Inclusive Instruction (5-12)**	3
	Gen Ed/Exploration	3

Spring Semester — **17 Credits**

CHEM 3200	Physical Chemistry I	4
CHEM 4750	Chemistry Seminar	3
PHYS 2400	General Physics II	4
CHEM 3015	Methods of Teaching Chemistry I**	3
	Gen Ed/Exploration	3

SENIOR YEAR

Fall Semester — **15 Credits**

CHEM 4850	Methods of Teaching Chemistry II**_	3
EDUC 3122	Sheltered English Immersion	3
	Gen Ed/Exploration	3
	Gen Ed/Exploration	3
	Gen Ed/Exploration	3

Spring Semester — **12 Credits**

CHEM 4012	Practicum Seminar	3
CHEM 4860	Practicum in a Secondary School I	4.5
CHEM 4870	Practicum in a Secondary School II	4.5

General Education: Foundation

3 credits Reading and Information Literacy (R and IL): First Year Experience
3 credits Writing (W): Writing I
3 credits Writing and Information Literacy (W and IL): Writing II
3 credits Quantitative Reasoning (QR) (MATH)
3 credits World Languages, Speaking and Listening (WS)

General Education: Exploration

3 credits Civic Learning (CV)
3 credits Diverse Perspectives (DP)
3 credits Ethical Reasoning (ER)
3 credits Fine Arts Expression and Analysis (FA)
3 credits Historical Inquiry and Analysis (HI)
3 credits Literary Inquiry and Analysis (LI)
3 credits Personal Wellness (PW)
3 credits Procedural and Logical Thinking (PL)
3 credits Scientific Inquiry and Analysis (SI)

General Education: Integration

9 credits AIA (3 of which must be Integrative High Impact Practice - IHIP)
OR
Minor (professional majors completing a minor or second major must include at least 9 credits in LA&S disciplines for that minor)

General Education: MAJ

There may be major courses that have been approved to fulfill up to 3 General Education requirements (at least 9 credits). Varies by major and concentration.

Suggested 4-year plan of study. Completion of 120 credits required for graduation.

11. Appendix K: Special Studies 2013-2021

INDEPENDENT STUDIES and RESEARCH PROJECTS: *(See below for Intro to Research & Internships)*				
Year	**Semester**	**Full Project Title**	**Student(s)**	**Instructor**
2013	Spring	Quantification of artificial dyes in beverages	Theresa Madrigal	Aisling O'Connor
2013	Spring	Development of Lab Activities for High School Chemistry Using the Vernier SpectroVis Plus Spectrophotometer	Nicholas Ludden	Aisling O'Connor
2015	Fall	Synthesis of unnatural amino acids using Click chemistry	Eric Ouellette	Mathangi Krishnamurthy
2016	Spring	Enzymatic Assays of Crosslinked Proteins	Tim Brinkman & Duluc Huynh	Billy Samulak
2016	Spring	Synthesis of thiazole derivatives	John Sanford	Mathangi Krishnamurthy
2016	Fall	Kinetic Analysis of Aldolase	Alex Serino & Barry Bouchard	Billy Samulak
2016	Fall	Phase Effects on the Nanoparticle Permeation Process	Alexander Steacy	Steven Fiedler
2016	Fall	Synthesis of pyrimidone and thiopyrimidone derivatives by Biginelli reaction	Kara Hudson and Marney Shattuck	Mathangi Krishnamurthy
2017	Spring	Study of Silver Nanoparticle Leaching in Commercial Products	Charles Goss	Emma Downs
2017	Spring	Phase Effects II: Dynamical Considerations	Alexander Steacy	Steven Fiedler
2017	Spring	Synthesis of unnatural amino acids with triazole side chains	Kara Hudson	Mathangi Krishnamurthy
2017	Spring	Synthesis and evaluation of fluorescent properties of 4-hydroxy coumarin derivatives (Honors project)	David Nunes	Mathangi Krishnamurthy
2017	Spring	SDS-PAGE Analysis of Crosslinked	Tim Brinkman	Billy Samulak

		Proteins		
2017	Spring	Functional Enzymatic Analysis of Crosslinked Proteins	Mike McGrath	Billy Samulak
2017	Spring	Mass Spectrometry & Crosslinked Aldolase	Blake Phinney	Billy Samulak
2017	Spring	Experiments for 3rd and 4th Graders at McKay Arts Academy	Melanie Bauer	Billy Samulak
2017	Spring	Preparation of Quinoline-heme Adducts	Enrique Coello	Dennis Awasabisah
2017	Fall	Effects of Ligands on Silver Nanoparticle Catalysts	Sarah Laleme	Emma Downs
2017	Fall	Synthesis of imidazole derivatives	Nicole Conley	Mathangi Krishnamurthy
2017	Fall	Analysis of Heavy Metals in Cosmetics	Yanarilista Rosario	Aisling O'Connor
2017	Fall	Effects of Ligands on Silver Nanoparticles as Catalysts for Nitrile Hydration	Sarah Laleme	Emma Downs
2017	Fall	Phase Effects III: Ensemble Effects	Reginald Sarpong	Steven Fiedler
2017	Fall	Synthesis of dication DNA intercalators	Georgina Asadu Islynn Agyepong Boakye	Mathangi Krishnamurthy
2017	Fall	Chemistry demonstrations and hands-on activities for middle school students	Mariah Irwin	Mathangi Krishnamurthy
2017	Fall	Synthesis of dication DNA intercalators	Islynn Agyepong Boakye Georgina Asadu	Mathangi Krishnamurthy
2017	Fall	Quantification and Mass Spectrometry Analysis of Crosslinked Proteins	Yelitza Rosario	Billy Samulak
2018	Spring	Effects of Ligands on Silver Nanoparticle Catalysts	Quinn Wold	Emma Downs
2018	Spring	Synthesis and electrochemistry of heme-quinoline compounds	Enrique Coello	Dennis Awasabisah
2018	Spring	Synthesis of fluorine-Containing Compounds	Lixandra Numbem	Dennis Awasabisah

2018	Fall	Effects of Silver Nanoparticles on Plant Herbivory	Nicole Skerry	Emma Downs
2019	Spring	Effects of Silver Nanoparticles on Plant Herbivory	James Gay	Emma Downs
2019	Spring	Synthesis of Fluorocarbons	Veronica L. Torres	Dennis Awasabisah
2019	Spring	Mass Spectrometry Quantification of Crosslinked Proteins	Justin Girard	Billy Samulak
2019	Spring	Effect of Silver Nanoparticles on Plant Herbivory	Nicole Skerry	Emma Downs
2019	Spring	Synthesis and electrochemistry of heme-quinoline compounds	Enrique Coello	Dennis Awasabisah
2019	Fall	The structure of hemozoin	Jack F. Gangemi	Dennis Awasabisah
2019	Fall	The Effect of Ligands on Silver Nanoparticles as Catalysts	Alexander Blinn	Emma Downs
2020	Spring	Study on heme models – focus on hemozoin formation	Kyle Robbins	Dennis Awasabisah
2020	Spring	Study on heme models – focus on hemozoin inhibition	Jack J. Gangemi	Dennis Awasabisah
2021	Spring	Mild synthetic procedures for deoxygenation of substituted phenols and their application in drug synthesis (honors project)	Matthew Sadowski	Mathangi Krishnamurthy
Introduction to Research (1 credit)				
2016	Fall	Heme and Heme Model Complexes (Sickle-cell disease)	Wilkerson Pierre	Dennis Awasabisah
2017	Spring	Diffusion of Carbonaceous Particles	Reginald Sarpong	Steven Fiedler
2018	Spring	Chemistry Research at FSU	Jeffrey Verner	Dennis Awasabisah

Internships

2017	Summer	Internship in Biomaterials and Engineering, MIT, Cambridge	Mikaela Berthiaume	Meledath Govindan
2017	Summer	Internship at New England Peptide (Gardner, MA)	Meghan Umbrello	Billy Samulak
2019	Summer	MA Environmental Police Intern (Boston, MA) / MA Dept of Conservation and Recreation Intern (West Boylston, MA) Unpaid	Alex Laderoute	Aisling O'Connor
2020	Spring	MA Department of Environmental Protection	Alexander Blinn	Emma Downs
2021	Summer	National Renewable Energy Laboratory (Golden, CO) Paid	Shaniah Greene	Aisling O'Connor

12. Appendix L: Mel Govindan's Contributions to the University's Study Abroad Programs

Dr. Meledath Govindan devoted much effort to increasing study abroad programs. He developed a course that was taught twice for our students in Verona, Italy. He also devoted his sabbatical time on endeavoring to increase opportunities for our students by establishing connections by visiting and teaching courses or classes in China, Germany, and India. These all occurred before COVID, and these have not been continued due to the pandemic and are described below.

Summer course in Verona Italy: In 2015 and 2018, Dr. Govindan designed and taught a 'Topics in Chemistry' course entitled "Chemistry in Verona – Chemistry of Wine, Cheese and Olive Oil." This was a successful experience and provided opportunities for 21 students in 2015 and 11 students in 2018, a few of whom took both courses. They not only received introduction to a new area of chemistry, but also got first-hand experience with Italian culture, wine making, olive oil making, cheese making and gelato making processes. According to Tracey Sarefield and Nellie Wadsworth of the Study Abroad program, very few institutions are providing such opportunities for their science students. Dr. Govindan attempted to teach this course in 2020 and 2021, however was unable due to the COVID epidemic.

Zhejiang Gongshang University (ZGSU) in Hangzhou, China: In spring 2018 Dr. Govindan intended to strengthen the study-abroad agreements we have with Zhejiang Gongshang University (ZGSU) in Hangzhou, China. He spent approximately three weeks in the School of Food Science and Biotechnology – where they teach chemistry and biology.   He taught an intensive short course, Natural Products Chemistry, to a class of 17 first year Master's level students. Overall, it appeared that the students enjoyed the class despite the intense nature – each class lasted 2 hours and 45 minutes and we met every day of the week.

Rheine-Waal University of Applied Sciences in Kleve, Germany: Dr. Govindan also visited Rheine-Waal University of Applied Sciences in Kleve, Germany with which we have had an exchange program for several years Kleve, located about 90 km from Dusseldorf, has a population of ~50,000. He also spent a week there teaching a class, attending several undergraduate classes, and meeting with several faculty and administrators. As a result of this trip four of their professors visited FSU in October 2018 to give guest lectures, meet with faculty, students and administrators and to learn more about the educational programs at FSU.

Establishing contacts in India: Dr. Govindan also spent two weeks in India teaching and exploring the possibility of establishing linkages with Indian universities. Here is a list of activities in India:

- He taught nine classes on various aspects of marine natural products chemistry at the Winter School of the Central Marine Fisheries Research Institute (CMFRI), Kochi, India. The attendees were in-service faculty from colleges and universities throughout India.
- He taught three classes on various aspects of natural products chemistry at the National Centre for Aquatic Animal Health, Cochin University of Science and Technology (CUSAT), Kochi, India. The attendees were faculty and graduate students from that Centre as well as the Department of Microbiology.

- He gave the 3rd Annual Professor Jose Mechery Memorial Lecture at St. Thomas College Postgraduate Department of Chemistry, Thrissur, Kerala, India. Audience were faculty and M.Sc. students.
- He gave a lecture on structure elucidation of natural products using NMR and mass spectrometry at the Department of Microbiology, Kannur University, Thalassery, Kerala. Audience consisted of faculty and graduate students.
- He discussed possible student exchange programs with faculty and administrators at CMFRI and CUSAT. There are opportunities for our students to go there for a semester or summer to participate in research projects, but traditional study-abroad programs are a bit difficult as the university curricula there are not adaptable for student exchanges.
- He also visited three recruitment agencies in India that specialize in recruiting Indian students to universities abroad – primarily U.S., Europe and Australia. A report has been submitted to Dean Becky Copper-Glenz, Nelly Wadsworth and Alberto Cardelle summarizing these meetings in Hyderabad and Mumbai.

13. Appendix M: Faculty teaching responsibilities in lecture and laboratory courses taught between Fall 2014 and Fall 2021.

Faculty teaching responsibilities in lecture and laboratory courses taught between Fall 2014 and Fall 2021.	
Course	**Faculty**
CHEM 1000 Chemistry in a Changing World	Fiedler, Govindan, Krishnamurthy
CHEM 1200 Chemistry for Health Sciences	Awasabisah, Samulak
CHEM 1300 General Chemistry I	Awasabisah, Downs, Fielder, O'Connor
CHEM 1400 General Chemistry II	Awasabisah, Downs, Fiedler, O'Connor
CHEM 2000 Organic Chemistry I	Awasabisah, Govindan, Krishnamurthy
CHEM 2100 Organic Chemistry II	Awasabisah, Govindan, Krishnamurthy
CHEM 2020 Biochemistry I (previously Foundations of Biochemistry)	Samulak, Krishnamurthy
CHEM 2400 General Analytical Chemistry	O'Connor
CHEM 3003 Environmental Chemistry	Downs
CHEM 3200 Physical Chemistry I	Fiedler
CHEM 3600 Descriptive Inorganic Chemistry	Downs
CHEM 4001 Topics: Proteomics	Samulak
CHEM 4020 Medicinal Chemistry	Krishnamurthy
CHEM 4400 Forensic Chemistry	O'Connor
CHEM 4750 Chemistry Seminar	O'Connor, Samulak
BIOL 1001 Intro. to Health Prof. Seminar	Govindan
BIOL 1650 Nutrition	O'Connor
HON 2250 - Seminar in Environmental Science	Downs
FYE 1015 First Year Experience: Science in Society	Downs
FYE 1015 First Year Experience: General Biology	Samulak

Appendix M1: 2-Year Rotation of Chemistry Courses

Chemistry			
CHEM	1000	Chemistry in a Changing World	Fall
CHEM	1200	Chemistry for Health Sciences	Every Semester
CHEM	1300	General Chemistry I	Fall; Spring (limited seats)
CHEM	1400	General Chemistry II	Spring
CHEM	1600	Introductory Research in Chemistry	As needed – special scheduling
CHEM	2000	Organic Chemistry I	Fall
CHEM	2100	Organic Chemistry II	Spring
CHEM	2400	General Analytical Chemistry	Spring
CHEM	2860	Intro to Secondary Teaching	Fall
CHEM	3030	Foundations of Biochemistry	Fall
CHEM	3200	Physical Chemistry I	Alternate years - Spring
CHEM	3300	Physical Chemistry II	Less than once every two years
CHEM	3600	Descriptive Inorganic Chemistry	Alternate years - Fall
CHEM	4000	Natural Products	Less than once every two years
CHEM	4012	Practicum Seminar	As needed
CHEM	4020	Medicinal Chemistry	Every three years - fall
CHEM	4040	Advanced Synthetic methods	Less than once every two years
CHEM	4200	Polymer Chemistry	Less than once every two years
CHEM	4400	Forensic Chemistry	Every three years - fall
CHEM	4500	Organic Spectroscopy	Less than once every two years
CHEM	4600	Chemical Instrumentation	Less than once every two years
CHEM	4750	Chemistry Seminar	Spring
CHEM	4850	Methods in Teaching Science	Alternate years - Fall
CHEM	4860	Chemistry Practicum I	As needed
CHEM	4870	Chemistry Practicum II	As needed
CHEM	4940	Internship	As needed – special scheduling

CHEM	4900	Independent Study in Chemistry	As needed – special scheduling
CHEM	4950	Internship	As needed – special scheduling
CHEM	4975	Directed Study	As needed – special scheduling

14. Appendix N: Google Docs Advising Sheet

Student Name:

Alternate PIN:

Semester/Year: Fall 2021

NOTES:

- **Registration times start Monday, April 12th.** Check your registration time and mark it in your calendar. **Directions:** Log into your Web4 (Click on Student → Registration → Check Your Registration Status → Pick Term → Submit)
- You will need to email Dr. Mel Govindan (mgovindan@fitchburgstate.edu) about X petition
- Here is a link to the petition form.
- Per our discussion, you will need to register for at least 2, if not 3 summer courses.
  - Class I
  - Class 2
  - Class 3

* If you take 2 summer courses, then you will have 6 classes in the fall or 17 credits. It is more cost effective to do this because once you pay for 12 credits, anything up to 18 credits is free. If you take 3 classes in the summer, you are paying more out of pocket, but will have fewer credits (15) in the fall. It is your choice. I have the schedule mapped so that you will take 17 credits in the fall.

1st Choice Plan: (This is just an example, student schedules would be completed)

CRN	Subject #	Course #	Course Title	Attribute	Credits
15526	HON	4991	Honors/Capstone Biology		3
	CHEM	2000	Organic Chemistry I		4
	CHEM	2000	Organic Chemistry I Lab		
	BIOL	XXXX	Biology Elective		3

Block schedule to map your planned courses:

	8:00	9:30	11:00	12:30	2:00	3:30
M						
T						
W						
Th						
F						

Helpful Links:

- Degree Evaluation: Log into your Web4 (Click on Student ⟶ Degree Evaluation)
- Courses Offered: FSU Seats List
- Student Success Collaborative
- Four Year Plan of Study (Click on your major)
- Resources for Current Students

Additional Supports:

- **Academic Coaching & Tutoring Center**
- **Counseling Services**
- **Disability Services**
- **Career Services & Advising Center**
- **Falcon Bazaar Food and Necessity Pantry**

15. Appendix O1: Chemistry Learning Goals/Outcomes
(Adapted from the American Chemical Society Standards)

1. Problem Solving Skills. Students should be able to define problems clearly, develop testable hypotheses, design and execute experiments, analyze data using appropriate statistical methods, understand the fundamental uncertainties in experimental measurements, and draw appropriate conclusions.

2. Disciplinary knowledge and skills
students should understand and be able to apply their understanding of all chemistry sub-disciplines and use appropriate laboratory skills and instrumentation to solve problems. These areas of knowledge and skills include:

- Basic chemical concepts such as stoichiometry, states of matter, atomic structure, molecular structure and bonding, thermodynamics, equilibria, and kinetics.
- Basic laboratory skills such as keeping a notebook, use of electronic balances and volumetric glassware, preparation of solutions, chemical measurements using pH electrodes and spectrophotometers
- Foundational knowledge and skills in analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, and physical chemistry.
- Foundational laboratory skills including synthesis of molecules, measurement of chemical properties, determination of structures, use of modern instrumentation and computational modeling.

3. Chemical Literature and Information Management Skills. Students should be able to retrieve information efficiently and effectively by searching the chemical literature, evaluate technical articles critically, and manage many types of chemical information.

4. Laboratory Safety Skills. Students should be able to demonstrate and apply their understanding of the concepts of safe laboratory practices. They should be able to evaluate and assess safety risks associated with laboratory experiences. Students must be able to:

- carry out responsible disposal techniques
- comply with safety regulations
- properly use personal protective equipment to minimize exposure to hazards
- recognize chemical and physical hazards in laboratories, assess the risks from these hazards, know how to minimize the risks, and prepare for emergencies.
- understand the categories of hazards associated with chemicals (health, physical, and environmental)
- use Safety Data Sheets (SDSs) and other standard printed and online safety reference materials

5. Communication Skills. Students should be able to present information in a clear and organized manner, write well-organized and concise reports in a scientifically appropriate style, and use relevant technology in their communications.

6. Team Skills. Students should be able to interact effectively in a group to solve scientific problems and work productively with a diverse group of peers.

7. Ethics. Students should understand and demonstrate responsible treatment of data, proper citation of others' work, and the standards related to plagiarism and the publication of scientific results. Students should also be able to explain the role of chemistry in contemporary societal and global issues, including areas such as sustainability and green chemistry.

Appendix O_2 - Chemistry Exit Exam

1. Identify the characteristics of a liquid.
   (A) indefinite shape and volume
   (B) indefinite shape, but definite volume
   (C) definite shape and volume
   (D) none of the above
   (E) all of the above

2. Identify the phase in which the water molecules are closest together.
   (A) gas
   (B) dry ice
   (C) solid
   (D) liquid

3. How many grams of Li3N can be formed from 1.75 moles of Li? Assume an excess of nitrogen.
   6 Li(*s*) + N2(*g*) → 2 Li3N(*s*)

   (A) 18.3 g Li3N
   (B) 20.3 g Li3N
   (C) 58.3 g Li3N
   (D) 61.0 g Li3N
   (E) 15.1 g Li3N

4. What species is represented by the following information?

   p+ = 47 n° = 62 e- = 46

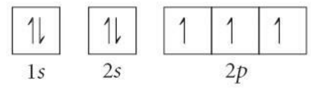
   (A) Ag+
   (B) Nd
   (C) Pd
   (D) Ag
   (E) Pd+

5. If 30.2 g of $BaCl_2$ is dissolved in 1.0 L of water, what is the resultant chloride (Cl^-) ion concentration?

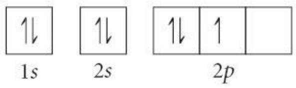
   (A) Less than 0.10 M
   (B) 0.11 - 0.20 M
   (C) 0.21 - 0.50 M
   (D) 0.51 - 1.0 M
   (E) More than 1.1 M

6. Choose the orbital diagram that represents the ground state of N.

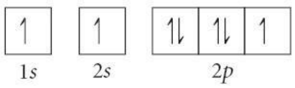
   (A)



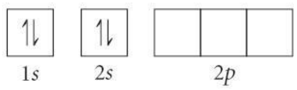
(B)



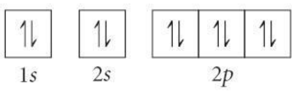
(C)



(D)



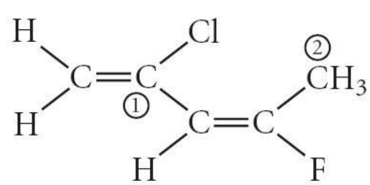
(E)



7. Identify the element that has a ground state electronic configuration of
[Ar] 4s2 3d10 4p1.

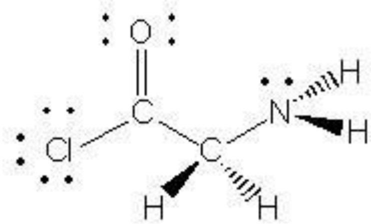
(A) Al
(B) In
(C) Ga
(D) B

8. Consider the molecule below. Determine the molecular geometry at each of the labeled carbons. 2



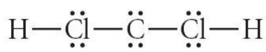
(A) C1 = tetrahedral, C2 = linear
(B) C1 = trigonal planar, C2 = bent
(C) C1 = bent, C2 = trigonal planar
(D) C1 = trigonal planar, C2 = tetrahedral
(E) C1 = trigonal pyramidal, C2 = see-saw

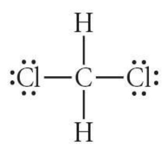
9. Consider the molecule below. Determine the hybridization at each of the three atoms (C,C, N) from left to right

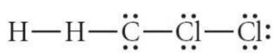


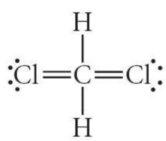
(A) 1 = sp2, 2 = sp3, 3 =sp2
(B) 1 = sp2, 2 = sp3, 3 = sp3
(C) 1 = sp3, 2 = sp3, 3 = sp3
(D) 1 = sp3, 2 = sp3, 3 = sp2
(E) 1 = sp, 2 = sp2, 3 = sp2

10. Choose the best Lewis structure for CH2Cl2.

(A) 

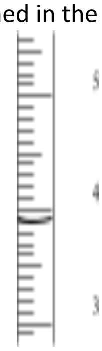
(B) 

(C) 

(D) 

11. Report the volume of the liquid contained in the graduated cylinder to the correct number of digits.

(A) 3 mL
(B) 3.9 mL
(C) 3.88 mL
(D) 3.887 mL
(E) 4.1 mL



12. Which glassware is best to measure 10.5 mL of a liquid?

(A) a graduated buret (with marking every 0.1 mL)
(B) a graduated cylinder (with marking every 1 mL)
(C) a fixed volume pipet (with only one marking)
(D) a graduated beaker (with marking every 10 mL)

13. How many grams of KBr are required to make 350. mL of a 0.115 M KBr solution?
(A) 0.338 g
(B) 3.04 g
(C) 4.79 g
(D) 40.3 g

14. How many milliliters of a stock solution of 11.1 M HNO_3 would be needed to prepare 0.500 L of 0.500 M HNO_3?
(A) 0.0444 mL
(B) 22.5 mL
(C) 2.78 mL
(D) 44.4 mL
(E) 0.0225 mL

15. Which of the following reactions is most likely to have a positive change in entropy ($\Delta S_{rxn} > 0$)?

$2LiOH(aq) + CO_2(g) \quad Li_2CO_3(aq) + H_2O(l)$

A. $2N_2O_5(g) \quad 4NO_2(g) + O_2(g)$

B. $CO(g) + 2H_2(g) \quad CH_3OH(l)$

C. $P_4(g) \quad P_4(s)$

D. $2IBr(g) \quad I_2(s) + Br_2(l)$

16. The thermodynamic equation for the formation of water is:

$2H_2(g) + O_2(g) \quad 2H_2O(g)\ \Delta H_{rxn} = -241.8$ kJ

What is the ΔH_{rxn} for the decomposition of 1 mole of water?
A. -241.8 kJ
B. -120.9 kJ
C. 120.9 kJ
D. 241.8 kJ
E. 483.6 kJ

17. We use coal to generate hydrogen gas (a possible fuel) by the **endothermic** reaction

$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$

If this reaction is at equilibrium, predict which of the following changes will result in an increased yield of hydrogen gas (H_2).

(A) Adding more C to the reaction mixture.
(B) Removing H_2O from the reaction mixture.
(C) Raising the temperature of the reaction mixture.
(D) Lowering the volume of the reaction mixture.
(E) Adding a catalyst to the reaction mixture.

18. Express the equilibrium constant for the following reaction:

N2(g) + 3 H2(g) $\rightleftharpoons$ 2 NH3(g)

(A) K = $\frac{[N_2][H_2]^{1/3}}{[NH_3]^{1/2}}$

(B) K = $\frac{[NH_3]^6}{[N_2]^3[H_2]^9}$

(C) K = $\frac{[NH_3]^2}{[N_2][H_2]^3}$

(D) K = $\frac{[N_2][H_2]^3}{[NH_3]^2}$

(E) K = $\frac{[NH_3]^{1/2}}{[N_2][H_2]^{1/3}}$

19. For the reaction 2A*(g)* ⇌ B*(g)*, the equilibrium constant is K_c = 0.76. A reaction mixture initially contains 0.20 M of each gas. Which statement is true of the reaction mixture?

a. The reaction mixture is at equilibrium.
b. The reaction mixture will proceed towards products.
c. The reaction mixture will proceed towards reactants.
d. There is not enough information to determine the direction of the mixture.
e. The mixture will never reach equilibrium.

20. For the reaction A + B C, the rate law is rate = k[A][B]^2. If the concentration of A is doubled, what will be the effect on the rate of the reaction?

i. Rate is unchanged.
b. Rate is doubled.
c. Rate is quadrupled.
d. Rate decreases to ½.
e. Rate decreases to ¼.

21. Given the mechanism below for the overall reaction AB + C A + BC, what is the rate law for the reaction?

AB + AB AB_2 + A *slow*

AB_2 + C AB + BC *fast*

a. Rate = k[2AB]
b. Rate = k[AB]^2
c. Rate = k[AB_2][A]
d. Rate = k[AB_2][C]
e. Rate = k[AB][BC]

22. For the reaction 2 NO_2 2 NO + O_2, the rate of decomposition of NO_2 is – 0.20 M/s. What is the rate of appearance of O_2?

a. – 0.10 M/s
b. – 0.40 M/s
c. 0.10 M/s
d. 0.20 M/s
e. 0.40 M/s

23. Which of the following represents the oxidation states of the individual atoms in CaC_2O_4?

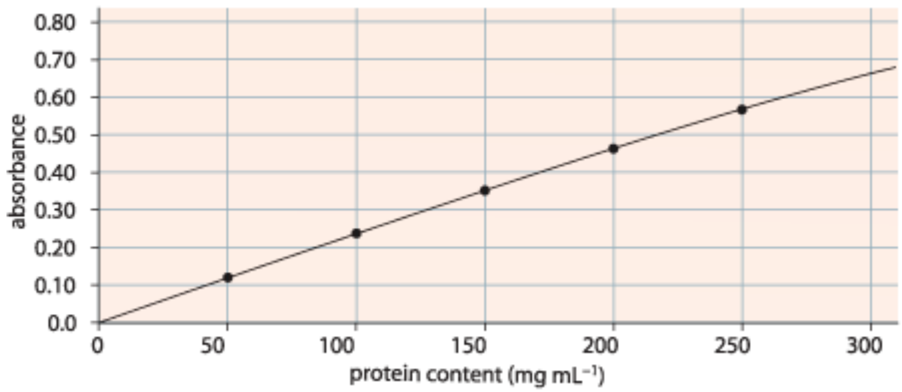
(A) Ca = +2; C = +3; O = -2
(B) Ca = +3; C = +2; O = -2
(C) Ca = +3; C = +4; O = -2
(D) Ca = -2; C = +3; O = -1
(E) Ca = -2; C = +2; O = -1

24. Equimolar 0.5 L solution of each of the following solutions were mixed, which choices below are buffers?

(1) NH_4Cl (*aq*) and NH_3(*aq*)
(2) HCl (*aq)* and NH_3 (*aq*)
(3) KF (*aq*) and HF *(aq*)
(4) NaOH (*aq*) and HCl (*aq*)
(5) $NaHCO_3$ (*aq*) and Na_2CO_3 (*aq*)

(A) 1 and 3
(B) 1, 3 and 5
(C) 1 and 5
(D) 2 and 5
(E) 2, 3, and 4

25. The protein content of a sample was determined using a reagent to convert the protein into a coloured complex. The absorbance of the complex was measured using a UV-visible spectrophotometer set at an appropriate wavelength. Using standard protein solutions, the calibration curve shown below was obtained. A sample containing protein was diluted 50 fold. The diluted solution was found to have an absorbance of 0.30. The protein content of the sample was



a. 125 mg mL^{-1}
b. 0.125 g mL^{-1}
c. 2.5 mg mL^{-1}
d. 6.25 g mL^{-1}

Appendix O_3 -Lab Safety Assessment

General Primer:

1. For each lab, students were asked to read through the experiment, find ALL chemicals and equipment to be used, and asked to look up the health and safety information (and codes), as well as the chemical and physical properties of each chemical/material using the Safety Data Sheet (SDS). Students had safety training/orientation and were taught how to look up data from the SDSs.

2. In each experiment, they get all 2 points if they provide the safety and health information of ALL the chemicals. They get 1 point if they provide half the information. In general, they get points taken off if they fail to provide satisfactory information.

Appendix O4 -Chemical Hygiene Assignment (Spring 2018)

The Fitchburg State University (FSU) Chemical Hygiene Plan (CHP) is available to view on Blackboard. Use the CHP document to answer the questions below. Answers can be neatly handwritten or typed. The answers should not be copied and pasted from the CHP document, rather they should be paraphrased i.e. written in your own words.

1. What is the purpose of a CHP?
2. What is the responsibility of the Chemical Hygiene Officer (CHO) in respect to the CHP?
3. Outline five of the other responsibilities of the CHO.
4. Who is responsible for ensuring Safety Data Sheets (SDS) are available for a particular chemical in the laboratory in which that chemical is used?
5. Who is responsible for developing and implementing a Standard Operating Procedure (SOP) for the handling and disposal of chemicals in a laboratory on campus?
6. What information must be listed on the containers of chemicals arriving at FSU?
7. What are the criteria which should be adhered to when a chemical is transferred from its original container into a secondary container?
8. According to the CHP, when must a chemical be used in a fume hood?
9. What four PPEs (Personal Protective Equipment) are recommended for use when handling hazardous chemicals?
10. Briefly discuss some of the other steps which can be taken (other than using PPEs) to minimize exposure to hazardous chemicals.
11. Briefly outline the guidelines for working alone in laboratories on campus.
12. How should hazardous chemicals be transported from building to building on campus?
13. How should flammable chemicals be stored?
14. How should corrosive chemicals be stored?
15. List five guidelines which should be followed when working in a fume hood.
16. What information should be on chemical waste containers?
17. What is a Satellite Accumulation Area (SAA)?
18. How long can waste containers be stored in a SAA?
19. What type of material can be disposed of down the drain?
20. How should organic solvents be disposed of?
21. How should mercury be disposed of?
22. How should gas cylinders be disposed of?

23. How should sharps be disposed of?

24. Briefly describe how the following types of emergencies should be managed: clean up with injury and cleanup with no injury.

25. How often should safety showers and eyewash stations be tested?

26. List and provide a description for the nine classes of Dangerous Goods as classified by the U.S. Department of Transport.

27. Provide a one-line description of the eight categories of adverse health effects of chemicals.

28. What steps should be taken if power to the fume hoods in a laboratory is lost?

29. Briefly describe how a chemical spill of one gallon or less should be managed.

30. What is the best type of glove to use when handling concentrated nitric acid?

31. What types of chemicals should not be stored with potassium chlorate?

32. How should oxidizers be stored?

33. Give three examples of air reactive chemicals.

34. According to the chemical storage guidelines, there are three types of corrosive chemicals which need to be stored apart. What are the three categories?

Appendix O5 -Poster Rubric

Presenter's Name: ____

Poster Title: ____

Content (60 points) _________/60

- Contains all the necessary components needed to describe topic to the audience
  - Name and title
  - Introduction/background of the issue they are exploring
  - Appropriate sections/subtopics
  - Conclusion/future directions
  - Figures, tables, graphs, etc. used appropriately

- Contains enough scientific knowledge, **especially chemistry**
- Presenter and poster demonstrate a thorough explanation of the topic

Design (40 points) _________/40

- Well-organized and easy to understand
- Visually appealing
- Appropriate font size
- Photographs, graphs and tables easy to see and well-labeled

Presentation (40 points) _________/40

- Presenter has a good understanding of their topic.
- Presenter explained their poster well.
- Presenter was professional.
- Presenter answered questions well.

Citations (10 points) _________/10

- Resources properly cited
- Citations for all figures not made by the author
- Several primary resources cited

Total ________/150

Notes:

Appendix O6 -Chemistry Seminar Oral Presentation Assessment

Presenter Name: ____________________ Presentation Title: ______________________________________

	Proficient 3	Sufficient 2	Deficient 1	Rating (1, 2, 3 or N/A)
Define problems clearly	Identifies a creative, focused, and manageable topic that addresses potentially significant yet previously less-explored aspects of the topic.	Identifies a focused and manageable/doable topic that appropriately addresses relevant aspects of the topic.	Identifies a topic that is far too general and wide-ranging as to be manageable and doable.	
Understanding	A detailed understanding is shown of all the underlying scientific concepts	A general understanding is shown of most of the underlying scientific concepts	Poor understanding is shown of the underlying scientific concepts	
Students present information in a clear and organized manner	Delivery of presentation is well-organized, professional, and coherent. Images and text are clearly readable to the audience.	Delivery of presentation is organized, professional, and coherent. Images and text are mostly readable to the audience.	Delivery of presentation lacks organization or is not always coherent. Images and text not always easily read by audience.	
Presents relevant <u>data</u>	Presents relevant in-depth data using clear, well organized, and easily readable figures, spectra, tables, etc.	Presents general data without emphasizing the relevant ones. Data is clear, readable, but lack some detailed information.	Data presented lacks organization. Presents mostly irrelevant data.	
Ability to retrieve information by searching the chemical literature	At least 8 journal articles retrieved.	5-8 journal journal articles retrieved.	<5 journal articles retrieved.	
Proper citation of others' work	Properly cites sources in text and for images used in the presentation. Citations are shown on the slides that they are referenced.	Mostly cite sources in text or for images used in the presentation. Displays a list of all references on one slide	Does not properly cite sources in text or for images used in the presentation	
Evaluate technical articles critically	Synthesizes in-depth information from relevant sources representing various points of view/approaches.	Presents information from relevant sources representing limited points of view/approaches.	Presents information from irrelevant sources representing limited points of view/approaches.	

16. Appendix P: Faculty *Curriculum vitae*

DENNIS AWASABISAH, Ph.D.
Fitchburg State University
Biology & Chemistry Department, 160 Pearl Street, Fitchburg, MA 01420
Office: 978-665-3248
Email: dawasabi@fitchburgstate.edu

EDUCATION

Ph.D. Chemistry (2015)
University of Oklahoma, Norman OK

- **Advisor:** Dr. George B. Richter-Addo.
- **Dissertation:** Synthesis and Redox Behavior of Group 8 Metalloporphyrins and Related Compounds. o I discovered new redox and reaction pathways of biologically relevant metalloporphyrin active sites.

M.S. Chemistry (2009)
Southern Illinois University Edwardsville

- **Advisor:** Dr. Timothy B. Patrick.
- **Thesis:** Free Radical Reactions of 3-Fluorobutenone.
  - I discovered the synthesis of new fluorocarbon compounds that could potentially be used as building blocks for drugs, agrochemicals and polymers.

B.Sc. Chemistry (2006)

- University of Cape Coast, Ghana.
- **Advisor:** Dr. Banyan A. Dadson.
- **Thesis:** Synthesis of Baclofen.
  - As part of my thesis, I performed a chemical synthesis of the drug baclofen, from readily available starting materials.

TEACHING EXPERIENCE

Assistant Professor of Chemistry (September 2016 – date)

- Biology/ Chemistry Department, Fitchburg State University
  - I teach a variety of chemistry courses, including General Chemistry, Organic Chemistry, and Chemistry for Health Sciences.
  - Assess student performance (grading)

- I supervise laboratory research with students
- I advise students
- I serve on department and university committees

Lecturer (June 2015 – May 2016)

- Chemistry and Biochemistry Department, University of Oklahoma
    - Taught upper-level Organic Chemistry II lecture course.
    - Taught General Chemistry I and II lecture course sequence
    - Prepared course syllabus and assessed student performance (grading).

POSTDOCTORAL EXPERIENCE

Postdoctoral Research Associate (June - December 2015; May – August 2016)

- Department of Chemistry and Biochemistry, University of Oklahoma
    - Engaged in research on the interactions of heme models and other coordination compounds with NO_x molecules
    - Investigated the role of nitric oxide as a vasodilator
    - Trained students on lab techniques, lab safety, etc.
    - Performed laboratory administrative work in the lab of Prof. George Richter-Addo

OTHER TEACHING/ RESEARCH EXPERIENCE

Graduate Teaching/Research Assistant (August 2009 – May 2015)

- University of Oklahoma
    - Taught junior-level Organic Chemistry Labs
    - Taught General Chemistry I and II Lab and recitation sessions
    - Taught senior-level Advanced Synthesis and Spectral Characterization lab
    - Performed research in the Richter-Addo lab as graduate research assistant
    - In charge of training undergraduates and new graduate students in the Richter-Addo lab. o Ensured compliance of personnel to personal lab safety and training
    - In charge of keeping and updating chemical inventory in the Richter-Addo lab.
    - In charge of purchases of laboratory chemicals and equipment
    - In charge of chemical waste disposal in the Richter-Addo lab
    - Point of contact between the Richter-Addo lab and other lab groups as well as OU campus management for building and construction/ renovation activities.

Graduate Teaching/Research Assistant (January 2008 – July 2009)

- Southern Illinois University Edwardsville

- Taught General Chemistry Labs
- Taught Sophomore Organic Chemistry Lab
- Taught Nursing Chemistry Lab
- Performed research in the Patrick Research Lab

Teaching Assistant (August 2006 – July 2007)

- University of Cape Coast, Ghana
  - Taught General Chemistry Lab and tutorial sessions
  - Taught level 200 (sophomore) Organic Chemistry Lab and tutorial sessions

SERVICE

University Committees, Fitchburg State University

- AUC Student Affairs Committee (AY 2020/2021) – date
- Search Committee for the Director for Student Diversity, Equity, and Belonging Programs (AY 2020/2021)
- Strategic Planning Sub-Committee (AY 2019/2020)
- University Parking Committee (AY 2017/2018 – AY 2018/2019)
- University Technology Assessment Committee (AY 2016/2017)

Biology/Chemistry Departmental Committees, Fitchburg State University

- Assessment Committee (AY 2016/2017 – date)
  - Co-chaired the committee in AY 2020/2021
- Student Affairs Committee (AY 2018/2019 – 2019/2020)
  - Co-chaired the committee in Spring 2020
- Equipment Committee (AY 2016/2017, AY 2018/2019 & AY 2021/2022)
  - Chairing the committee in AY 2021/2022
- Department Administrative Assistant Search Committee (AY 2017/2018)
  - Reviewed applications, interviewed and recommended a candidate to fill the department's administration position.

Reviewer Services

- Reviewer for the journal *Transition Metal Chemistry* (2015 – date)
  - Review journal articles and made recommendations for acceptance, revision or

rejection of peer reviewed articles

- Book Chapter Reviews
  - o Reviewed two chapters of a General Chemistry book for W.H Freeman Co. Publishers (2016) o Reviewed seven chapters of Macmillan's, "Organic Chemistry" textbook by Richard Mullins (2020)

Other Services

- Southern Illinois University Edwardsville Probst Lecture Poster Session.
  - o Serve as a judge for research poster session in Spring 2021
- CMSACS Undergraduate Chemical Research Symposium (April 2018)
  - o Co-organizer for the symposium, and served as career panel moderator
- The New England Regional Conference of the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS) Conference in 2018
  - o Served as a judge for a poster session
- 62^{nd} Oklahoma Pentasectional Meeting of the ACS (March 2017)
  - o Served as a judge for a poster session

PUBLICATIONS

1. Xu, N.; Yan, B.; Awasabisah, D.; Powell, D. R.; Richter-Addo, G. B. *"Preparation and infrared spectroelectrochemical studies of five-coordinate (por)Fe(OC(=O)R) compounds (por = TPP, OEP; R = CCl_3, CH_2Cl)". Inorg. Chim. Acta.* **2018,** *469,* 183-188*,*

2. Awasabisah, D.; Xu, N.; Sharmah Gautam, K. P.; Powell, D. R.; Shaw, M. J.; Richter-Addo, G. B. *" Preparation, characterization, electrochemistry, and infrared spectroelectrochemistry of ruthenium nitrosyl porphyrins containing η^1-O bonded axial carboxylates". Eur. J. Inorg. Chem.* **2016,** 509-518.

3. Awasabisah, D.; Powell, D. R.; Richter-Addo, G. B. "Crystal structure of N-(2-{[2,6-bis(2,2,2-trifluoroacetamido)phenyl]disulfanyl}-3-(2,2,2-trifluoroacetamido)phenyl)-2,2,2-trifluoro acetamide." *Acta Cryst*. **2015**, E71, o639-o640.

I am the corresponding author of this paper.

4. Awasabisah, D.; Richter-Addo, G. B. BOOK CHAPTER: "Chapter One – NO_x linkage isomerization in metal complexes: In *Advances in Inorganic Chemistry* – NO_x related Chemistry" (**2015**). Eds. Van Eldik, R. & Olabe, J. A. Academic Press, Waltham, MA, USA. Vol. 67. pp. 1-86. *This work is the comprehensive review of linkage isomerization of NO_x-coordinated porphyrin and non-porphyrin complexes.*

5. Awasabisah, D.; Powell, D. R.; Richter-Addo, G. B. "Crystal structure of chlorido{5,10,15,20- tetrakis[2-(2,2-dimethylpropanamido)phenyl]porphyrinato}iron(III). *Acta Cryst*. **2015**, E71, m42-m43. *I am the corresponding author of this paper.*

6. Abucayon, E. G.; Awasabisah, D.; Powell, D. R.; Richter-Addo, G. B. "(1-Methylimidazole)(*o* nitrosotoluene)(5,10,15,20-tetraphenylporphyrinato)iron(II) dichloromethane solvate". *Acta Cryst.* **2014**, E70, m51–m52.
I mentored a student for 7 weeks leading to the publication of this paper.

7. Awasabisah, D.; Xu, N.; Sharmah Gautam, K. P.; Powell, D. R.; Shaw, M. J.; Richter-Addo, G. B. "Stable ruthenium nitrosyl porphyins with axial *O*-bonded ligands; preparation and redox behavior". *Dalton Trans.,* **2013**, *42*, 8537-8540.
This paper was selected as Cover Art for the issue in which the paper was published.

8. El-Attar, M.; Xu, N.; Awasabisah, D.; Powell, D. R.; Richter-Addo, G. B. "Cyclic voltammetric and fiber-optic infrared spectroelectrochemical studies of six-coordinate (por)Ru(NO)Cl compounds (por = porphyrinato dianion)." *Polyhedron*, **2012**, *40*, 105-109.

9. Patrick, T. B.; Awasabisah, D. "Meerwein arylation with 3-fluorobutenone". *J. Fluorine Chem.*, **2010**, *131*, 396-397.

SCHOLARSHIPS, GRANTS & AWARDS

- **Major Grant award recipient ($2,500).** Special Projects Grant, Fitchburg State University (AY 2020/2021)

- **Major Grant award recipient ($2,500).** Special Projects Grant, Fitchburg State University (AY 2021/2022)

- **"Most Inspiring Faculty Award" (2016)**
  - Awarded to faculty members who have motivated and inspired student-athletes in the 2015-2016 Academic Year at the University of Oklahoma
  - Received one of three awards. I received this award during my first year of teaching at the University of Oklahoma.

http://www.soonersports.com/ViewArticle.dbml?DB_OEM_ID=31000&ATCLID=210884497

- **"Belle W. Goodman Scholarship Award" (2015)**
  - In recognition of outstanding achievement and superior service during the 2014 – 2015 academic year as a graduate student at the University of Oklahoma.
  - One of 2 student awards (out of ~100 students).
  - Monetary amount of $1,000
  - Received a certificate

- **"Jerry J. Zuckerman Award" (2013)**
  - In recognition of outstanding performance in research during the 2012 – 2013 academic year at the University of Oklahoma.
  - Provided annually to an outstanding graduate student pursuing a degree program in organometallic or inorganic chemistry at the University of Oklahoma
  - One award was given (out of ~100 graduate students).
  - Monetary amount of $300
  - Received a certificate

- **"Lloyd E. Swearingen Award" (2012)**
  - In recognition of outstanding performance in research during the 2011 – 2012 academic year.
  - Selected on the basis of outstanding performance in research as a graduate student at the University of Oklahoma
  - One award (out of ~100 students).
  - Received a certificate

- **"Outstanding Graduate Teaching Award" (2009)**
  - For exemplary academic achievement in the Department of Chemistry at Southern Illinois University Edwardsville.
  - One of 2 student awards (out of ~30 graduate students).
  - Monetary amount of $50

PRESENTATIONS AND PROFESSIONAL CONFERENCES ATTENDED

1. Dennis Awasabisah; Jack F. Gangemi (UG); Douglas R. Powell. "*Synthetic Heme-antimalarial Adducts: Synthesis and Electrochemistry*" presentation at the 2020 NOBCChE Virtual Conference. **Sept. 24-25, 2020.**

2. Dennis Awasabisah; Jack F. Gangemi (UG); Douglas R. Powell. "*Synthesis and Characterization of Heme Quinoline-based Antimalarial Adducts."* Gave a talk at the ACS Fall 2020 Virtual Meeting and Exposition, **Aug. 17-20, 2020**. https://doi.org/10.1021/scimeetings.0c06648

3. Jack F. Gangemi (UG); Douglas R. Powell; Dennis Awasabisah. "*Synthetic Heme-antimalarial Adducts: Synthesis and Electrochemistry*" Poster presentation at the 259th ACS National Meeting & Exposition, Philadelphia, PA, United States, **March 22-26, 2020 (2020),** INOR0668. https://doi.org/10.1021/scimeetings.0c06434.

4. Jack F. Gangemi (UG); Douglas R. Powell; Dennis Awasabisah. "*Synthetic Heme-antimalarial Adducts: Synthesis and Electrochemistry*" Poster presentation at the Bridgewater University

18th Annual Symposium on Sustainability and the Environment. **November 23, 2019.**

5. Attended as a participant at the ACS New Faculty Workshop at Little Rock, Arkansas. *November 9 -2 10* ***2018.***

6. NSF Day. **Sept. 12, 2017.** Attended as a participant at the NSF Day meeting at University of Saint Joseph, CT.

7. Awasabisah, D.; Powell, D. R.; Richter-Addo, G. B. Poster: "*Reactions of nitric oxide with iridium phosphine complexes*." 70th Southwest Regional Meeting of the American Chemical Society, Fort Worth, TX (**2014**)

8. Awasabisah, D.; Xu, N.; Gautham, K. P.; Powell, D. R.; Shaw, M. J.; Richter-Addo, G. B. Poster: "*Six coordinate ruthenium nitrosyl porphyrins with carboxylate and aryloxide ligands: Preparation and redox behavior*". 245th ACS National Meeting & Exposition, New Orleans, LA (**2013**).

9. Awasabisah, D.; Xu, N.; Richter-Addo, G. B. Poster: "*Ruthenium porphyrins with O-bound ligands trans to nitric oxide*." 241st National Meeting of the American Chemical Society, Anaheim, CA (**2011**).

10. Awasabisah, D.; Xu, N.; Gautham, K. P.; Powell, D. R.; Shaw, M. J.; Richter-Addo, G. B. Poster: "*Stable ruthenium analogues of nitrosyl heme tyrosinates; preparation and redox behavior*". 57th Annual Oklahoma Pentasectional Meeting of the American Chemical Society, Cameron University, Lawton, OK (**2012**).

11. Awasabisah, D.; Xu, N.; Richter-Addo, G. B. Poster: "*Ruthenium porphyrins with O-bound ligands trans to nitric oxide*." 55th Annual Pentasectional Meeting of the American Chemical Society, Norman, OK (**2010**).

12. Patrick, T. B.; Awasabisah, D. Poster: *"Free radical reaction of fluorovinyl ketone".* Poster for Probst Lecture: Southern Illinois University Edwardsville, Edwardsville, IL (**2009**).

SCIENTIFIC MEMBERSHIP AND PROFESSIONAL SOCIETIES

2011 – Present American Chemical Society

2019 – present National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE)

TECHNICAL AND EXPERIMENTAL SKILLS

• Schlenk techniques and handling air-sensitive reactions

• Glovebox operation and maintenance

• Operation and handling of solvent purification system

• Synthesis of new target compounds

• Electrochemistry and spectroelectrochemistry

• NMR spectroscopy

• IR spectroscopy

• UV-vis spectroscopy

• X-ray data analysis

• Small molecule crystallization

• Mass Spectrometry data analysis

• Chemical purchasing and inventory

• Chemical waste and lab safety

• Blackboard

• Microsoft Office

• Desire2Learn and Blackboard for teaching

• Degreeworks for advising

• Student Success Center (SSC) for advising

Emma L. Downs, Ph.D.
160 Pearl St. edowns1@fitchburgstate.edu
Fitchburg, MA 01420 978-665-3621

EDUCATION

University of Oregon (2009 -2014) *Eugene, OR*
Doctor of Philosophy: Chemistry 2014
Dissertation: "An Exploration of Transition Metal Catalysts for Cyanohydrin Hydration: The Interface of Homogeneous and Heterogeneous Catalysis"

University of Massachusetts (2005 - 2009) *Amherst, MA*
Bachelor of Science: Chemistry, *magna cum laude* 2009
Bachelor of Arts: English, *magna cum laude* 2009

Phillips Academy Andover (2001 - 2005) *Andover, MA*

TEACHING EXPERIENCE

Department of Biology and Chemistry, Fitchburg State University Fitchburg, MA
Assistant Professor of Chemistry 2015-present
- Teaching general chemistry I and II with associated lab sections.
- Teaching inorganic chemistry as a core course for chemistry majors.
- Teaching environmental chemistry as an upper level elective.
- Teaching honors seminar in environmental science.

Chemistry Program, Centre College Danville, KY
Visiting Assistant Professor of Chemistry 2014-2015
- Taught a course in chemistry for non-scientists containing 24 students, as well as multiple sections of general chemistry lab, each with around 24 students.

Department of Chemistry and Biochemistry, University of Oregon Eugene, OR
Head Teaching Assistant 2012-2014
- Four terms as head TA supervising 10-15 lab instructors for organic chemistry lab courses. Tasks included training TAs, overseeing labs, proctoring and grading exams, and preparing and delivering 2-4 lectures per term to a class of 180-250 students.

Discussion Leader 2014
- Ran peer led discussion sections of the majors' organic chemistry lecture, overseeing workshops each week for three sections of 15-20 students.

Teaching Assistant 2009-2012
- Nine terms as a lab TA supervising two lab sections of 12-20 students per term for general and organic chemistry courses including both majors and non-majors.

RESEARCH

Fitchburg State University *Fitchburg, MA*
2015-present
- Supervise research of 6 undergraduates.
- Research on easily synthesized silver nanoparticles.
- Studying the effects on catalytic rates of different ligands and stabilizers for nanoparticles.
- Studying the leaching of silver nanoparticles in commercial products under various conditions.
- Examining the effects of silver nanoparticles on plants with Dr. Erin Rehrig and Dr. Catherine Buell

- Summer research collaborative – interdisciplinary study of the effects of human activity on the Nashua River

University of Oregon *Eugene, OR*
2009-2014

- Worked under Professor David Tyler studying inorganic chemistry and catalysis.
- Focused on the synthesis and testing of new catalysts for the hydration of nitriles and cyanohydrins to amides towards a greener industrial synthesis of methyl methacrylate.
- Synthesized Ag, Ni, and Pt nanoparticles catalyst and characterized using TEM, XPS, UV-vis.
- Synthesized platinum phosphine complexes using air-free techniques and characterized using NMR and Mass Spec.
- Monitored catalyst kinetics using NMR techniques.
- Conducted mechanistic studies on homogeneous and heterogeneous catalysts.
- Mentored four undergraduate researchers. Three have gone on to graduate school.

University of Massachusetts *Amherst, MA*
2007-2009

- Worked under Professor Richard Vachet studying bioanalytical chemistry.
- Studied copper binding to protein (β-2-microglobulin) and the effects of the binding on protein unfolding and subsequent amyloid formation.
- Monitored with fluorescence spectroscopy and mass spectrometry.

PUBLICATIONS

- Buell, C.; Downs, E.L; Rehrig, E.M. "Using MATLAB to study Plant Health and Herbivory for Small-scale Research Experiments" *Science Education Resource Center*, *Carleton College,* **2019**, Peer Reviewed Conference Procceding
- Downs, E.L.; Zakharov, L.N.; Tyler, D.R. "Crystal Structure of *trans*-dihydrido-bis-[tris(dimehtylamino)phosphane]-platinum(II)" *Acta Cryst*, **2015,** *E71***,** m83-m84
- Downs, E.L.; Tyler, D.R. "A Review of Nanoparticle Catalysts for Nitrile Hydration" *Coordination Chemistry Reviews,* **2014,** *280,* 28-37.
- Sherbow, T.J.; Downs, E.L.; Sayler, R.I.; Razink, J.J.; Juliette, J.J.; Tyler, D.R. "Synthesis and Characterization of PTA Stabilized Silver Nanoparticles and Use as Catalysts for Nitrile Hydration" *ACS Catalysis,* **2014**, *4(9)*, 3096-3104
- Downs, E.L..; Tyler, D.R. "Nitrile and Cyanohydrin Hydration with a Nanoparticle Catalyst formed *In Situ* from a Platinum Dihydride Complex" *Journal of Inorganic and Organometallic Polymers and Materials*, **2014**, 1-8

PRESENTATIONS

Biennial Conference on Chemical Education 2020 *Cancelled*
July 2020

Fitchburg State University Summer Research Collaborative: An Interdisciplinary Research Experience to Improve STEM Retention and Graduate School Attendance (with Dr. Aisling O'Connor, abstract accepted)

American Chemical Society 2020 National Spring Meeting *Held Virtually*
March 2020

The Effects of Silver Nanoparticles on the Plant Physiology of *Arabidopsis thaliana* (virtual poster)

Association of Limnology and Oceanography Aquatic Sciences Meeting *San Juan, Puerto Rico*
February 2019

Fitchburg State University Summer Research Collaborative: An Interdisciplinary Research Experience to Improve STEM Retention and Graduate School Attendance (with Dr. Elizabeth Gordon and Dr. Daniel Welsh)

Northeast Nanomaterials Meeting *Lake Placid, NY*
June 2, 2018
Silver Nanoparticles for Nitrile Hydration: Effects of Various Stabilizing Ligands (Poster)

Fitchburg State University Development Day *Fitchburg, MA*
May 21, 2018
The Effects of Silver Nanoparticles on Plants (with Dr. Erin Rehrig)

Central Massachusetts American Chemical Society New Faculty Night *Worcester, MA*
November 15, 2017
Silver Nanoparticles: Catalysts and Much More

New England Association of Chemistry Teachers Annual Meeting *Wellesley, MA*
April 30, 2016
Using Green Chemistry Principles to Improve Production of Plexiglas: Exploration of Catalysts for Cyanohydrin Hydration

2nd Annual International Materials Congress *Zhenjiang, China*
May 18, 2013
Synthesis of Acrylate Monomers; Metal Nanoparticles as Hydration Catalysts for Nitrile and Cyanohydrin Hydration

UNIVERSITY SERVICE

Honors Advisory Committee 2019 – 2020
Updating the honors curriculum

First Year Experience Committee 2016 – present
Developing the classroom component of the "Reimagining the First Year Experience"

Liberal Arts and Sciences Council 2016 – 2019
Redesigned the general education requirements.

Biology and Chemistry Department Student Affairs Committee 2018-present
Selected winners for student awards, administering a student satisfaction survey, organizing workshops for student success

Biology and Chemistry Department Graduate Committee 2015 – 2019
Worked toward realigning the department's graduate offerings to better meet enrollment and the needs of our students.

Sustainability Committee 2015 – 2016

Earth and Geographic Science Search Committee 2017
Reviewed 77 applications, held 12 phone interviews and 3 on campus interviews resulting in a successful tenure track hire.

Biology & Chemistry Search Committee 2019
Reviewed 35 applications, held 8 phone interviews and 3 on campus interviews resulting in a successful tenure track hire.

GRANTS

IE3 Inclusive Excellence Grant *Howard Hughes Medical Institute*
With Inclusive Excellence Workgroup Pending, Submitted January 2020

Special Project Mini Grant *Fitchburg State University*
2020
Exploring the Relationship between Water Quality Indices and Urbanization of the Nashua River

Special Project Grant *Fitchburg State University*
The Effects of Silver Nanoparticles on Plants (with Drs. Erin Rehrig and Catherine Buell) 2018

Special Project Grant *Fitchburg State University*
Exploring the Catalytic Properties of Silver Nanoparticles 2016

PROFESSIONAL ACTIVITIES

VIPEr Workshop on Using Literature in the Inorganic Classroom June 2017
Developed literature discussion and other learning objects for the VIPEr website

PKAL Conference Co-Chair June 2017
Arranged the meeting with the steering committee and national office. Reviewed proposals and scheduled presentations, workshops, and a panel with local industry leaders on what skills they look for in new hires.

Central Massachusetts Division of the American Chemical Society Member 2015-present

University of Oregon Women in Graduate Sciences Member 2009-Present

The Women in Graduate Science (UOWGS) organization at the University of Oregon is an organization which focuses on the professional development of women in all disciplines of science to enable them to become successful contributors to their fields. This mission is accomplished by informative workshops, inspirational speakers, and a community outreach program. The organization has around 50 members (women and men from various scientific disciplines) and continues to grow.

Public Relations Chair 2010-2011
- Responsible for the advertisement of WGS workshops, seminars, and activities.

Treasurer 2011-2012
- Managed the finances of the group and assisted in planning events such as a communication workshop and a Members' Banquet.

Seminar Chair 2012-2013
- Invited speakers and planned seminars and workshops on various topics in career choice and development.

Outreach
- Organized and participated in Girls' Science Adventure Days with local museum The Science Factory. Topics included chemistry in food, polymer chemistry, and chemistry of combustion.
- Helped organize a CSI day for Girl Scouts at the University of Oregon

- Participated in the Duck Village Science booth during the 2012 Olympic Track Trials
- Did demonstrations at several middle school science nights on campus.

SCINECE WRITING EXPERIENCE

New England Interstate Water Pollution Control Commission *Lowell, MA*

Outreach Intern

2007-2009

- Wrote and supplied research for several articles for NEIWPCC's newsletter, *Interstate Water Report,* relating to current issues in chemistry and water pollution. These articles were intended to communicate scientific topics to an audience with little or no scientific training.

University of Oregon *Eugene, OR*

Science Journalism Course

- Taught by John Palfrey, former editor for the PBS program Frontline

Steven Fiedler, Ph.D.

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Department of Biology and Chemistry
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Education

2002 Ph.D. Chemistry, University of California, Irvine
1998 M.S. Chemistry, University of California, Irvine
1997 B.S. Chemistry, Michigan Technological University

Professional Experience

2018 – present Associate Professor of Chemistry, Fitchburg State University
2014 – 2018 Assistant Professor of Chemistry, Fitchburg State University
2013 – 2014 Visiting Assistant Professor, Pomona College
2010 – 2013 Lecturer, Research Fellow, California State University, Northridge (CSUN)
2006 – 2010 Senior Research Fellow, University of Michigan (U–M), Ann Arbor 2003 –
2006 Research Fellow, University of Jyv¨askyl¨a, Finland

Peer-reviewed Publications

18. Interaction of Helium Rydberg State Molecules with Dense Helium, N. Bonifaci, Z. Li, J. Eloranta, S.L. Fiedler, *J. Phys. Chem. A*, 120, 9019-9027 (2016).
17. A Local Wave Tracking Strategy for Efficiently Solving Mid- and High-Frequency Helmholtz Problems, M. Amara, S. Chaudhry, R. Djellouli, J. Diaz, S. L. Fiedler, *Comput. Methods Appl. Mech. Engrg.*, 276, 473-508 (2014).
16. Interaction of helium Rydberg state atoms with superfluid helium, S. L. Fiedler, J. Eloranta, *J. Low Temp. Phys.* 174, 269-283 (2014).
15. Role of Water and Ions on the Dynamical Transition of RNA, H. Zhang, S. Khodadadi, S. L. Fiedler, J. E. Curtis, *J. Phys. Chem. Lett.* 4, 3325-3329 (2013).
14. Theoretical modeling of ion mobility in superfluid ^{4}He, S. L. Fiedler, D. Mateo, T. Aleksanyan, J. Eloranta, *Phys. Rev. B* 86, 144522 (2012).
13. Experimental and theoretical characterization of the long-range interaction between $He^*(3s)$ and $He(1s)$, N. Bonifaci, F. Aitken, V. M. Atrazhev, S. L. Fiedler, J. Eloranta. *Phys. Rev. A* 85, 042706 (2012).
12. Nonadiabatic dynamics by the mean-field and surface-hopping approaches: Energy

conservation considerations, S. L. Fiedler (corresponding author), J. Eloranta, *Molec. Phys.* 108, 1471-1479 (2010).

11. Simulation of Nanoparticle Permeation through a Lipid Membrane, S. L. Fiedler, A. Violi, *Biophys. J.* 99, 144-152 (2010).

10. Application of mean-field and surface-hopping approaches for interrogation of the Xe^{+}_{3} molecular ion photoexcitation dynamics, S. L. Fiedler, H. Kunttu, J. Eloranta *J. Chem. Phys.* 128, 164309 (2008).

9. The effect of temperature on nanoparticle clustering, S. L. Fiedler, S. Izvekov, A. Violi, *Carbon* 45, 1786-1794 (2007).

8. Electronic spectroscopy of C_2 in solid rare gas matrixes, S. L. Fiedler, J. M. Eloranta, K. J. Vaskonen, H. M. Kunttu, *J. Phys. Chem. A*, 109, 4512-4516 (2005).

7. Effects of static and dynamic perturbations on isotropic hyperfine coupling constants in some quinone radicals, S. L. Fiedler, J. Eloranta, *Magn. Reson. Chem.*, 43, 231-234 (2005).

6. Charge transfer states of C_2 in Kr clusters, S. L. Fiedler, H. Kunttu, J. Eloranta, *Chem. Phys.*, 307, 91-95 (2004).

5. Host-guest charge transfer states: CN doped Kr and Xe, S. L. Fiedler, K. Vaskonen, J. Ahokas, H. Kunttu, J. Eloranta, V. A. Apkarian, *J. Chem. Phys.*, 117, 8867-8878 (2002).

4. Infrared study of five- and six-membered type cyclic imides, R. A. Nyquist, S. L. Fiedler, *Vib. Spec.* 8, 365-386 (1995).

3. Infrared study of styrene oxide and phenylacetylene in various solutions, R. A. Nyquist, S. Fiedler, *Vib. Spec.*, 7, 149-162 (1994).

2. Infrared study of vinyl acetate, methyl acrylate and methyl methacrylate in various solvents, R. A. Nyquist, S. L. Fiedler, R. Streck, *Vib. Spec.*, 6, 285-291 (1994).

1. Infrared study of n-alkanes in CCl_4, $CDCl_3/CCl_4$, and $CDCl_3$ 0.5% solutions, R. A. Nyquist, S. L. Fiedler, *Appl. Spec.*, 47, 1670-1682 (1993).

Mathangi Krishnamurthy
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Phone: 707-480-2046
mkrish1@fitchburgstate.edu

Education

Ph.D. Pharmaceutical Sciences
University of Tennessee Health Science Center, Memphis, December 2005

Dissertation title: **Probing the ligand binding pocket of cannabinoid receptors: Design, synthesis, structural analysis and biological evaluation of novel receptor agonists and antagonists**.

B. Pharm. The Tamil Nadu Dr. MGR Medical University, Chennai, India, June 1999

Work Experience

05/2018 – Present
Associate Professor, Dept. of Biology/Chemistry, Fitchburg State University, Fitchburg, MA
Responsible for instruction of courses in Organic Chemistry to undergraduates

09/2011 – 04/2018
Assistant Professor, Dept. of Biology/Chemistry, Fitchburg State University, Fitchburg, MA
Responsible for instruction of courses in Organic Chemistry to undergraduates

01/2011 – 05/2011
Adjunct Faculty Member, Dept. of Chemistry, Stonehill College, Easton, MA Responsible for instruction of lab courses in General Chemistry for undergraduates

02/01/2006 - 12/15/2009
Research Fellow, Howard Hughes Medical Institute
Joint Appointment in Department of Genetics, Harvard Medical School and Department of Molecular Biology, Massachusetts General Hospital

Development of an efficient self replicating genetic system that would be used in assembly of a protocell
Synthesized 2′-amino and 3′-amino -5′-phosphorimidazole activated nucleosides for non enzymatic primer extension of DNA. These compounds were able to penetrate fatty acid vesicles and effect rapid and efficient copying of DNA homopolymer templates encapsulated in these vesicles.
Bolaamphiphile-based vesicle systems
Synthesized a series of long chain monounsaturated dicarboxylic acids and evaluated the membrane forming properties of these double headed amphiphiles.

01/2005 - 12/2005
Lecturer, Dept. of Chemistry, Sonoma State University, Rohnert Park, CA Taught undergraduate General Chemistry and Organic Chemistry courses

08/1999 - 01/2005
Graduate Research Assistant, University of Tennessee Health Science Center, Memphis, TN
Design, synthesis, and biological evaluation of pyrazole class of cannabinoids

The effects of pyrazole substitution on ligand conformation and binding affinities were studied by using high field NMR spectroscopy and systematic molecular mechanics geometry searches. Design, synthesis, and biological evaluation of novel phenyl-substituted side-chain analogues of Δ^8-THC

The side-chain geometries of these analogues were determined using high field NMR spectroscopy and molecular mechanics searches to understand substituent effects on binding affinity and gain insights into the side-chain binding pocket of the cannabinoid receptors. Some of these analogues displayed potent cytotoxic effects on human glioma cell lines.

Research skills

Chemistry:

- Multi-step synthesis of modified nucleotides for non-enzymatic DNA synthesis and scale-up thereof for synthesis of oligonucleotides.
- Multi-step synthesis of drug-like organic molecules of varied chemical classes such as pyrazoles, benzopyrans, coumarins, and pentamidines.
- Synthetic methodologies such as aromatic functional group interconversions, orthogonal protection/deprotection strategies, palladium-mediated coupling reactions, Grignard chemistry, and utilization of terpene precursors for preparing chiral intermediates with sound understanding of underlying reaction mechanisms.
- Purification techniques including column chromatography, ion-exchange chromatography, thin layer chromatography, recrystallization, vacuum distillation, and sublimation.

Analytical: Proficient in spectroscopic techniques including mass spectrometry, IR, UV, and NMR spectroscopy, with expertise in interpretation of both 1D and 2D NMR (Homonuclear and Heteronuclear) spectra.

Biology: Expertise in cell culture techniques, in vitro cytotoxicity assay techniques and ligand receptor binding assay techniques involving radioisotopes.

Publications

1. Schrum JP, Ricardo A, Krishnamurthy M, Blain C, and Szostak, JW, "Efficient and Rapid Template-Directed Nucleic Acid Copying using 2′-amino-2′, 3′-dideoxyribonucleoside-5′-phosphorimidazolide Monomers, " Journal of the American Chemical Society, 131, 40, 14560-70 (2009)
2. Ferreira AM, Krishnamurthy M, Moore BM II, Finkelstein D, and Bashford D, "Quantitative structure-activity relationship (QSAR) for a series of novel cannabinoid derivatives using descriptors derived from semi-empirical quantum-chemical calculations, " Bioorganic & Medicinal Chemistry, 17, 2598-2606 (2009)
3. Mansy SS, Schrum JP, Krishnamurthy M, Tobé S, Treco DA, and Szostak JW, " Template-directed synthesis of a genetic polymer in a model protocell, " Nature, 454, 122-125 (2008)
4. Krishnamurthy M, Gurley S, and Moore BM II, "Exploring the substituent effects on a novel series of C1'-dimethyl-aryl Δ^8-tetrahydrocannabinol analogs, " Bioorganic & Medicinal Chemistry, 16, 6489-6500 (2008)
5. Duntsch C, Divi MK, Jones T, Zhou Q, Krishnamurthy M, Boehm P, Wood G, Sills A, and Moore BM II, "Safety and efficacy of a novel cannabinoid chemotherapeutic, KM-233, for the treatment of high-grade glioma," Journal of Neuro-Oncology, 77, 2,143-152 (2006)
6. Ferreira AM, Moore BM II, and Krishnamurthy M, "Theoretical analysis of the NMR and electronic

structure of novel Δ^8-THC derivatives," Journal of Molecular Structure THEOCHEM, 674, 131-138 (2004)

7. Krishnamurthy M, Li W, and Moore BM II, "Synthesis, biological evaluation, and structural studies on N1 and C5 substituted cycloalkyl analogues of the pyrazole class of CB1 and CB2 ligands," Bioorganic & Medicinal Chemistry, 12, 393-404 (2004)
8. Krishnamurthy M, Ferreira AM, and Moore BM II, "Synthesis and Testing of Novel Phenyl Substituted Side-Chain Analogues of Classical Cannabinoids," Bioorganic & Medicinal Chemistry Letters, 13, 3487-3490 (2003)
9. Nadipuram AK, Krishnamurthy M, Ferreira AM, Li W, and Moore BM II, "Synthesis and Testing of Novel Classical Cannabinoids: Exploring the Side Chain Ligand Binding Pocket of the CB1 and CB2 Receptors," Bioorganic & Medicinal Chemistry, 11, 3121- 3132 (2003)

Presentations

1. Krishnamurthy M, Ferreira AM, and Moore BM II, "Probing the Ligand-Binding Pocket of the Cannabinoid Receptors: Synthesis and Testing of Novel Phenyl Substituted Side Chain Analogs of Δ^8-THC," 228th ACS National Meeting, Philadelphia, Pennsylvania, 2004
2. Divi MK, Nallamothu R, Krishnamurthy M, Nazarova MA, Wood GC, Thoma LA, Moore BM II, and Duntsch C, "Development and Evaluation of Parenteral Formulations for a New Chemical Entity," Pharm Forum, University of Tennessee Health Science Center, Memphis, Tennessee, 2004
3. Krishnamurthy M, and Moore BM II, "Novel Pyrazole Cannabinoid Antagonists," 29th Annual MALTO Medicinal Chemistry-Pharmacognosy Meeting, Monroe, Louisiana, 2002 4. Krishnamurthy M, "From pot to pill", American Chemical Society Central MA section meeting, Fitchburg, MA, 2013
5. Krishnamurthy M, Moore BM II, "Finding new cures for cancer- design, synthesis and biological testing of D8-THC analogs, FSU Science Colloquium, Fitchburg, MA, 2014 6. Krishnamurthy M, "What's in your spice- GC-MS analysis of essential oils", 75th NEACT Summer Conference, Fitchburg, MA, 2014
7. Krishnamurthy M, "Colorful chemistry with glucose oxidation", 76th NEACT Summer Conference, Clark University, Worcester, MA, 2015
8. Krishnamurthy M "Improving student retention through active learning", 24th Biennial Conference on Chemical Education, University of Northern Colorado, Greeley, CO, 2016 9. Krishnamurthy M " Marijuana: The Wonder Drug" 77th NEACT Summer Conference, Massachusetts College of Liberal Arts, North Adams, MA, 2016

Patents

1. Moore BM II, Ferreira AM, and Krishnamurthy M, "Cannabinoid Derivatives, Methods of Making and Use thereof", U.S. Patent No. 7169942, Issue date: Jan 30, 2007

Professional affiliations

1. Member, American Chemical Society
2. Member, Rho Chi Pharmacy Honor Society, Alpha Nu Chapter
3. Coordinator for the Central MA ACS section, Chemists Celebrate Earth Day 4. Coordinator for the Central MA ACS section, National Chemistry Week 5. Coordinator for the Central MA ACS section, Chemistry Olympiad

Grants and Fellowships

1. The Discovery Museum / National Science Foundation Science Communication Fellowship (2013)
2. Special Project grant in the area of faculty scholarship from Fitchburg State University (July

2013-June 2014)

3. Innovation in Teaching grant from the Center for Teaching and Learning at Fitchburg State University (2013-2014)
4. ACS Science Coach program in partnership with McKay Arts Academy (Oct 2014-June 2015)
5. ACS Science Coach program in partnership wtih McKAy Arts Academy (Oct 2015-June 2016)
6. ACS Science Coach program in partnership with McKay Arts Academy (Oct 2017-June 2018)

Awards

1. ACS Outreach Volunteer of the Year 2015

Aisling M. O'Connor,
31 Misty Lane,
Westford,
MA 01886.
Tel. (978) 902 4471
Email: aisling_oconnor@hotmail.com

1. E DUCATION

2005-2007 <u>Postgraduate Studies</u> - University of Massachusetts, Lowell, MA
Graduate Certificate in Foundations of Business (2007).

1994-1998 <u>Postgraduate Studies</u> - University of Limerick, Ireland Ph.D. Degree (1998), by research and thesis. Title of research project: Carbon Dioxide Reforming of Methane over Pt/ZrO_2 Catalysts.

1990-1994 <u>Undergraduate Studies</u> - University of Limerick, Ireland Bachelor of Science in Industrial Chemistry (1994). Awarded a second class honors, grade one degree.

2. P ROFESSIONAL E XPERIENCE

September 2008-Present <u>Assistant / Associate Professor</u> – Fitchburg State College, Fitchburg, MA
I am currently an assistant professor of chemistry. I teach lecture and lab courses in General Analytical Chemistry, General Chemistry I and General Chemistry II. I also teach a Forensic Chemistry course which does not have a lab component and Chemistry Seminar which is a class for senior level capstone course. In addition to teaching, duties include student advising, service to my department (Biology and Chemistry) and the wider college community and continuing scholarship. Currently, I am actively involved in a multi-disciplinary research project assessing the health of the Nashua River.

February 2008-July 2008 <u>Technical Support Manager</u> – Lowell Centre for Sustainable Production, University of Massachusetts, Lowell, MA In this position, I worked with industry, academics and NGOs promoting sustainable practices including using safer alternatives in products and green chemistry. During my short term in this position, I contributed to projects with industry partners, Interface Fabrics and United Technologies and organized the 3rd Green Chemistry and Commerce Council Roundtable held at the Nike Campus, Beaverton, OR in July 2008.
July 2006-December 2007 <u>Sr. Applications Chemist</u> – Waters Corporation, Milford, MA
I was a member of a team of applications chemists providing support to the environmental, food safety, food and beverage industries. Duties include the research, identification and development of

applications on Waters HPLC, UPLC, single and tandem quad MS instrumentation, collaboration with customers (industry & government) support of customers, sales staff, and field service/applications staff. Other responsibilities include sample analysis and presentation of applications, methods and Waters technologies at seminars and conferences.

March 2002-June 2006 Sr. Development Engineer – Waters Corporation
I was employed in the Development Evaluation Laboratory at Waters Corporation. My job involved the evaluation of Waters instruments and software during development and prior to customer release. I have worked on the development of the following products:
HPLC autosamplers and pumps, UV detectors, evaporative light scattering detector, electrochemical detector, UPLC system, single quad mass detector and triple quad mass detector. I served as evaluation project manger for various products including UPLC control software, an electrochemical detector and single quad mass spectrometer.

March 2000-March 2002 Evaluation Scientist – Waters Technolog ies Ireland, Wexford, Ireland
I worked in the Development Evaluation Laboratory at Waters (Ireland). Projects worked on include the evaluation of instrument control software products and the development of qualification workbooks for LC/MS systems. In addition, I was
involved in new instrument testing at the New Product Introduction Department (Waters, Milford, MA) and LC Grants (Scotland), installing and qualifying LC/MS equipment, instrument troubleshooting and maintenance.

March–Oct. 1999 Technical Officer - Environmental Protection Authority, NSW, Australia
I was employed in the Organic Chemistry Section of the NSW EPA's Analytical Chemistry Laboratory. The position involved the extraction and analysis of organic compounds such as pesticides, herbicides, phenols, PAHs, VOCs and chlorphylls in various sample matrices (soil, water, biota and air) as well as oil fingerprinting. Analysis was performed by GC, GC-MS and HPLC. Other responsibilities included liaison and support of EPA Environmental Inspectors, method development, instrument maintenance, troubleshooting and calibration, LIMS and database operation, internal auditing of standard methods and writing/updating of standard method manuals.
June–Dec. 1998 Laboratory Analyst/Project Administrator - BHP Laboratories, Limerick, Ireland
In this position, I had the dual role of Laboratory Analyst and Project Administrator for a large project involving the sampling and analysis of soil, water and air samples from contaminated sites. Laboratory Analyst duties included method development and analysis of samples by HPLC, GC, GC-MS, ICP and AAS for compounds such as PAHs, phenols, VOCs, sulphur and metals. Project Administrator duties involved LIMS management, staff training, writing SOPs, audit preparation, quality control, customer liaison, subcontracting and report issuing.

Oct. 1994–June 1998 Laboratory Demonstrator/Ph.D. Candidate - University of Limerick, Limerick, Ireland

Laboratory demonstrator duties included the supervision and demonstration of undergraduate laboratory sessions. The position involved teaching 3 laboratory sessions (9 contact hours) each week during the academic year. I supervised general, organic, physical, and analytical chemistry and chemical engineering laboratories. Demonstrations included the use of instrumentation such as GC, HPLC, XRD, FTIR and UV. I was also responsible for the supervision of three final year project students during the academic years 95/96, 96/97 and 97/98.

The primary task of my research was the investigation of Pt/ZrO_2 catalysts for the conversion of natural gas to synthesis gas using CO_2 as an oxidant. Various supported catalysts were made and tested for activity and stability using a test rig with on line GC analysis. Characterization of these catalysts was carried out by XRD, AAS, H_2 chemisorption, BET surface area and pore size distribution measurements. In-situ Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS) experiments and Temporal Analysis of Products (TAP) investigations were carried out to elucidate the reaction mechanism over the Pt/ZrO_2 catalyst.

This project was funded by Kinetic Technology International (KTI), Zoetermeer, The Netherlands and the European Commission under the JOULE II Programme (*Conversion of Natural Gas to Synthesis Gas and C_2+ Hydrocarbons*). The project involved collaboration with KTI on an ongoing basis, with a view to industrializing the process. There were also six monthly reports and meetings with the other EU partners. During the course of my research I attended three meetings with project partners in Norway, France and Greece, carried out experimental work at University of Patras, Greece and Institut de Recherches sur la Catalyse, Villeurbanne, France and participated in four international conferences on catalysis giving both oral and poster presentations.

March – Nov. 1992 Intern - Asahi Chemical Co., Nobeoka, Japan This position, based in the Rayon Plant, involved the establishment of an automatic titration system for the total alkali and sulfur contents in viscose mixtures. The automatic titration system consisted of a sequenced controlled robotic arm and an automatic titration unit.

3. AWARDS

- Received a MSCA Professional Development Funding Grant ($720) from Fitchburg State University (2020) to partly fund travel to the 26th Biennial Conference on Chemical Education
- Awarded a Special Projects Grant ($1,200) from Fitchburg State University (2016) to fund research equipment for the health of the Nashua River project.
- Granted a Special Projects Grant ($700) from Fitchburg State University (2013) to fund travel to the ChemEd 2013 Conference at University of Waterloo, Canada.
- Selected to receive a 2012 AAUW (American Association of University Women) Community Action Grant ($10,000). This grant was awarded to fund the expansion of Science Club for Girls in the Fitchburg / Leominster area.
- Awarded two Special Projects Grants from Fitchburg State University (2012). The first grant ($1,000) was in support of a project which involved compiling, documenting and photographing a collection of instrument components to be used for teaching analytical chemistry. The other grant ($700) was awarded to fund travel to the Biennial Conference on

Chemical Education 2012, State College, PA to present the work funded by the first project.

- Received a Special Projects Grant from Fitchburg State University (2011) which helped to support an elementary school outreach project and two after school Science Clubs for Girls sites ($1,000).
- Received a Ruth Butler Grant from Fitchburg State University (2010) which allowed me to present and get feedback on my work in service learning at Biennial Conference on Chemical Education 2010, Denton, TX ($825).
- Received a Crocker Center for Civic Engagement Faculty Award from Fitchburg State University (2009) in support of an elementary school chemistry outreach project ($500).
- Obtained five awards for extraordinary effort from Waters Corporation (2001, 2002 and 2004).
- Received a Basic Research Award from Forbairt, The Irish Research Council (1994- 1997) and a University of Limerick Scholarship (1994-1998) to pursue postgraduate studies.
- Named on the UL president's list for academic excellence during the first (1993) and second (1994) terms in the fourth year of my degree programme.
- Awarded a place on the Asahi Scholarship and Study Programme (1992), which enabled me to spend 9 months working in a Japanese company.

4. PUBLICATIONS AND PRESENTATIONS

- Oral presentation given at **ChemEd 2013, Waterloo, Ontario, Canada,** July 28 – Aug. 1, 2013. "Lab activities for high school chemistry using the Vernier SpectroVis Plus Spectrophotometer".
- Oral presentations given at the **Biennial Conference on Chemical Education 2012 (BCCE), State College, PA**, July 29 – August 2, 2012. "How Surfactants Work" and "Trash to Treasure: Using Instrument Components to Teach Instrumental Analysis"
- Oral presentation given at **ChemEd 2011, Kalamazoo, MI,** July 24 – 28, 2011. "A Green Chemistry Curriculum for Science Club for Girls".
- Oral presentation given at the **Biennial Conference on Chemical Education 2010 (BCCE), Denton, TX**, August 1 – 5, 2010. "Service Learning in Chemistry for Non Majors".
- Oral presentation given at **The National Environmental Monitoring Conference (NEMC), Cambridge, MA**, August 19 -25, 2007. "Analysis of Perfluorinated Compounds by UPLC/MS/MS: Contamination Reduction Strategies".

- Poster presentation given at **The Florida Pesticide Residue Workshop, St. Pete Beach, FL**, July 22 - 25, 2007. "Analysis of Nerve Agent Degradation Products by UPLC/MS/MS".
- Oral presentation given at **The Pittsburg Conference on Analytical Chemistry and Applied Spectroscopy (Pittcon) Chicago, IL**, February 25 – March 2, 2007. "Sample Screening Using LC/MS and LC/MS/MS Libraries".
- Oral presentation given at **The National Environmental Monitoring Conference (NEMC), Arlington, VA**, August 28 -31, 2006. "Enhancement of EPA Method 535: Resolving Alachlor and Acetochlor ESA Metabolites".
- A.M. O'Connor, Y. Schuurman, J.R.H. Ross, and C Mirodatos, Transient Studies of Carbon Dioxide Reforming of Methane over Pt/ZrO_2 and Pt/Al_2O_3 Catalysts, **Catalysis Today**, 115 (1), p.191-198, Jun 2006
- Poster presentation given at **The Society of Forensic Toxocology (SOFT) Annual Meeting** in New Orleans, 2001. "Determination of Gamma-Hydroxybutrate (GHB) and Related Compounds in Forensic Samples by LC/MS".
- J.R.H. Ross, A.H.J.van Keulen, A.M. O'Connor, et al., Effect of the method preparation and pretreatment on the dispersion and catalytic behavior of finely divided Pt or Ni particles supported on zirconia for the dry reforming of methane, **Abstracts of Papers of the American Chemical Society** 219: 68-Petr Part 2, Mar 26, 2000.
- A.M. O'Connor and J.R.H. Ross, The Effect of O_2 Addition on the Carbon Dioxide Reforming of Methane over Pt/ZrO_2 Catalysts, **Catalysis Today** 46 2-3 (1998) 203- 210**.**
- M.E.S. Hegarty, A.M. O'Connor and J.R.H. Ross, Syngas Production from Natural Gas using

Zirconia supported Metals, **Catalysis Today** 42 3 (1998) 225-232. A.M. O'Connor, F.C. Meunier , and J.H.R. Ross, An in-situ DRIFTS study of the mechanism of the CO_2 reforming of CH_4 over a Pt/ZrO_2 catalyst, **Studies in Surface Science and Catalysis** 119 (1998) 819-824.

- J.R.H. Ross , A.M. O'Connor, Hegarty MES, Syngas production from natural gas using CO_2-reforming or CO_2 reforming combined with steam reforming or partial oxidation over a Pt/ZrO_2 catalyst, **Abstracts of Papers of the American Chemical Society** 215: 216-Coll. Part 1 April 2 1998.
- Oral presentation given at **The 3rd Workshop, C_1-C_3 Hydrocarbon Conversion, Krasnoyarsk, Russia**, July 14 -17, 1997. "Syngas Production from Natural Gas using Zirconia supported Metals".
- Poster presentation given at **The RSC 3rd International Symposium on Supported Reagents and Catalysis in Chemistry, University of Limerick, Ireland** July 8 - 11, 1997. "The Conversion of Natural Gas by Oxygen and / or Carbon Dioxide over Pt based Catalysts".

- Oral presentation given at **The 5th European Workshop on Methane Activation, University of Limerick, Ireland**, 8 - 10 June, 1997. "The Effect of O_2 Addition on the Carbon Dioxide Reforming of Methane over Pt/ZrO_2 Catalysts".
- Poster presentation given at **The 1st H.S. Taylor Conference, Nottingham Trent University, UK**, 1 - 4 September, 1996. "The Conversion of Natural Gas by Oxygen and / or Carbon Dioxide over Pt based Catalysts".
- Oral presentation given at **The 5th Meeting on the Conversion of Natural Gas to Synthesis Gas, C_2+ Hydrocarbons and Alternative Fuels (EU JOULE 2 Programme), Villeurbanne, France**, 21 - 23 October, 1995. "The Effect of Al_2O_3 Addition on Pt/ZrO_2 Catalysts for Methane Reforming by CO_2".

Billy Samulak

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EDUCATION:

Ph.D., Chemistry, University of Michigan, May 2013
Mentors: Philip C. Andrews, Janine R. Maddock, Hollis Showalter

M.S., Secondary Science Education, University of Michigan, December 2012

Preparing Future Faculty Seminar Participant: 2011

M.S., Chemistry, University of Michigan, 2009

B.S., Chemistry, University of Michigan – Flint, 2007

EXPERIENCE:

Fitchburg State University, Department of Biology and Chemistry
Assistant Professor, September 2014-Present

Lectured, wrote exams and quizzes, designed laboratory activities, graded assignments for both small classes and large lectures (<80 students)

Courses taught: Chemistry for Health Sciences (1 semester general, organic, biochemistry class for nursing students), Biochemistry I, Organic Chemistry labs, Food Chemistry, Proteomics, Chemistry Senior Seminar, First Year Experience

Designed independent, internally-funded research projects, mentored student nine research assistants, published papers, wrote peer-reviewed textbook materials, presented at conferences

Participated in university wide and departmental committees, see service below.

Advised 12-20 students per semester on careers and classes in biology, chemistry, premajors, IDIS majors, incoming freshmen, wrote letters of recommendation.

Massachusetts College of Pharmacy, New England School of Acupuncture
Adjunct Lecturer, September 2019-December 2019

Lectured, wrote exams and quizzes, designed hands-on activities, graded assignments for a chemistry class for acupuncture students

University of Michigan, Chemistry
Post-doctoral Research Fellow, 2013-August 2014

Performed externally funded research activities, mentored graduate and undergraduates students, wrote papers for peer-reviewed journals, attended national conferences

University of Michigan, Center for Research on Learning and Teaching
Practice Teaching Facilitator, 2011-Present
Gave seminars in teaching techniques for new graduate student instructors, facilitated practice teaching sessions, offered suggestions for teaching improvement, provided instruction in incorporating active learning technologies into the classroom

University of Michigan
Graduate Student Instructor, 2007-2010
Designed lesson plans, brief lectures, assignments, and quizzes; demonstrated laboratory techniques; edited, proctored, and graded exams; graded laboratory reports and assignments.

University of Michigan
Tutor, 2004, 2007-present
Taught multiple students math and chemistry both for classes and pre-professional exams, including students with minor learning disabilities

University of Michigan – Flint
Supplemental Instructor, 2006-2007
Prepared lesson plans, taught chemistry for nursing students, and graded assignments and papers

University of Michigan - Flint
Laboratory Assistant, 2004 - 2007
Assisted and supervised students with laboratory work, graded laboratory notebooks, and mentored independent study students

INTERNSHIPS:

National Institutes of Health, Bethesda, Maryland
May 1, 2006 – August 25, 2006
Advisor: Dr. Sonja Hess of The Proteomics and Mass Spectrometry Laboratory at The National Institute of Diabetes, Digestive and Kidney Diseases
Project: Analysis of glycated hemoglobin chains using HPLC and mass spectrometry
Result: Presented a poster at the Undergraduate Poster Session at NIH on August 3, 2006

National Institutes of Health, Bethesda, Maryland
May 15, 2005 – August 25, 2005
Advisor: Dr. Sonja Hess of The Proteomics and Mass Spectrometry Laboratory at The National Institute of Diabetes, Digestive and Kidney Diseases
Project: Analysis of the human proteome using free flow electrophoresis and mass spectrometry
Result: Presented a poster at the Undergraduate Poster Session at NIH on August 4, 2005

PEER-REVIEWED PUBLICATIONS:

- B. Samulak. The Status of GOB chemistry courses in the United States. 2021
  Manuscript in progress.

- B. Samulak. Case studies provided as an accompaniment to the textbook, Essentials of General, Organic, and Biochemistry by Denise Guinn, 3rd edition. Published in 2018.
  A Patient Case Study: Diagnosing Blood pH Imbalance.

Case Study: Insulin – Protein Structure and Function
Ketamine: The Importance of a Correct Dose.

- B. Samulak. Ten tutorials provided as an accompaniment to the textbook, Essentials of General, Organic, and Biochemistry by Denise Guinn, 3rd edition. Published in 2018.

- B.M. Samulak, S. Niu, P.C. Andrews, B.T. Ruotolo. Ion Mobility-Mass Spectrometry Analysis of Cross-Linked Intact Multiprotein Complexes: Enhanced Gas-phase Stabilities and Altered Dissociation Pathways. *Anal. Chem.* 2016, *88*, 5290-5298.

- B. Clifford-Nunn, H.D.H. Showalter, P.C. Andrews. Quaternary Diamines as Mass Spectrometry Cleavable Crosslinkers for Protein Interactions. *JASMS* 2012, *23,* 201-212.

PATENTS:

- B. Clifford-Nunn, H.D.H. Showalter, P.C. Andrews. Novel Class of Chemical Crosslinkers for High-Throughput Protein Complex Analysis

PRESENTATIONS & ABSTRACTS:

- B. Samulak. A Comparison of Crosslinker Length on Crosslinked Peptide Identification. In Advancing Mass Spectrometry for Biophysics and Structural Biology, July 2019, Amherst, MA.

- B. Samulak. Quantification of Differentially Crosslinked Proteins and Peptides. In American Society for Mass Spectrometry, June 2019, Atlanta, GA.

- B. Samulak. Supporting Students with Multiple Gap Years in Accelerated Chemistry Courses. In 2019 Massachusetts PKAL Network Winter Meeting, January 2019, Norton, MA.

- B. Samulak. Enzymatic Analysis of Crosslinked Protein Complexes. In Central Massachusetts Section - American Chemical Society, October, 2015, Worcester, MA.

- B. Samulak, P.C. Andrews, B.T. Ruotolo. Structural Analysis of Protein Complexes Using Integrated Crosslinking and Ion Mobility-Mass Spectrometry. In American Society for Mass Spectrometry, June 2014, Baltimore, MD.

- B. Clifford-Nunn, L. Han, Y. Zhong, P. Andrews, B. Ruotolo. Combined Crosslinking and Ion Mobility-Mass Spectrometry for Structural Analysis of Protein Complexes. In American Society for Mass Spectrometry, June 2013, St. Paul, MN.

- B. Clifford-Nunn, J. Maddock, P. Andrews. Crosslinking RNA and DNA with DC4: Reactivity of NHS Esters. In American Society for Mass Spectrometry, May 20-24, 2012, Vancouver, BC, Canada.

- B. Clifford-Nunn, J. Maddock, P. Andrews. Interaction Analysis of Ribosomal Particles Using the Mass Spectrometry Cleavable Crosslinker DC4. In Vaughan Symposium, July 28, 2011, University of Michigan, Ann Arbor, MI.

- B. Clifford-Nunn, J. Maddock, P. Andrews. Interaction Analysis of Ribosomal Particles Using the Mass Spectrometry Cleavable Crosslinker DC4. In American Society for Mass Spectrometry, June 5-9, 2011, Denver, CO.

- B. Clifford-Nunn, H. K. Kweon, P. C. Andrews. Crosslinking Reagents and Tags with Intrinsic Positive Charges for Protein Interactions. In Michigan Mass Spectrometry Discussion Group, 11 December 2010, Ann Arbor, MI

- B. Clifford-Nunn, J.R. Maddock, H.D.H Showalter, P. C. Andrews. A New Category of Protein Crosslinkers for Protein Complexes. In American Society for Mass Spectrometry, May 23-27, 2010, Protein Conformations and Chemical Crosslinking - 077, May 2009, Salt Lake City, UT.

- B. Clifford-Nunn, E. Simon, P. C. Andrews. MS Cleavable Crosslinker for Protein Interactions. In American Society for Mass Spectrometry, 2009, Protein Conformations II, 431, May 31- June 4, 2009, Philadelphia, PA.

FACULTY LED STUDENT PROJECTS:

- Alex Serino, Summer 2015 worked with me on the Functional Enzymatic Analysis of Crosslinked Aldolase

- Barry Bouchard, Summer 2015 worked with me on the Functional Enzymatic Analysis of Crosslinked Aldolase

- Duluc Huynh, Fall 2016 worked with me on the Functional Enzymatic Analysis of Crosslinked Aldolase. He presented at a department poster session with biology and chemistry students.

- Timothy Brinkman, Fall 2016 worked with me on the Functional Enzymatic Analysis of Crosslinked Aldolase. He presented at a department poster session with biology and chemistry students, December 2016.

- Timothy Brinkman, Spring 2017 worked with me on SDS-PAGE Analysis of Crosslinked Proteins. He presented at the FSU Undergraduate Conference for Research and Creative Practice, April 2017.

- Mike McGrath, Spring 2017 worked with me on Functional Enzymatic Analysis of Crosslinked Aldolase.

- Melanie Bauer, Spring 2017 worked with me on Designing Experiments for McKay Arts Academy Students.

- Blake Phinney, Spring 2017 worked with me on Mass Spectrometry Quantification of Crosslinked Proteins. He presented at the Fitchburg State University Undergraduate Conference for Research and Creative Practice, April 2017.

- Yelitza Rosario, Fall 2017 worked with me on Mass Spectrometry Quantification of Crosslinked Proteins

- Justin Girard, Spring 2019 worked with me on Mass Spectrometry Quantification of Crosslinked Proteins

INTERNAL FUNDING:

- 2017, Fitchburg State University Special Projects Grant, $2163

- 2014-2019, Fitchburg State University Continuing Scholarship funds

- 2015, Special Projects Grant, $1500

INSTRUMENTATION:

- Mass Spectrometry: ABI 4800 TOF-TOF, Thermo Scientific LTQ Orbitrap, Bruker TOF-TOF, Waters Synapt
- HPLC: Agilent with capillary pump, nanoLC
- Nuclear Magnetic Resonance Spectroscopy: Varian, Bruker
- Cary UV-Vis spectrophotometer
- FT-IR spectrophotometry
- Fluorometry

SERVICE:

Departmental Service

- Inorganic Chemist Search Committee, AY2014-2015
- 1 Year Temporary Biologist Search Committee, AY2014-2015
- Departmental Curriculum Committee, AY2015-2016, 2018-2020
- Wrote 5 AUC proposals for a new concentration, “Biochemistry” within the Chemistry major, including the new classes required for the concentration, AY2018-2019
- Biology and Chemistry Club Advisor, AY2014-2021

- Planned several departmental events 2014-2018
- Planned and hosted a telecast from ACS on Red Planet Chemistry, 2018
- Organized, advertised, and planned the Annual Science Symposium, 2014-2019

Divisional Service

- Coauthored a new concentration in General Science for IDIS Majors and presented the proposals through AUC – 2016-2018
- Biosafety plan and biosafety writing committee – AY2015-2016
- STEM Working group committee member, 2015-2016
- Guided Pathways to Success Committee Member – 2015-2017
- Coauthored a grant on inclusive excellence, 2020

University-Wide Service

- Academic Policies Committee Member AY2014-2020. Secretary in 2014-2015 and 2016-2017, Vice Chair in 2018-2019.
- Partnered with alumni office to plain an alumni dinner, 2018-2019
- Coordinator for middle school general science and high school chemistry education programs 2019-present.

Service to the Community

- Planned four visits each, with three third grade classrooms at McKay Arts Academy where I did science experiments with the students. Then the students came back to FSU to get a tour of the science building and do experiments here. This was done in 2015, 2016, 2017. In 2018, I had the students visit campus only.
- Planned a tour for FSU for a local area daycare, 2018.

AWARDS:

- Fitchburg State University Advisor of the Year, 2016-2017
- Fitchburg State University Biology and Chemistry Club Co-Advisor of the Year 2014-2015 • Vaughan Symposium Poster Session Travel Award – 2011
- Rackham Travel Grants – 2009, 2010, 2011, 2012
- Maize & Blue Award – 2007
- Outstanding Graduating Chemistry Senior Award – 2007
- Freeman Chemistry Scholarship – 2006
- Freeman Honors Scholarship – 2006
- Honors Service Award

• McKinnon Scholarship – 2004, 2005, 2006

• Cyrus Farrahi Scholarship – 2004

• Outstanding Freshman Chemistry Student Award – 2004

• Michigan Scholar Award – 2003
    -Full Tuition and Fees to the University of Michigan – Flint

• Honors Program Scholarship

AFFILIATIONS:

• New England Association of Chemistry Teachers, 2016-Present • American Chemical Society, 2004, 2007, 2014-2019

• American Society for Mass Spectrometry, 2008-2014, 2019-2020 •

University of Michigan – Flint Chemistry Club, 2003 – 2007 • Honors Student Council, 2003 – 2007

17. Appendix Q: Embedded Tutors (Supplemental Instruction) Proposal

Supplemental Instruction Proposal
Peer-Led Weekly Review Sessions for At-Risk Students in Introductory Chemistry Courses

The General and Organic Chemistry course sequences often pose an academic hurdle for Fitchburg State students, particularly students that are underrepresented in STEM disciplines. Instructors of these classes have worked with the Tutor Center for a number of years in order to provide such students additional opportunities for instruction outside of the regular classroom. The gains from this supplemental instruction cannot be understated: It is clear that the students who regularly attend tutoring sessions are more proficient, confident, and less frustrated with the course material than their counterparts.

Over the last two academic years, members of the Chemistry faculty have engaged in a pilot study by offering additional supplemental instruction in the form of weekly review sessions. While it was known that conventional exam review sessions could provide students with a last-minute opportunity for instruction, it was found that weekly review sessions regularly offered throughout the duration of the semester, allowed students to work through often challenging material at a more measured pace and improved knowledge retention. Surprisingly, the weekly student attendance nearly matched that of the exam reviews, with approximately 20% of the class adding this review to their schedule despite work and student activity related conflicts.

In informal discussion, we discovered that the individual Chemistry instructors independently followed a remarkably similar progression by developing a series of activities and worksheets to provide structure to these review sessions. Students cite help with this supplemental material as one of their motivating forces to attend the sessions. To maintain and extend these efforts, the Chemistry faculty are seeking funding assistance for experienced students to serve in the role of an embedded tutor, by which these "peer-led" instructors would be provided the necessary resources to effectively instruct these review sessions. Such "peer-led" instructors would be encouraged to attend the course (with appropriate compensation) and would work closely with their faculty course-advisor to instruct to best assist students at their review session with the activities and worksheets developed by the faculty in the pilot study.

For the Spring 2017 semester, the Chemistry faculty are formally requesting funding for six peer-led tutors for the below courses. The number of lecture sections and corresponding tutors are indicted parenthetically.

- General Chemistry I (1)
- General Chemistry II (2)
- Organic Chemistry II (2)
- Biochemistry (1)

Proposal Sponsors:

- Dennis Awasabisah
- Emma Downs
- Steven Fiedler
- Meledath Govindan
- Mathangi Krishnamurthy
- Aisling O'Connor
- Billy Samulak

18. Appendix R: Student Handbook

Biology and Chemistry Department

http://www.fitchburgstate.edu/academics/academic-departments/biology-chemistry/

Undergraduate Student Handbook

Last updated: August 2021

19. Appendix S: General Education Curriculum Guidance Documents and Course Learning Objectives

Procedural and Logical Thinking

Definition
Procedural and Logical Thinking is the process of designing, evaluating and/or implementing a logical, sequential strategy to answer an open-ended question or achieve a desired goal (modified from the AAC&U Problem Solving rubric).

Rationale and Intent
Courses addressing problem solving within the LAS curriculum teach a variety of interrelated but distinct skills, including quantitative reasoning, scientific inquiry and analysis, and constructing and analyzing logical arguments to generate a solution; we identify this latter skill as Procedural and Logical Thinking. A subset of Procedural and Logical Thinking is computational thinking. Decomposing problems or tasks into smaller parts, pattern recognition, modeling, and developing sequential steps for solving a problem or answering a question can constitute computational thinking, according to the International Society for Technology in Education (ISTE) and Computer Science Teachers Association (CSTA). While computational thinking is essential to the development of computer applications, it can also be used to support problem solving across all disciplines, including the humanities, mathematics, and science. Disciplines including, but not limited to, computer science, engineering, logic, mathematics, and the natural, physical, and behavioral sciences, all include coursework that focuses on preparing students to better engage in Procedural and Logical Thinking.

Goal
Fitchburg State University students will use a rational, systematic procedure to arrive at conclusions, examine or build underlying patterns and structures, or deduce further information.

Potential Course Objectives
The objectives below are recommended as models for general education course syllabi. The list is not meant to be complete. Faculty should feel free to adopt these as course objectives, or they may develop their own.

- Predict and explain the outcomes of a sequence of instructions
- Create and modify a sequence of instructions that provide a solution to a given task
- Develop and follow strategies to minimize committing common fallacies in thinking that impair accurate conclusions and predictions (e.g., confirmation bias, post hoc explanations, implying causation from correlation)
- Break down a complex task into small, meaningful parts
- Combine a sequence of instructions to follow a pattern
- Recognize and find patterns or trends
- Generalize and transfer a problem-solving process to a wide variety of tasks
- Ignore detail that is not of interest, simplifying a complex task
- Represent data through abstractions such as models and simulations

- Analyze a procedural solution to a task and formulate a more efficient process
- Identify and correct errors in a sequence of instructions to analyze a solution and formulate a more efficient solution
- Apply existing data analysis tools to extract information

Scientific Inquiry and Analysis
Definition
"Inquiry" is a systematic process of exploring issues, objects or works through the collection and analysis of evidence that results in informed conclusions or judgments. "Analysis" is the process of breaking complex topics or issues into parts to gain a better understanding of them (AAC&U Inquiry and Analysis VALUE rubric). Scientific Inquiry and Analysis focuses specifically on evidence related to questions about the natural and physical world through an analytical process that involves systematic observation, data collection and interpretation (the scientific method). This process requires a unique set of skills that set it apart from inquiry and analysis into other realms of human experience and endeavor.

Rationale and Intent
Many elements of modern society are built on hundreds of years of scientific advances that have transformed our world. The pace of change and discovery is only increasing and the students of today will face profound impacts from science and technology that are already underway. While it is impossible to prepare students for, or even to fully anticipate all the scientific impacts in the years ahead, it is critical to equip them with the skills to effectively evaluate scientific claims using evidence. The Fitchburg State University Scientific Inquiry and Analysis course requirement and learning outcome teaches students how to collect, analyze and interpret physical evidence, and how to determine whether that evidence can help answer questions about the natural or physical world.

Goal
Fitchburg State University students will engage with and answer questions about the natural, and physical world using scientific practices including collecting, analyzing and interpreting data.

Potential Course Objectives
The objectives below are recommended as models for general education course syllabi. The list is not meant to be complete. Faculty should feel free to adopt these as course objectives, or they may develop their own.
● Apply scientific reasoning to evaluate hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
● Construct an explanation based on valid and reliable scientific evidence obtained from a variety of sources, including students' own investigations, models, theories, simulations, or peer review.
● Conduct a scientific research project to answer a question or solve a problem, narrow or broaden the inquiry when appropriate, and synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

● Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
● Plan and conduct a scientific investigation individually or collaboratively to produce data that serve as the basis for evidence. In the design of the investigation, decide on types, quantity, and accuracy of data needed to produce reliable measurements, and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time); refine the design accordingly.
● Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
● Evaluate the scientific evidence behind currently accepted explanations or solutions to determine the merits of arguments.
● Apply concepts of statistics and probability to scientific and engineering questions and problems, using digital tools when feasible.
● Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.

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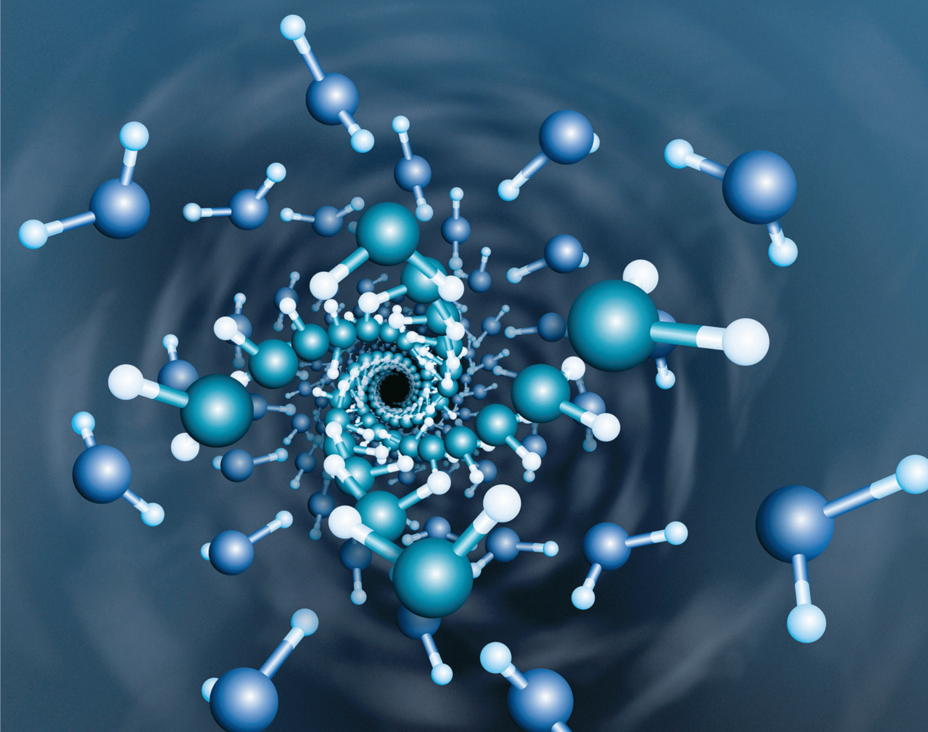
ACS Chemistry for Life®

Undergraduate Professional Education in Chemistry

ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs



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ACS recognizes that the chemistry program would make appropriate accommodations for students with temporary or permanent disabilities to allow them to complete degree and certification requirements.

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I. GUIDELINES FOR PROGRAM APPROVAL AND STUDENT CERTIFICATION

1. Goals of Program Approval and Student Certification

Chemistry is central to intellectual and technological advances in many areas of science. The traditional boundaries between chemistry subdisciplines are blurring, and chemistry increasingly overlaps with other sciences. Unchanged, however, is the molecular perspective that lies at the heart of chemistry. Chemistry programs have the responsibility to communicate this molecular view to their students and to teach the skills necessary for their students to apply this perspective.

The American Chemical Society (ACS) promotes excellence in chemistry education for undergraduate students through approval of baccalaureate chemistry programs. ACS has charged the Committee on Professional Training (CPT) with the development and administration of guidelines for this purpose. ***ACS, through CPT, approves chemistry programs*** meeting the ACS guidelines. Approved programs offer their students a broad-based and rigorous chemistry education that provides them with the intellectual, experimental, and communication skills necessary to become successful scientific professionals. Offering such a rigorous program requires an energetic and accomplished faculty, a modern and well-maintained infrastructure, and a coherent chemistry curriculum that develops content knowledge and broader skills through the utilization of effective pedagogical approaches. ACS recognizes that the diversity of institutions and students is a strength in higher education. Thus, these guidelines provide approved programs with opportunities to develop chemistry degree tracks that are appropriate to the educational missions of their institutions.

ACS authorizes the chair of the ACS-approved program to certify graduating students who complete a bachelor's degree meeting the ACS guidelines. Graduates who attain a certified degree must complete requirements that may in fact exceed those of the degree-granting institution, but this comprehensive undergraduate experience provides an excellent foundation for a career in the molecular sciences. An ACS-certified degree signifies that a student has completed an integrated, rigorous program including introductory and foundational course work in chemistry and in-depth course work in chemistry or chemistry-related fields. The certified degree also emphasizes laboratory experience and the development of professional skills needed to be an effective chemist. Certification gives a student an identity as a chemist and helps in the transition from undergraduate studies to professional studies or employment.

ACS approval publicly recognizes the excellent chemistry education opportunities provided by an institution to its students. It also provides standards for a chemistry curriculum based on broad community expectations that are useful for a program when designing its curriculum or acquiring resources. The approval process provides a mechanism for faculty to evaluate their programs, identify areas of strength and opportunities for change, and leverage support from their institutions and external agencies. Faculty benefit from the commitment to professional development required of approved programs. Students benefit from taking chemistry courses from a program that meets the high standards of ACS approval, and ACS-certified graduates benefit from their broad, rigorous education in chemistry and the recognition associated with their degree.

2. Institutional Environment

An approved chemistry program requires a substantial institutional commitment to an environment that supports long-term excellence. Because the approved program exists in the context of the institutional mission, it must support the needs, career goals, and interests of the institution's students. Competitive policies should be implemented regarding faculty salaries, duties, promotions, and tenure decisions. Similarly, in order to support a viable and sustainable chemistry program, the institutional environment must provide the attributes described in this section.

2.1 Institutional Accreditation. The institution must be accredited by the regional accrediting body. Such accreditation ensures broad institutional support in areas such as mathematics, related sciences, and the humanities.

2.2 Program Organization. The administration of the approved program should rest in a chemistry department organized as an independent unit with control over an adequate budget, faculty selection and promotion, curriculum development, and assignment of teaching responsibilities. If the program is

part of a larger unit, the chemistry faculty must have reasonable autonomy over these functions.

2.3 Program Budget. An approved chemistry program requires continuing and stable financial support. The institution must have the ability and will to make such a commitment at a reasonable level that is consistent with the resources of the institution and its educational mission. Adequate support enables a program to have

- a chemistry faculty with the scientific breadth to offer the educational experiences described in these guidelines,
- nonacademic staff and resources for administrative support services, stockroom administration, and instrument and equipment maintenance,
- a physical plant that meets modern safety standards with adequate waste-handling and disposal facilities,
- resources for capital equipment acquisition and replacement along with the expendable supplies required for high-quality laboratory instruction,
- modern chemical information resources,
- support for maintaining and updating instructional technology,
- research resources for faculty and students,
- personnel support to assist with the acquisition and administration of external funding,
- support for faculty and student travel to professional meetings, and
- opportunities for professional development and scholarly growth by the faculty, including sabbatical leaves.

2.4 Minimum Number of Graduates. Initial and continuing approval requires that the program award an average of at least two chemistry degrees per year during any six-year period. There is no required minimum number of certified graduates.

3. Faculty and Staff

Faculty members are responsible for defining and executing the overall goals of the undergraduate program. The faculty facilitates student learning of content knowledge and development of professional skills that constitute an undergraduate chemistry education. An energetic and accomplished faculty is essential to an excellent undergraduate program. An approved program therefore has mechanisms in place to maintain the professional competence of its faculty, provide faculty development and mentoring opportunities, and provide regular feedback regarding faculty performance.

3.1 Faculty. The faculty of an approved program should have a range of educational backgrounds and the expertise to provide a sustainable, robust, and engaging environment in which to educate students. In addition:

- There must be at least five full-time permanent faculty members wholly committed to the chemistry program. Most vigorous and sustainable approved programs have a larger number. Currently approved programs with fewer than five permanent faculty will have until 2025 to meet this requirement. In cases where faculty contracts are renewed on a regular basis, the individuals in these positions should hold the expectation for both long-term and full-time employment.
- At least 75% of the permanent chemistry faculty members must hold the Ph.D. or an equivalent research degree.

The collective expertise of the faculty should reflect the breadth of the major areas of modern chemistry. Because faculty members serve as important professional role models, an ACS-approved program should have a faculty that is diverse in gender, race, and ethnic background.

3.2 Adjunct, Temporary, and Part-Time Faculty. Courses leading to student certification in an approved program should be taught by permanent faculty. Programs may occasionally engage highly qualified individuals outside the regular faculty to deliver special courses or to replace permanent faculty members who are on sabbatical or other leaves of absence. The Committee strongly discourages excessive reliance on temporary or part-time faculty by an ACS-approved program and carefully reviews such situations.

3.3 Teaching Contact Hours. Contact hours are the actual time spent by faculty and instructional staff in the direct supervision of students in a classroom (face-to-face or online) or laboratory. Online activities that are developed as substitutes for classroom instruction should be assigned at least the same contact hour value as equivalent face-to-face classroom experiences. The institution's policies about teaching contact hours should provide all faculty and instructional staff adequate time for professional development, regular curriculum assessment and improvement, contact with

students outside of class, and when appropriate, supervision of research. For the purpose of these guidelines, the following two groups of faculty and instructional staff are identified, based on their teaching responsibilities:

Group A. For faculty and instructional staff who teach only in the classroom or in both the classroom and laboratory, the number of contact hours *must not exceed 15 total hours per week.* Fifteen contact hours is an upper limit, and a significantly smaller number should be the normal teaching obligation, particularly for faculty supervising undergraduate research.

Group B. For faculty and instructional staff who teach exclusively laboratory courses, the number of contact hours *must not exceed 16 total hours per week.*

In any given academic year, exceptions may be made for up to two individuals in Group A and two individuals in Group B above, provided that:

- The average for each individual in Group A does not exceed 15 contact hours per week during the academic year and the average for each individual in Group B does not exceed 16 contact hours per week.
- The maximum for each individual does not exceed 18 contact hours in any semester or quarter.
- The maximum contact hours for each individual are exceeded in only one quarter or semester of the academic year.

3.4 Professional Development. Institutional policies and practices should provide opportunity and resources for scholarly activities that allow faculty and instructional staff to stay current in both their research specialties and modern pedagogy in order to teach most effectively.

- The institution should provide opportunities for renewal and professional development through sabbaticals, participation in professional meetings, and other professional activities. Faculty and instructional staff should use these opportunities for improvement of instructional and research programs. Institutions should provide resources to ensure program continuity during sabbaticals and other leaves.
- Excellent programs provide formal mechanisms by which established faculty mentor junior colleagues. Proper mentoring integrates all members of the faculty and instructional staff into the culture of their particular academic unit, institution, and the chemistry profession, ensuring the stability and vitality of the program.

3.5 Support Staff. A sustainable and robust program requires an adequate number of administrative personnel, stockroom staff, and technical staff, such as instrument technicians, machinists, and chemical hygiene officers. The number of support staff should be sufficient to allow faculty members to devote their time and effort to academic responsibilities and scholarly activities.

3.6 Student Teaching Assistants. The participation of upper-class chemistry undergraduates and graduate students in the instructional program as teaching assistants both helps them reinforce their knowledge of chemistry and provides a greater level of educational support for students they supervise. If undergraduate or graduate students serve as teaching assistants, they must be properly trained and supervised.

4. Infrastructure

A modern and comprehensive infrastructure is essential to a vigorous undergraduate program. Program infrastructure must receive strong institutional support to provide sustainability through inevitable changes in faculty, leadership, and funding levels.

4.1 Physical Plant. An approved program should have classroom, teaching laboratory, research, office, and common space that is safe, modern, well-equipped, and properly maintained.

- Chemistry classrooms and faculty offices should be reasonably close to instructional and research laboratories. Classrooms should adhere to modern standards for lighting, ventilation, and comfort and have proper demonstration facilities, projection capabilities, and internet access.
- Laboratories for research and instruction in the chemical sciences must be suitable for their purpose and must meet applicable government regulations. Properly functioning and appropriate fume hoods, safety showers, eyewashes, first aid kits, and fire extinguishers must be readily available. Construction or renovation of laboratory facilities must conform to Occupational Safety and Health Administration (OSHA), national, and state regulations.
- The number of students supervised by a faculty member or by a teaching assistant in an instructional lab should not exceed 25. Many laboratories require smaller numbers for safe and effective instruction.
- Faculty and student research laboratories should have dedicated facilities appropriate for the type of work conducted in them. These facilities should permit experiments to be maintained for extended periods of time during ongoing research projects.
- The program should have access to support facilities such as machine, electronic, and glass fabrication shops to support both teaching and research.

4.2 Instrumentation. Characterization and analysis of chemical systems require an appropriate suite of modern, high quality, and properly maintained instrumentation and specialized laboratory equipment that are utilized in undergraduate instruction and research.

Approved programs must have a functioning NMR spectrometer on site that undergraduates use. The field strength and capabilities of the NMR instrumentation should support the instructional and research needs of the program. If the on-site instrument does not meet all of the program's research needs, stable arrangements must be made with proximal sites to provide ready access to appropriate NMR instrumentation.

In addition, instruments from at least four of the following five categories must be on site and used by undergraduates:

- optical molecular spectroscopy (e.g., FT-IR, fluorescence, Raman, UV-Vis)
- optical atomic spectroscopy (e.g., atomic absorption, ICP-atomic emission)
- mass spectrometry (e.g., MS, GC-MS, LC-MS)
- chromatography and separations (e.g., GC, GPC, HPLC, ion chromatography, capillary electrophoresis, SEC)
- electrochemistry (e.g., potentiometry, amperometry, coulometry, voltammetry)

Programs must maintain an additional complement of instrumentation that is adequate to support the curriculum, including undergraduate research. For example, programs might have multiple instruments from one or more of the categories listed above or additional supplemental instrumentation, which might include vacuum and inert-atmosphere systems (e.g., Schlenk line, dry box), thermal analysis (e.g., DSC, TGA), x-ray diffraction, or imaging and microscopy methods (e.g., electron microscopy, scanning probe microscopy, confocal microscopy), or biochemical instrumentation (e.g., thermocyclers, centrifuges, gel electrophoretic systems).

In all cases, the institution must maintain the instrumentation in adequate operating condition.

4.3 Computational Capabilities and Software. The ability to compute chemical properties and phenomena complements experimental work by enhancing understanding and providing predictive power. Students should have access to computing facilities and use computational chemistry software.

4.4 Chemical Information Resources. A broad range of the peer-reviewed chemical literature must be readily accessible to both faculty and students.

- An approved program must provide immediate institutional access to no fewer than 14 current and archival, peer-reviewed journals whose subject matter spans the chemical sciences. At least three of the journals must have a general focus (for example, *Science, JACS, Angewandte Chemie International Edition, Chemistry – A European Journal, Chemical Communications,* etc.), and at least one must come from each area of analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, physical chemistry, and chemistry education. In addition, the library must provide timely access to journal articles that are not available on site by a mechanism such as interlibrary loan or a document delivery service.
- Students must have access to technical databases and other resources that enable development of skills in searching the literature, including structure-based searching, and support research and instructional activities.

4.5 Laboratory Safety Resources. The program must be conducted in a safe environment that is consistent with the following features:

- There must be a written chemical hygiene plan consistent with OSHA and state standards. A mechanism for harmonizing this plan with the teaching and research activities of the program is required for the establishment of a safety culture.

- Laboratory safety plans need to recognize hazards encountered in the instructional and research activities in the program. Common hazards include chemical hazards (health, physical, and environmental), extreme temperatures, high pressures and voltages, ionizing and non-ionizing

radiation, and intense light sources.

- For materials and equipment that present particular hazards, specific standard operating procedures (SOPs) should be developed and incorporated into the chemical hygiene and chemical safety plans of the program.
- Hazardous waste management must be part of the chemical hygiene plan and adhere to institutional, federal, and state regulations regarding hazardous waste management and laboratory safety. This includes maintenance of proper facilities for chemical waste disposal and personnel to address this task.
- Safety information and reference materials, such as Safety Data Sheets, should be accessible from or available in the laboratories.
- Appropriate personal protective equipment must be readily available to students, staff, and faculty.
- Regularly tested and inspected eyewash and shower stations must be located in all laboratories in which such safety devices are mandated.
- Regularly tested and inspected fume hoods must be present in all laboratories that involve the use of potentially hazardous materials.
- The chemistry program must promote a safety culture by coordinating safety inspections of laboratories, receiving and analyzing accident reports, receiving emergency response training and assuring that everyone working in instructional and research laboratories is properly educated on safety issues. The mechanism for promoting a safety culture, which will often include a safety committee or safety officer, should be a collaborative endeavor with the institutional environmental health and safety office (if one exists) and the chemical hygiene officer.

4.6 Support and Resources for Transfer Students. Many students transfer among institutions during their undergraduate education, including those who start their course work at community colleges. Approved programs should be aware of the educational backgrounds and unique challenges facing transfer students. Programs should provide an advisor to assist transfer students with orientation, academic advising, and successful integration into their new institution. They should also engage in activities to encourage and ease transfer student matriculation and provide a vibrant, supportive framework for their success.

5. Curriculum

The curriculum of an approved program provides both a broad background in chemical principles and in-depth study of chemistry or chemistry-related areas that build on this background. These guidelines describe the chemistry curriculum in terms of content and development of student skills. The content areas encompass five of the traditional subdisciplines of chemistry: analytical, biochemistry, inorganic, organic, and physical, and include both small molecules and macromolecules. Student learning progresses from beginner to expert knowledge and comprises introductory, foundation, and in-depth experiences. Beyond the *introductory* chemistry experience, *foundation* experiences provide breadth of coverage across the traditional subdisciplines. Rigorous *in-depth* experiences build upon the foundation. Furthermore, because chemistry is an experimental science, substantial laboratory work is integral to these three levels of experience. Programs have the opportunity to design innovative curricula that meet the needs and interests of their students by defining degree tracks or concentrations requiring specified in-depth course work. The curriculum must also include experiences that develop student skills essential for their effective performance as scientific professionals (see Section 7).

5.1 Content Requirements. To provide students with an intellectual framework that covers the breadth of modern chemistry, the foundation experience of the curriculum must cover the five subdisciplines listed above. Student laboratory experiences must include at least four of the five subdisciplines.

Recognizing that the synthesis, analysis, and physical properties of small molecules give an incomplete picture of the higher order interactions that occur in macromolecular, supramolecular, mesoscale, and nanoscale systems, the principles that govern these systems must be part of the curriculum required for certified graduates. This instruction must cover the preparation, characterization, and physical properties of such systems. At least two of the following four types of systems must be covered: synthetic polymers, biological macromolecules, supramolecular aggregates, meso- or nanoscale materials. Coverage of these topics may be distributed across multiple courses, in which case it should constitute the equivalent of approximately one-fourth of a standard semester course.

5.2 Introductory or General Chemistry. The introductory or general chemistry experience plays a vital role in educating all students. The purpose of

introductory chemistry course work for those students pursuing a degree in chemistry is preparation for the foundation course work. This introduction provides students with basic chemical concepts such as stoichiometry, states of matter, atomic structure, molecular structure and bonding, thermodynamics, equilibria, and kinetics. The diversity of institutions and students requires a variety of approaches for teaching general or introductory chemistry. Possible approaches range from a full-year course to a one-semester course to waiving the introductory course requirement for very well-prepared students. To accommodate all these situations, these guidelines focus on the requirements and characteristics of experiences beyond the introductory level.

To prepare students properly for the foundation laboratories, laboratories in introductory or general chemistry courses must be primarily hands-on, supervised laboratory experiences. Students need to be instructed in basic laboratory skills such as safe practices, keeping a notebook, use of electronic balances and volumetric glassware, preparation of solutions, chemical measurements using pH electrodes and spectrophotometers, data analysis, and report writing.

5.3 Foundation Course Work. Foundation course work provides breadth and lays the groundwork for the in-depth course work. Certified graduates must have instruction equivalent to a one-semester course of at least three semester credit hours in each of the five traditional subdisciplines of chemistry: analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, and physical chemistry. Programs operating on the quarter system can achieve this breadth with at least eight three-credit one-quarter courses that include the equivalent of at least one quarter of coverage in each of the five areas.

Foundation course work builds on the introductory chemistry experience. Foundation course work uses specialized books or materials that serve as an introduction to each field, rather than a general chemistry textbook. Exam questions should cover concepts in greater detail than in an introductory or general chemistry course. A student completing a foundation course should have mastered the vocabulary, concepts, and skills required to pursue in-depth study in that area.

Some areas, particularly organic and physical chemistry, have traditionally been taught as year-long courses. In these cases, the first-semester course in the sequence can be used as a foundation course and the second-semester course as an in-depth course. Integrated foundation course work may provide exposure to multiple foundation areas of chemistry or a group of topics organized by overarching themes (for example, synthesis, characterization, and reactivity) rather than by the traditional organization of chemistry subdisciplines.

5.4 In-Depth Course Work. The curriculum required for certification must also include a minimum of the equivalent of four one-semester or six one-quarter in-depth courses and correspond to at least 12 semester or 18 quarter credit hours. Because in-depth courses build on prerequisite foundation course work, the goals of in-depth courses are both to integrate topics introduced in the foundation courses and to investigate these topics more thoroughly. Exams and other assignments associated with in-depth courses should require critical thinking and problem-solving skills. The second semester in a two-semester course sequence such as organic or physical chemistry can be considered an in-depth course.

In-depth course work could focus on content that increases a student's understanding of one or more of the foundation areas. It could also include courses that support a specialized degree track (see Section 5.8). One or more of the in-depth courses may be taught in another department, but they must contain significant chemistry or chemistry-related content at a level beyond the foundation. The Committee encourages programs to integrate modern topics in chemistry such as catalysis, environmental chemistry, green/sustainable chemistry, materials science, and toxicology into the in-depth courses.

Laboratory courses provide an important aspect of in-depth course work for certified graduates. In general, associated classroom and laboratory courses (e.g., the second semester of organic chemistry lecture and laboratory) count as a single course in satisfying the requirement for four in-depth courses even if they have separate course numbers. Likewise, a laboratory that represents the first laboratory exposure to a foundational area is not considered an in-depth course. For a laboratory course to be considered as one of the four in-depth courses required for certification, it must represent an advanced laboratory experience that includes the integration of student skills and builds on the foundation laboratory experiences. In-depth laboratory experiences involve experiment design, execution, data analysis, and use of the chemical literature. In these courses, students are typically in the laboratory for at least six hours per week. Such courses may have an accompanying classroom component. No single laboratory or lecture course can be used to satisfy both foundation and in-depth requirements.

5.5 Frequency of Course Offerings. The most effective programs teach five foundation courses annually. Approved programs must teach at least four foundation courses annually, covering at least four of the five foundation areas. For programs on the quarter system, this requirement translates to teaching at least six of eight foundation courses every year. Each foundation course must be taught at least once in any two-year period. If any foundation courses are not taught annually, the program must make arrangements to ensure that students can complete the requirements for certification in four years.

While permanent full-time chemistry faculty usually teach all of the foundation courses, in some cases it may be appropriate to include courses taught by faculty outside the chemistry department. For example, a student might obtain a foundation biochemistry experience through a course taught in a biochemistry or biology department. In cases where course work in one of the foundation areas is taught by another department, the chemistry faculty must teach all of the remaining foundation courses annually.

Because in-depth courses determine the rigor of the undergraduate experience, the chemistry faculty must teach at least four semester-long or six quarter-long in-depth courses annually, exclusive of research. These courses must correspond to at least twelve semester or 18 quarter hours. The frequency of the in-depth course offerings must allow students to complete the requirements for a certified chemistry degree in four years. Although courses taken outside the chemistry program may be used to satisfy an individual student's in-depth course requirements, the program is still required to teach at least four in-depth semester (six quarter-long) courses, as defined in Section 5.4, in each academic year.

5.6 Laboratory Experience. The certified graduate must have 400 hours of laboratory experience beyond the introductory chemistry laboratory. Laboratory course work must cover at least four of the five traditional chemistry subdisciplines and may be distributed between the foundation and in-depth levels. Laboratory course work is an ideal place in the curriculum to develop the student skills described in Section 7. The laboratory experience must include synthesis of molecules, measurement of chemical properties, determination of structures, hands-on experience with modern instrumentation such as that listed in Section 4.2, data analysis, and computational modeling. Laboratory experiences should be designed to teach students to understand the operation and theory of modern instruments and use them to solve chemical problems. In a computational chemistry laboratory experience, the students would be expected to use the same principles of experiment design, execution, and data analysis characteristic of hands-on laboratory experiences. In contrast, virtual laboratory experiences that replace activities that are traditionally performed hands-on cannot be used as part of the 400 laboratory hours.

5.7 Cognate Courses. Certified graduates must complete course work equivalent to two semesters of calculus and two semesters of physics with laboratory. The Committee strongly recommends a calculus-based physics curriculum and study of multivariable calculus, linear algebra, and differential equations.

5.8 Degree Tracks or Concentrations. A degree track used to certify graduates is a specialized, faculty-designed curriculum meeting the foundation, in-depth, and laboratory requirements. Degree tracks offer the opportunity to incorporate emerging areas of chemistry, make use of local expertise, and align with faculty and student interests. The faculty is responsible for defining degree tracks for its program. While the ACS approves chemistry programs, it does not approve specific degree tracks developed by individual chemistry programs. Consequently, if programs develop additional degree tracks, they may certify graduates from these tracks so long as the students meet the requirements for certification.

A degree track can broadly cover the field of chemistry or focus on a specific chemistry subdiscipline or chemistry-related multidisciplinary area. A chemistry degree track might require the second semesters of organic and physical chemistry, along with the equivalent of two semesters of in-depth electives (which can include undergraduate research). More specialized tracks might provide greater depth of instruction focused on a chemistry area such as advanced organic synthesis, computational chemistry, biochemistry, or chemical measurement science. Examples of multidisciplinary tracks include chemical education, chemical physics, environmental chemistry, forensic chemistry, materials science, medicinal chemistry, polymer chemistry, or other specialties. Degree tracks might also require additional courses, either within the chemistry program or offered in another department, which would not count as in-depth courses because they do not have sufficient chemistry content that builds on the foundation course work.

5.9 Pedagogy. An approved program should use effective pedagogies in classroom and laboratory course work. Programs should teach their courses in a challenging, engaging, and inclusive manner that accommodates a variety of learning styles. Additionally, a program should provide opportunities for faculty to maintain their knowledge of effective practices in chemistry education and modern theories of learning and cognition in science. An approved program should regularly review its pedagogical approaches to ensure that they promote student learning and build the skills needed to be an effective professional.

Faculty should incorporate pedagogies that have been shown to be effective in undergraduate chemistry education. Examples include problem- or inquiry-based learning, peer-led instruction, learning communities, and technology-aided instruction such as the use of personal response systems and flipped or hybrid classes. Laboratory work provides a particularly attractive opportunity for inquiry-driven and open-ended investigations that promote independent thinking, critical thinking and reasoning, and a perspective of chemistry as a scientific process of discovery.

5.10 Capstone Experiences. Certified graduates should be provided with an integrative experience that requires them to synthesize the knowledge and skills introduced across the curriculum. Such experiences provide a bridge between the students' academic and future professional activities. These experiences can take many different forms. An important aspect of this integrative experience is the opportunity it provides programs to assess the ability of students to integrate knowledge, use the chemical literature, and demonstrate effective communication skills. Such assessments typically involve some combination of written or oral exams, required presentations, and written reports.

These integrative experiences could be provided in an existing upper-level, designated capstone course (e.g., senior seminar) or distributed among several courses taught in the chemistry department. Typically, a stand-alone capstone course could not be used to fulfill the in-depth course requirement. Mentored teaching also provides an excellent opportunity for students to integrate their knowledge and skills, as does an independent research experience that also requires a research report and presentation of the student's results.

5.11 Online and Virtual Instruction. Classes taught partially or wholly online should provide at least the same skill development and content as the corresponding wholly face-to-face experience. Programs should ensure that students in such courses have adequate access to faculty and instructors and opportunities for collaboration with peers. Faculty contact-hour credit for virtual and online instruction should be at least equivalent to the corresponding classroom experience.

Chemistry is an empirical science that requires the safe and effective physical manipulation of materials, equipment, and instrumentation. This hands-on expertise cannot be developed through virtual laboratory exercises. Virtual labs may supplement hands-on laboratory exercises, but they must not replace them (see also Section 5.6).

6. Undergraduate Research

Undergraduate research allows students to integrate and reinforce chemistry knowledge from their formal course work, develop their scientific and professional skills, and create new scientific knowledge. A vigorous research program is also an effective means of keeping faculty current in their fields and provides a basis for acquiring modern instrumentation. Original research culminating in a comprehensive written report provides an effective means for integrating undergraduate learning experiences and allows students to participate in the advancement of science.

Conducting undergraduate research with a faculty advisor allows the student to draw on faculty expertise and encourages a student-faculty mentor relationship. The research project should be envisioned as a component of a publication in a peer-reviewed journal. It should be well-defined, stand a reasonable chance of completion in the available time, apply and develop an understanding of in-depth concepts, use a variety of instrumentation, promote awareness of advanced safety practices, and be grounded in the primary chemical literature.

Research can satisfy up to four semester credit hours or six quarter credit hours of the in-depth course requirement for student certification and can account for up to 180 of the required 400 laboratory hours. A student using research to meet the ACS-certification requirements must prepare a well-written, comprehensive, and well-documented research report, including safety considerations where appropriate. Thorough and current references to peer-reviewed literature play a critical role in establishing the overall scholarship of the report. Although oral presentations, poster presentations, and journal

article co-authorship are valuable, they do not substitute for the student writing a comprehensive report.

Research performed during the summer or performed off-campus, even though it might not receive academic credit, may count toward student certification. In such cases, the student must prepare a comprehensive written report that a faculty member of the home institution evaluates and approves.

7. Development of Student Skills

In order to prepare students to enter the workforce or postgraduate education, programs must provide experiences that go beyond chemistry content knowledge to develop competence in other critical skills necessary for a professional chemist. Faculty mentoring is another key component of student development because it helps students gain confidence and provides guidance about career planning and networking. Approved programs should have an established process by which they assess the development of student skills. A capstone experience (as described in Section 5.10) provides an excellent opportunity for this assessment. In addition, either dedicated courses or integration of learning opportunities throughout the curriculum can be used to develop and assess student skills.

7.1 Problem Solving Skills. An important goal of chemistry education is to provide students with the tools to solve problems. Students should be taught how to define problems clearly, develop testable hypotheses, design and execute experiments, analyze data using appropriate statistical methods, understand the fundamental uncertainties in experimental measurements, and draw appropriate conclusions. Throughout the curriculum, students should be challenged to apply their understanding of all chemistry subdisciplines and use appropriate laboratory skills and instrumentation to solve problems.

7.2 Chemical Literature and Information Management Skills. Essential student skills include the ability to retrieve information efficiently and effectively by searching the chemical literature, evaluate technical articles critically, and manage many types of chemical information. Students must be instructed in effective methods for performing and assessing the quality of searches using keywords, authors, abstracts, citations, patents, and structures/substructures.

The program should provide ready access to technical databases with sufficient depth and breadth of the chemical literature for effective searching. Students' ability to read, analyze, interpret, and cite the chemical literature as applied to answering chemical questions should be assessed throughout the curriculum. Instruction should also be provided in data management and archiving, record keeping (electronic and otherwise), and managing citations and related information. This includes notebooks, data storage, information and bibliographic management and formatting. Undergraduate research and/or individual or group projects provide excellent opportunities for development and assessment of literature searching and information management skills. A stand-alone course can be an effective means of imparting information-retrieval skills, though such a course usually would not qualify as an in-depth course.

7.3 Laboratory Safety Skills. Programs must instruct students in the aspects of modern chemical safety appropriate to their educational level and scientific needs. Approved programs need to promote a safety-conscious culture in which students demonstrate and apply their understanding of the concepts of safe laboratory practices. The promotion of safety awareness and skills must begin during the first laboratory experience and should be incorporated into each lab experience thereafter. Students must undergo general safety instruction as well as lab-specific instruction before beginning undergraduate research. Classroom and laboratory discussions need to stress safe practices and should actively engage students in the evaluation and assessment of safety risks associated with laboratory experiences. Safety understanding and skills must be developed and assessed throughout the curriculum.

Programs should provide students with training that allows them to

- carry out responsible disposal techniques
- comply with safety regulations
- properly use personal protective equipment to minimize exposure to hazards
- understand the categories of hazards associated with chemicals (health, physical, and environmental)
- use Safety Data Sheets (SDSs) and other standard printed and online safety reference materials

- recognize chemical and physical hazards in laboratories, assess the risks from these hazards, know how to minimize the risks, and prepare for emergencies.

7.4 Communication Skills. Effective communication is vital to all professional chemists. Speech and English composition courses alone rarely give students sufficient experience in oral and written communication of technical information. The chemistry curriculum should include critically evaluated writing and speaking opportunities so students learn to present information in a clear and organized manner, write well-organized and concise reports in a scientifically appropriate style, and use relevant technology in their communications. Because chemistry is a global enterprise, knowledge of one or more foreign languages or an international experience can be a valuable asset to chemistry students and add greatly to a student's ability to communicate with other chemists worldwide.

7.5 Team Skills. Solving scientific problems often involves multidisciplinary teams. The ability to work in such teams is essential for a professional chemist. Programs should incorporate team experiences into classroom and laboratory components of the chemistry curriculum, thus providing opportunities for students to learn to interact effectively in a group to solve scientific problems and work productively with a diverse group of peers. Effective group experiences provide students with the opportunity to develop both leadership and team skills.

7.6 Ethics. Ethics should be an intentional part of the instruction in a chemistry program. Students should be trained in the responsible treatment of data, proper citation of others' work, and the standards related to plagiarism and the publication of scientific results. The curriculum should expose students to the role of chemistry in contemporary societal and global issues, including areas such as sustainability and green chemistry. As role models, faculty should exemplify responsible conduct in their teaching, research, and all other professional activities.

8. Program Self-Evaluation

An approved program should regularly evaluate its curriculum and pedagogy, faculty development opportunities, and infrastructure needs relative to the program's teaching and research mission. Self-evaluation is a continual process that enables programs to both introduce change in a deliberate way and improve overall effectiveness. Steps in the self-evaluation process include identifying the goals of the program, collecting and analyzing data to determine if these goals are being met, implementing changes as needed to meet the program goals, and then, after an appropriate period of time, beginning the process anew. Thoughtful and thorough self-evaluation can lead to improved or modernized course content or pedagogy, identification of areas in which the curriculum may be strengthened and student outcomes improved, and increased support for professional development and scholarly activities of faculty. Such evaluation can also provide a strong infrastructure to support the educational and scientific missions of the program.

9. Certification of Graduates

The chair of an approved program certifies those graduates receiving a baccalaureate degree consistent with these guidelines. Students usually receive certification when they complete the baccalaureate degree. It is also possible to certify students who initially obtain a non-certified baccalaureate degree from an approved program and subsequently complete additional study in an ACS-approved program to qualify for certification. The Office of Professional Training provides certificates for certified graduates.

II. APPROVAL PROCESS AND REVIEW PROCEDURES

1. Membership of the Committee

The CPT has 17 members. The ACS Board of Directors and the president of the Society with the advice of the ACS Committee on Committees jointly appoint 16 voting members. There is also one nonvoting staff Secretary. One voting member serves as an appointed chair and one serves as an elected vice chair. Initial appointments are usually for a three-year term, and reappointment for up to a total of three 3-year terms of service is possible. The Committee typically retains one or more former members or appoints individuals with special expertise as nonvoting consultants. Members of CPT are experienced educators and scientists from all areas of the country, chosen to represent different fields of chemistry and reflect much of the breadth of the chemistry community. The Secretary communicates the results of all reviews conducted by CPT and consults with faculty and administrators about guidelines and procedures related to ACS approval.

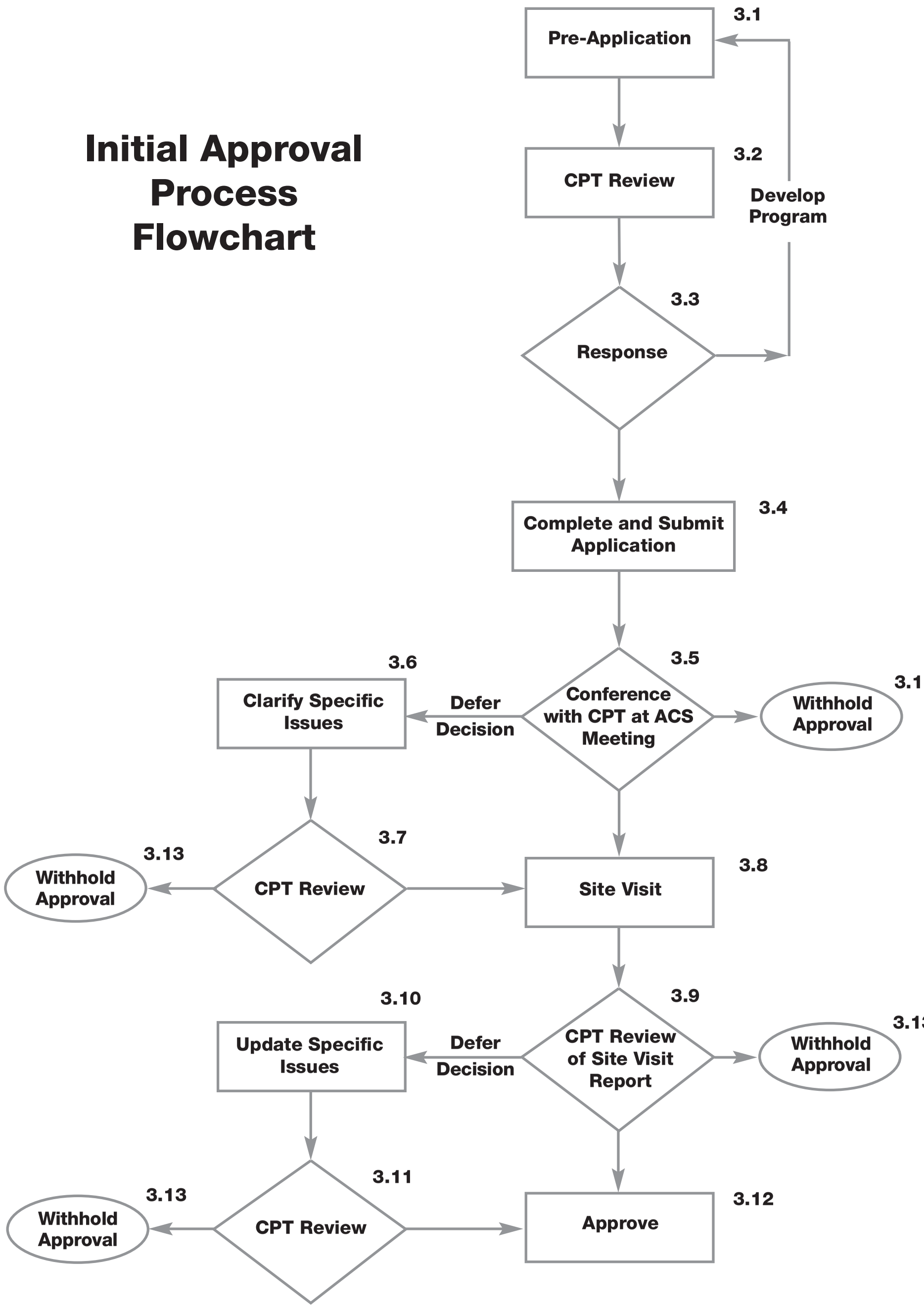
2. Costs Associated with the CPT and the Approval Program

The Society does not charge academic institutions for the evaluation of the chemistry program, including site visits by Visiting Associates of CPT (Section 8).

3. Initial Approval Process

The ACS, through CPT, establishes the recommendations and requirements for approval of bachelor's degree programs in chemistry and policies for administering the approval process. The chemistry faculty should conduct a self-study to determine the program's readiness to begin the approval process. The following flowchart summarizes the steps of the initial approval process, and the accompanying text describes each of the steps in the flowchart.

Initial Approval Process Flowchart



3.1 Pre-Application. The chemistry program completes a pre-application form, which is available on the CPT website, and submits it during the time periods identified on the pre-application web page.

3.2 CPT Review. The Committee reviews the pre-application form within two months of the submission deadline.

3.3 Response. The Secretary of the Committee reports the outcome of the review to the department chair by letter. Two outcomes are possible.

1) *The program does not meet* the requirements for ACS approval that are covered by the pre-application form. The letter identifies the deficiencies and instructs the program to submit a new pre-application form after addressing the areas of noncompliance.
2) *The program meets* the requirements for ACS approval covered by the pre-application form. The Committee invites the department to submit a full application package.

3.4 Complete and Submit Application Package. The program completes a comprehensive self-study questionnaire and provides supporting documentation including course syllabi, examinations, and student research reports (when research is required). The ACS staff check the package for completeness and assign the application for review by the Committee at the next ACS national meeting.

3.5 Conference with CPT. The chair of the department applying for approval is expected to meet with the Committee to discuss the chemistry program and answer questions about certain aspects of the application package. If the chair of a combined department is not a chemist, a chemistry faculty member must attend the conference. Additional chemistry faculty members or administrators may also meet with the Committee. The Secretary of CPT communicates the outcome of CPT's review to the chair of the department that administers the chemistry program. Three outcomes are possible.

1) *The Committee agrees that the program is ready for a site visit* (Section 3.8) by Visiting Associates. (Section 8)
2) *The Committee defers a decision* pending clarification of certain aspects of the application. (Sections 3.6, 3.7)
3) *The Committee withholds approval of the program.* (Section 3.13)

3.6 Clarify Specific Issues. The program must clarify the specific issues identified in the letter from the Secretary of CPT and submit a response by the deadline given in the letter. This step may only be taken once following submission of an application for approval.

3.7 CPT Review. ACS staff verifies that the information submitted by the applicant is complete and schedules the application for review at the next regular CPT meeting. Two outcomes are possible.

1) *The Committee agrees that the program is ready for a site visit* (Section 3.8) by Visiting Associates. (Section 8)
2) *The Committee withholds approval of the program.* (Section 3.13)

3.8 Site Visit. The Secretary of CPT reports the decision to proceed with a site visit by letter to the chair of the department that administers the chemistry program. The president (or chief administrative officer) of the institution must then invite ACS to make a site visit. Two Visiting Associates will make the site visit, which typically is spread over two days. The ACS pays all expenses of the site visitors. ACS staff provide the site visitors with background information and instructions from the Committee. The president or chief administrative officer of the institution must be available to meet with the site visitors. The site visitors submit a written report to the Secretary of CPT within one month following the visit. For more information on Visiting Associates, see Section 8.

3.9 CPT Review of Site Visit Report. CPT reviews the written report on the site visit at the first regular meeting after it is received. Three decisions are possible after this review.

1) *The Committee approves the chemistry program.* (Section 3.12)
2) *The Committee requests additional or updated information.* (Sections 3.10, 3.11)
3) *The Committee withholds approval of the program.* (Section 3.13)

3.10 Update Specific Issues. The program must clarify or update the specific issues identified in the letter from the Secretary of CPT to the chair of the department administering the chemistry program and submit a response by the deadline given in the letter. This is not an iterative step and occurs only once following the site visit.

3.11 CPT Review. CPT reviews the program's report describing the resolution of the specific issues. Two decisions are possible after this review.

1) *The Committee approves the chemistry program.* (Section 3.12)
2) *The Committee withholds approval of the program.* (Section 3.13)

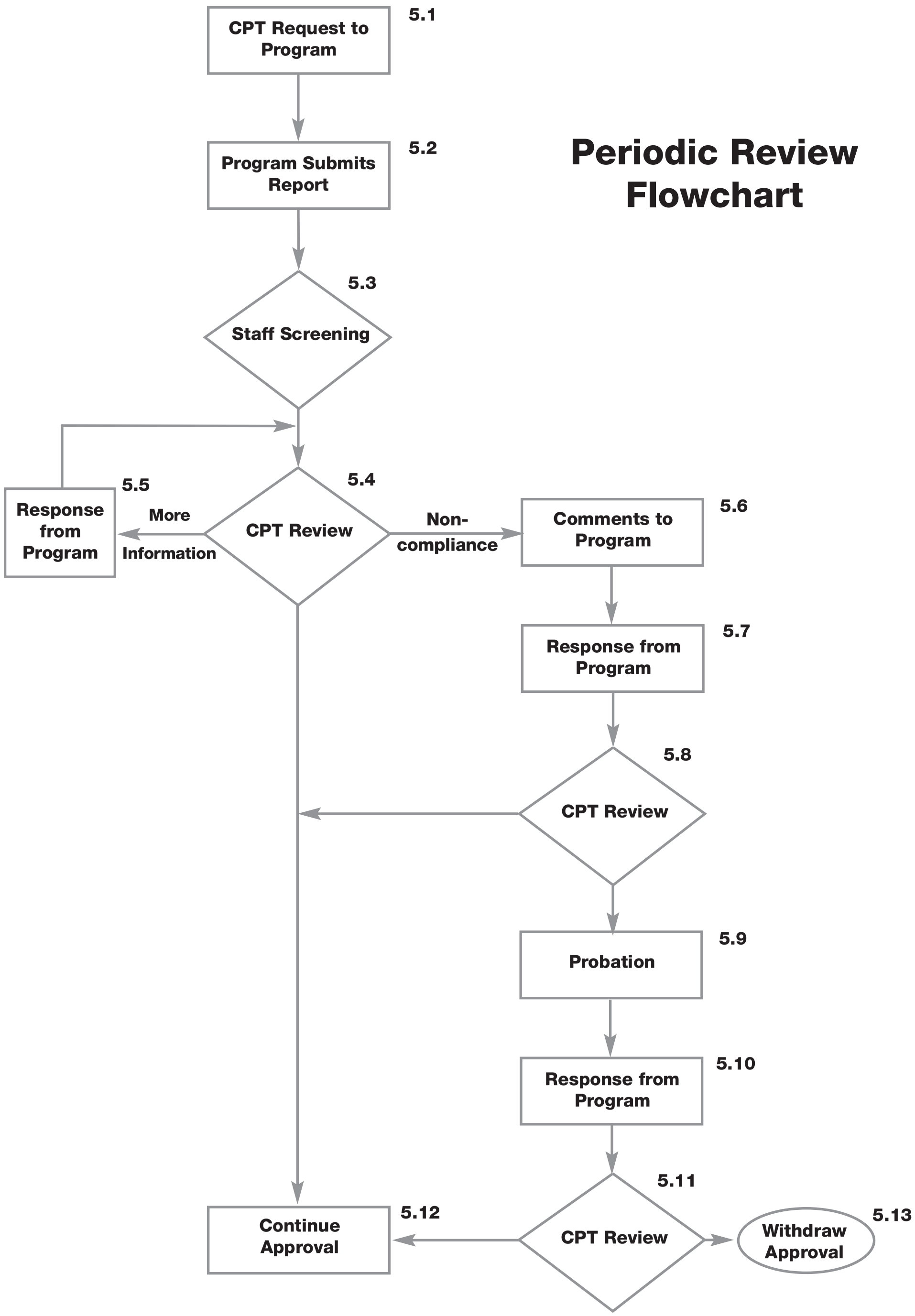
3.12 Approve. The Secretary of CPT writes to the president of the institution and the chair of the department that administers the chemistry program to report this decision. The Committee will post the name of the institution on the list of ACS-approved programs on the ACS website. An approved program must satisfy the reporting requirements described in Sections 4 and 5. Failure to comply with the annual and periodic review requirements will lead to probationary action. (Section 6)

3.13 Withhold Approval. The letter from the Secretary of CPT describes the areas of noncompliance. This letter is sent to the chair of the department administering the chemistry program with a copy to the president or chief administrative officer. After addressing these concerns, the program returns to the pre-application step of the approval process. The institution may appeal this decision as described in Section 7.

4. Annual Review

Approved programs must report annually to the Committee on the number of degrees granted by the chemistry program, information on graduates at all degree levels, the certification status of the baccalaureate graduates, and supplemental information on the curriculum and faculty. The Family Educational Rights and Privacy Act (FERPA) allows institutions to provide the names, gender, and graduation dates of all graduates to CPT. The Committee reviews the report for completeness and consistency with the guidelines and may request additional information from the program. The Committee summarizes and publishes the statistical information about the numbers of graduates at the various degree levels each year.

Periodic Review Flowchart



5. Periodic Review

To ensure compliance with the ACS guidelines, approved programs must submit a periodic report about their program using a form provided by CPT. The adjacent flowchart summarizes the steps of the review process, and the accompanying text describes each of the steps in the flowchart.

5.1 Request for Periodic Report. The Secretary of CPT contacts the chair of the department that administers the ACS-approved chemistry program with instructions for completing the report. A report form with questions on all components of the ACS guidelines, a checklist of supporting documents to be submitted, and a copy of the letter reporting the final outcome of the previous review will be provided. Among the supporting documents that may be requested are copies of specific course syllabi, examinations, and student research reports. Approved programs must submit a periodic report at least every six years. In cases where programs have been given an extended period of time to address significant issues, the next periodic report will be requested no sooner than 12 months after the outcome of the previous review has been communicated to the chair of the department.

5.2 Program Submits Report. The program must respond by the deadline provided in the letter from the Secretary.

5.3 Staff Screening. An ACS staff member checks the periodic report package for completeness and corresponds with the department chair to obtain any missing or other information as authorized by CPT.

5.4 CPT Review. The Committee reviews the periodic report at one of its three yearly meetings. Three outcomes are possible.

1) *The Committee requests more information.* This is not an iterative step and may occur only once following the initial submission of the periodic report. (Section 5.5)
2) *The Committee determines that the chemistry program is not in compliance* with the requirements specified in the guidelines or has not adequately addressed the recommendations from the previous periodic review. (Section 5.6)
3) *The Committee continues approval.* (Section 5.12)

5.5 Request more information. The CPT members may find that essential information is missing from the report package or clarification of ambiguous information is needed. The response is returned to CPT for review and a decision of continue approval or noncompliance is made.

5.6 Comments to Program. The Secretary of CPT identifies the area(s) of noncompliance in a letter to the chair of the department, including a reasonable timeframe for response as established by the Committee.

5.7 Response from Program. The program must report to CPT on the measures taken to address the deficiencies by the deadline provided in the letter from the Secretary.

5.8 CPT Review. The Committee reviews the program's response at the first possible meeting after receiving it. Two outcomes are possible.

1) *Continue approval.* (Section 5.12)
2) *Probation.* (Section 5.9)

5.9 Probation. If the deficiencies have not been corrected, CPT places the chemistry program on probation. The Secretary of CPT communicates this decision and the areas of noncompliance in a letter to the president (or chief administrative officer) of the institution and the chair of the department that administers the chemistry program. The probation decision is confidential between CPT and the institution. During probation, the institution remains on the list of ACS-approved schools, and the department chair may continue to certify graduates who have satisfied the requirements as specified in the guidelines.

5.10 Response from Program. The probationary period normally lasts from 12 to 18 months. The institution must provide a written report that describes how it has corrected all of the areas of noncompliance, including supporting documentation as appropriate. Either the chair of the department administering the chemistry program or a member of the administration may submit the response to the Secretary of CPT before the end of the probationary period.

5.11 CPT Review. The Committee reviews the program's response at the first regular meeting after receiving it. In some circumstances, CPT may request a site visit by Visiting Associates (Section 8). Two outcomes are possible.

1) *Continue approval.* (Section 5.12)
2) *Withdraw approval.* (Section 5.13)

5.12 Continue Approval. If CPT determines that the chemistry program meets all of the requirements for ACS approval and the spirit of the guidelines, the Committee continues approval of the program. The Secretary of CPT reports this outcome in a letter to the chair of the department responsible for administering the ACS-approved chemistry program, with a copy to the president (or chief administrative officer) of the institution. The Committee may identify aspects of the program that must be addressed as part of the next periodic review. Failure to respond adequately may lead to a determination of noncompliance in the future. The letter may also contain CPT's suggestions for further development of the chemistry program. Under certain circumstances, CPT may request a shorter review cycle.

5.13 Withdraw Approval. If the program does not meet all of the requirements for ACS approval by the end of the probationary period, CPT withdraws approval of the chemistry program. The Secretary of CPT reports this outcome in a letter to the president (or chief administrative officer) of the institution and the chair of the department responsible for administering the chemistry program. The institution may appeal this decision as described in Section 7. The name of the institution will be removed from the published list of ACS-approved schools, and the chair may no longer certify graduates after the period for submitting an appeal has elapsed.

If a previously approved program wishes to re-apply for ACS approval within 12 months following the letter withdrawing approval, the program is not required to follow the regular application procedure. The program must submit a request for reinstatement to the Committee accompanied by a completed periodic report package for the current year. The possible outcomes of this review will be approval or withhold approval. The normal appeal procedure will still apply. (See Section 7)

In cases where a chemistry program submits a request to have ACS approval withdrawn, CPT will act to withdraw approval at the next regular meeting of the Committee. No probation period will be imposed. The normal appeal procedure will still apply. (See Section 7)

6. Administrative Probation

The Committee may place an ACS-approved program on probation if it does not comply with any of the following administrative requirements for maintaining approval:

- Submission of a periodic review report by the deadline.
- Submission of additional information requested during CPT review of a periodic report.
- Completion of an annual report by the deadline.

The chair of the department responsible for administering the chemistry program receives two warnings that the program has missed the deadline before the Secretary of CPT contacts the president (or chief administrative officer) of the institution. The Secretary of CPT notifies the president that the chemistry program does not comply with the requirements for maintaining approval and allows 30 days to correct the situation before placing the program on administrative probation. Administrative probation lasts no longer than 60 days. During administrative probation, programs retain approval and may certify graduates. The Committee withdraws approval of any program that fails to submit the required report or information within the 60-day period.

7. Appeal of an Adverse Decision

An institution may petition for review of an adverse decision (withhold or withdrawal of approval) if it believes that the Committee did not have access to all of the necessary evidence, has not adhered to its own established policies and procedures, or has failed to consider all of the evidence and documentation presented during the evaluation. The petition must reach the Committee within 60 days following the date of the letter advising the institution of the adverse decision. Following the Committee's review of the petition, the institution must provide any additional information and documents in support of the petition by the provided deadline, typically no more than six months. After receiving the petition and supporting information, the Committee reviews the matter at its next regular meeting, which may include a conference with representatives of the institution if desired by either the institution or the Committee. After the meeting and deliberation, the Secretary of CPT reports the Committee's findings to the president of the institution and the chair of the department that administers the chemistry program.

Any action of any Society unit is always subject to review by the Society's Board of Directors, which has full legal responsibility for all Society activities.

7.1 Appeal of Withdraw Approval. A program undergoing its periodic review may follow the procedures described above to appeal this decision. Two outcomes of the appeal are possible.

1) *The Committee continues approval.* (Section 5.12)
2) *The Committee affirms the decision to withdraw approval.* (Section 7.3)

7.2 Appeal of Withhold Approval. A program applying for approval may follow the procedures described above to appeal this decision. Three outcomes of the appeal are possible.

1) *The Committee approves the chemistry program.* (Section 3.12)
2) *The Committee agrees that the program is ready for a site visit* (Section 3.8) *by Visiting Associates.* (Section 8)
3) *The Committee affirms the decision to withhold approval.* (Section 7.3)

7.3 Independent Appeals Board. Every institution has the right to appeal the Committee's final decision to an independent Appeals Board convened for that purpose. The Society's president and the chair of its Board of Directors will appoint an Appeals Board, consisting of three individuals who are not members of the Committee, to hear the appeal. No further appeal is available after the action of the Appeals Board.

8. Visiting Associates

The Committee selects Visiting Associates who are experienced educators and scientists familiar with the ACS guidelines and the administrative and technical aspects of conducting a successful chemistry program. In the selection of the Visiting Associates, the Committee makes every effort to eliminate any possibility of bias or conflict of interest. The Committee periodically holds meetings with Visiting Associates to brief them on guidelines policy and evaluation procedures. Visiting Associates receive comprehensive and detailed instructions on CPT's expectations for the site visit that also are sent to the chair of the department to aid in preparation for the visit. In addition, the Associates receive confidential comments from CPT that describe aspects of the program that should receive careful attention during the site visit and in the site visit report. Finally, Visiting Associates serve as fact-finders for CPT and do not fill the role of external consultants who might advise the faculty on the development of the chemistry program.

9. Confidentiality

The information provided to the Committee and all related discussions and correspondence between the Committee and an institution are solely for the confidential use of the Committee. In the event that an institution appeals a Committee decision, the Committee provides the information necessary for the proper conduct of the appeal to the Appeals Board.

The Committee communicates all decisions to the chair of the department that administers the chemistry program. In the case of initial approval, continued approval, report on a site visit, probation, withdrawal of approval, and appeals, the Committee also informs the president (or chief administrative officer) of the institution. These communications summarize the reasons for the decisions made by the Committee.

In its annual published reports, the Committee identifies those institutions whose programs are currently approved as meeting the ACS guidelines for undergraduate professional education in chemistry. These annual reports also summarize statistical information provided by each institution about its chemistry graduates. Otherwise, the Committee does not publish any additional information about a particular program or evaluation.

10. Complaints

Any administrative official of an institution, department chair, faculty member, student, or other person who disagrees with one or more of the policies, procedures, or activities of the Committee and who wishes to present a complaint should do so in an appropriately documented letter to the Committee Secretary. The same procedure is to be followed should the complaint allege failure of an approved institution to adhere to the ACS guidelines or allege that there is a situation tending to jeopardize the quality and vitality of a program at an approved institution. In both cases, the Committee will evaluate the matter and take actions where appropriate.

APPENDIXES

A. The Formal Mandate of the Committee on Professional Training

A resolution of the ACS Council established the Committee on Professional Training in 1936, and the Committee published the first edition of the guidelines for approval of undergraduate programs in 1939. In 1968, the Committee became a Joint Committee of the ACS Board and Council, reporting to both. In 1979, the Society codified the responsibilities of the CPT in ACS Bylaw III,3,(h):

1) The SOCIETY shall sponsor an activity for the approval of undergraduate professional programs in chemistry. The Committee on Professional Training, constituted as an Other Joint Board-Council Committee under this Bylaw, shall act for the Board and Council in the formulation and implementation of the approval program with published criteria and/or guidelines, as well as published evaluation policies and procedures.

2) The goals of the approval program shall be *inter alia:*
   - a. promoting and assisting in the development of high standards of excellence in all aspects of postsecondary chemical education, and undertaking studies important to their maintenance,
   - b. collecting and making available information concerning trends and developments in modern chemical education, and
   - c. cooperating with the SOCIETY and other professional and educational groups having mutual interests and concerns.

3) Institutions may petition for review of adverse evaluation decisions to an established Appeals Board consisting of three members of the SOCIETY, not members of the Committee, appointed jointly by the President and the Chair of the Board.

B. Members of the Committee on Professional Training

CPT Members – 2015

Dr. Edgar A. Arriaga, *University of Minnesota-Twin Cities*

Dr. Ronald Brisbois, *Macalester College*

Dr. Michelle O. Claville, *Hampton University*

Dr. Ron W. Darbeau, *McNeese State University, Vice Chair 2013*

Dr. Steven A. Fleming, *Temple University (Committee Associate)*

Dr. Suzanne Harris, *University of Wyoming, Vice Chair 2009 (Consultant)*

Dr. Bob A. Howell, *Central Michigan University*

Dr. Jeffrey N. Johnston, *Vanderbilt University*

Dr. Kerry K. Karukstis, *Harvey Mudd College*

Dr. Laura L. Kosbar, *IBM T.J. Watson Research Center*

Dr. Clark R. Landis, *University of Wisconsin-Madison, Vice Chair 2015*

Dr. Cynthia K. Larive, *University of California, Riverside, Vice Chair 2007-08, Chair 2009-11 (Consultant)*

Dr. Stephen Lee, *Cornell University*

Dr. Anne B. McCoy, *The Ohio State University, Vice Chair 2011, Chair 2012-14*

Dr. Lisa McElwee-White, *University of Florida*

Dr. Christopher R. Meyer, *California State University, Fullerton*

Dr. Lee Y. Park, *Williams College, Vice Chair 2010 (Consultant)*

Dr. Richard W. Schwenz, *University of Northern Colorado*

Dr. Joel I. Shulman, *University of Cincinnati (Consultant)*

Dr. Greg M. Swain, *Michigan State University*

Dr. Thomas J. Wenzel, *Bates College, Vice Chair 2014, Chair 2015*

Dr. George S. Wilson, *University of Kansas (Consultant)*

Former CPT Members Who Participated in the Development of the Guidelines

Dr. Ron C. Estler, *Fort Lewis College, Vice Chair 2012*

Dr. Joseph S. Francisco, *University of Nebraska-Lincoln*

Dr. Carlos G. Gutierrez, *California State University, Los Angeles*

Dr. Scott C. Hartsel, *University of Wisconsin-Eau Claire*

Dr. John W. Kozarich, *ActivX Biosciences*

Dr. Nancy S. Mills, *Trinity University*

Dr. Jeanne E. Pemberton, *University of Arizona, Chair 2000-02*

Dr. William F. Polik, *Hope College, Vice Chair 2005, Chair 2006-08*

Dr. Barbara A. Sawrey, *University of California, San Diego*

Dr. Maria da Graca H. Vicente, *Louisiana State University*