



AY 2018-2019
Program Review

Chemistry

**PROGRAM REVIEW
2018**

**BACHELOR OF SCIENCE IN CHEMISTRY
COLORADO MESA UNIVERSITY**

Prepared by

The Chemistry Faculty

Compiled and completed by

**David R. Weinberg
Associate Professor of Chemistry**

Contents

1. Introduction and Program Overview	
a. Program description	7
b. Brief History of the Program	7
c. Recommendations from the 2012 PES Review	7
d. Mission and Goals	10
e. Support of Other Programs	11
f. Locational and Comparative Advantages	12
g. Unique Characteristics	13
2. Curriculum	
a. Breadth/Depth of Program	14
b. Program Currency	15
c. Description of Program Delivery	15
3. Analysis of Student Demand and Success	
a - d. Enrollment, Credit Hours, and Graduates	17
e. Student Successes and Recognition	18
4. Program Resources	
a. Faculty	21
b. Financial Information	24
c. Library Assessment	25
d. Physical Facilities	26
e. Instructional Resources	27
f. Efficiencies in Program Operations	28
5. Student Learning Outcomes and Assessments	
a. Student Learning Outcomes	29
b - d. Assessment of Student Learning Outcomes, Student Satisfaction, and Program Improvements	30
6. Program Resources	
a. Vision	38
b. Strengths and Challenges	38
c. Use of the Program Review Process to Improve Teaching and Learning	41
d. Recommendations for Addressing Challenges	42

Tables

Table 1. Chemistry Courses Supporting Other Degree and Minor Programs	12
Table 2. Summary of Majors and Graduates by Degree Program	17
Table 3. Summary of Chemistry Enrollment and Credit Hours by Level for AY13 through AY18	19
Table 4. Composition of chemistry faculty in AY 13 and AY 19	21
Table 5. Full-time Equivalent Students and Faculty for AY13 and AY18	22
Table 6. Percentage of Credit Hours Generated by Each Type of Faculty, AY14 - AY18	22
Table 7. Expenditures in AY12 and AY17	25
Table 8. Number of sections of lower-division and organic (CHEM 311) labs	27
Table 9. ETS Major Field Test (MFT) results based on national percentiles for institutional averages	31
Table 10. ETS Major Field Test (MFT) results based on national percentiles for median students	32

Appendices

Appendix I.	Chemistry FTES, FTEF, and FTES:FTEF	45
Appendix II.	Course Evaluation Form	49
Appendix III.	Library Assessments and Periodical Lists	55
Appendix IV.	Chemistry Curriculum Map, AY19	75
Appendix V.	Program Outcome and Assessment Report	79
Appendix VI.	CMU Alumni Survey Results	103
Appendix VII.	Curricula Vitae for Tenured and Tenure-Track Faculty	121
Appendix VIII.	Curricula Vitae for Full-Time Faculty	161
Appendix IX.	Curriculum Vitae for the Laboratory Coordinator	181

1. Introduction and Program Overview

a. Program Description

The Chemistry Program at Colorado Mesa University is housed in the Department of Physical and Environmental Sciences, along with the Environmental Sciences, Geology and Physics programs. Although these programs are all part of the same department and overseen by a single department head, they are managed as independent units. Each program has its own faculty, labs, and budget. Each program also controls its own curriculum, schedules its own classes, and sets its own priorities. The Department is dedicated to providing excellent undergraduate education within each of these academic disciplines. Our programs are characterized by small major class sizes, learning in close collaboration with faculty members and ample undergraduate research opportunities.

The Chemistry Program at Colorado Mesa University offers a Bachelor of Science degree in Chemistry and a Bachelor of Science degree in Chemistry with a Biochemistry Concentration. The Program also offers a Chemistry Minor.

b. Brief History of the Program

Prior to 1995, CMU offered a Bachelor of Science in Physical and Mathematical Sciences. This degree allowed for a variety of emphases, including geology, physics, mathematics and computer science. There was no degree program for chemistry, although a limited number of chemistry courses were offered. The Bachelor of Science in Physical Sciences with a Chemistry Concentration was first offered in the Fall of 1995. This degree utilized a curriculum comparable to those typically required by chemistry degree programs around the country. In 1995, the Chemistry Program included three full-time faculty and served one Chemistry Major student.

Over the next two decades, student interest in and institutional support of the Chemistry Program has grown. In the Fall of 2013, the Bachelor of Science in Chemistry was offered as a stand-alone degree rather than a concentration of the Physical Sciences degree. While the title changed, there was no significant change to the actual curriculum. In Fall 2016, a new Biochemistry Concentration for the Bachelor of Science in Chemistry was offered for the first time. The Chemistry Program currently (Fall 2018) includes five (5) tenured/tenure-track faculty, three (3) permanent full-time instructors, one (1) temporary full-time instructor, one (1) laboratory coordinator/instructor, and three (3) part-time instructors. The Program currently serves 103 chemistry and biochemistry majors and 117 chemistry minors.

c. Recommendations from the 2012 PES Review

Recommendation made by the Department of Physical and Environmental Sciences in the Review:

The main challenge to the chemistry program is being able to accommodate an on-going increase in majors, minors, and students requiring chemistry courses for other majors. If enrollments

continue to increase at a high rate, the chemistry program will need to hire another full-time faculty member to begin as early as the fall semester of 2014.

Response: The number of full-time faculty has increased from five (5) to nine (9) since 2012.

Recommendations made by the External Reviewer - Highest Priority:

Recommendation 1: All programs can justify additional tenure-track faculty positions.

Response: The number of full-time faculty has increased from five (5) to nine (9) since 2012.

Recommendation 2: Develop and execute an Assessment Plan for each program (concentration or "major").

Response: The Chemistry Program has developed and enacted a robust Assessment Plan.

Recommendation 3: Seek final approval for discrete chemistry, geology and physics designated major programs. (Based on the site visit, this change is "in progress.")

Response: The Department of Physical and Environmental Sciences now offers both a stand-alone Bachelor of Science in Chemistry and a Bachelor of Science in Chemistry with a Biochemistry Concentration. These are executed via the Chemistry Program.

Recommendation 4: Identify strategies to convert students identified as program majors to graduates (particularly chemistry).

Response: The chemistry faculty were presented with lists of students who were close to graduating but who had not yet submitted a plan for graduation. For the students who might be interested in pursuing graduation, they were contacted by a chemistry faculty member and provided with encouragement and guidance.

Recommendation 5: Continue to explore additional program opportunities, particularly at the boundary of traditional disciplines, and which rely on existing resources in-so-far as possible.

Response: The Department of Physical and Environmental Sciences now offers a Bachelor of Science in Chemistry with a Biochemistry Concentration.

Recommendation 6: As the future is contemplated, develop a firm, persuasive vision (or "sense of self") for the physical sciences' disciplines.

Response: With the introduction of the stand-alone degrees in Chemistry, the Chemistry Program now has a greater "sense of self" in both the eyes of its faculty and students.

Other Recommendations made by the External Reviewer:

The following are comparatively minor, secondary recommendations suggested to refine circumstances.

Regarding faculty evaluation, broaden the physical sciences "definition" for the scholarly expectation.

Response: In both the Colorado Mesa University Professional Personnel Employment Handbook and the published Interpretive Guidance for the handbook, the scholarship expectations across campus are defined to accommodate a broad range of activities. During the last program review cycle, the Interpretive Guidance was added to broaden the definition of scholarship with respect to the Teacher-Scholar Philosophy. Unfortunately, the interpretation of these guidelines on campus has been highly dependent on the person currently employed as CMU's Vice President for Academic Affairs (VPAA). In contrast to the guidelines, the previous VPAA seemed to only count publications as scholarship.

Regarding CMU Catalog descriptions, review Catalog course descriptions for CHEM, GEOL, and PHYS to ensure accurate and informative copy.

Response: The Catalog descriptions for some Chemistry courses have been improved. This continues to be addressed.

Regarding laboratory-based instruction, such offerings to accompany lecture course counterparts seem to be at a minimum (perhaps based on staffing and space considerations).

Response: This recommendation was aimed primarily at programs within the Department of Physical and Environmental Sciences other than the Chemistry Program.

However, the American Chemical Society recommends more laboratory contact hours than we currently require. To follow the ACS recommendations, we would either need to incorporate two additional upper division lab courses or require that students take CHEM 315L: Biochemistry I Laboratory and 2 credits of research. Adding labs would exacerbate the issue of faculty having too many contact hours per week in that each lab involves three contact hours but only counts for two faculty teaching credits. Requiring students to take research credits could be problematic due to the research lab space issues described in Sections 4 and 6 of this program review.

Regarding preservice secondary teacher education, investigate the State of Colorado guidelines for licensure for teaching middle and secondary school Science" subjects (inclusive of biology/life science, chemistry, earth science, and physics).

Response: This is not currently relevant to the Chemistry Program.

d. Mission and Goals

Colorado Mesa University serves the citizens of Colorado, in general, with a specific emphasis on increasing the level of educational attainment of residents in its 14-county region in Western Colorado. Colorado Mesa University's mission, established by the Colorado Legislature, is contained in Colorado Revised Statutes (C.R.S.) 23-53-101:

There is hereby established a College at Grand Junction, Colorado, to be known as Colorado Mesa University, which shall be a general baccalaureate and graduate institution with selective admission standards. Colorado Mesa University shall offer liberal arts and sciences, professional and technical degree programs, and a limited number of graduate programs. Colorado Mesa University shall also maintain a community college role and mission, including career and technical education programs. Colorado Mesa University shall receive resident credit for two-year course offerings in its commission-approved service area. Colorado Mesa University shall also serve as a regional education provider.

The CMU Board of Trustees' has also established an Institutional Mission Statement:

Committed to a personal approach, Colorado Mesa University is a dynamic learning environment that offers abundant opportunities for students and the larger community to grow intellectually, professionally, and personally. By celebrating exceptional teaching, academic excellence, scholarly and creative activities, and by encouraging diversity, critical thinking, and social responsibility, CMU advances the common good of Colorado and beyond.

As a product of this review, as well as the recent development of the stand-alone degree now offered, the Chemistry Program has also articulated its programmatic mission:

The Chemistry Program at Colorado Mesa University strives to excel in preparing and motivating students for a wide variety of careers and graduate programs by providing exceptional instruction, significant research opportunities and personalized mentoring.

The courses, degrees and minor offered by the Chemistry Program, including the Bachelor of Science in Chemistry and the Bachelor of Science in Chemistry – Biochemistry Concentration, are intentionally designed to fulfill these mandates.

Additionally, CMU has established learning outcomes for each degree level. The institutional outcomes for a baccalaureate degree program state that a CMU baccalaureate degree graduate will be able to:

- construct a summative project, paper or practiced-based performance that draws on current research, scholarship and/or techniques, and specialized knowledge in the discipline (applied learning; specialized knowledge);
- analyze data critically, reason logically, and apply quantitative analysis methods correctly to develop appropriate conclusions (quantitative fluency);
- make and defend assertions about a specialized topic in an extended well-organized document and an oral presentation that is appropriate to the discipline (communication fluency); and
- describe reasoned conclusions that articulate the implications and consequences for a particular decision by synthesizing information and methodologies (critical thinking).

The Program-Level Student Learning Outcomes for Chemistry, as well as the individual courses required for a B.S. in Chemistry, align with these objectives. A student who completes the B.S. in Chemistry will have the ability to:

1. Demonstrate fluency in the concepts from the major fields of chemistry (inorganic, organic, physical, and analytical...) (Specialized Knowledge).
2. Utilize mathematics to solve chemical problems (Quantitative Literacy/Critical Thinking).
3. Employ proper experimental techniques (Applied Learning).
4. Interpret chemical information from peer-reviewed publications (Information Literacy).
5. Communicate chemical topics effectively, both verbally and in writing (Communication Fluency).

e. Support of Other Programs

In addition to providing instruction for Chemistry majors and minors, the Chemistry Program plays a vital role in supporting other programs at CMU. In the 2017-2018 academic year (AY18) Chemistry courses had a total enrollment of 2639.

Many Chemistry courses are required or listed as options by other degree and minor programs (Table 1). Five of these can also be used to fulfill the Essential Learning requirement in Natural Science. In the chemistry courses that service the University's Essential Learning Curriculum, the students are given tools to help them progress toward at least two of the University's Essential Learning SLOs: (1) Demonstrate investigative and analytical thinking skills to solve problems and (2) Select and use appropriate information or techniques in an academic project. These courses also generally cover the University's Essential Learning SLO associated with demonstrating quantitative literacy.

Table 1. Chemistry Courses Supporting Other Degree and Minor Programs

CHEM	Programs Listing Course as a Requirement	Programs Listing Course as an Option
100		Essential Learning
121, 121L	BS, Education: Secondary Ed – Biological Sciences AAS, Supervision, Construction Technology AAS, Medical Laboratory Technician AAS, Water Quality Management	BS, Environmental Science and Technology AAS, Mechanical Engineering Technology AAS, Wildland Fire Management Essential Learning
122, 122L	BS, Education: Secondary Ed – Biological Sciences	Essential Learning
123		BS, Environmental Science and Technology
131, 131L	BS, Biological Sciences BS, Biological Sciences – Eco, Evo, and Org Bio BS, Exercise Science BS, Environmental Geology – Geosciences BS, Geology – Geosciences BS, Education: Secondary Ed – Geosciences AAS, Medical Laboratory Technician	BS, Biological Sciences – Cell, Mol, and Dev Bio BS, Environmental Science and Technology AAS, Mechanical Engineering Technology Essential Learning
132, 132L	BS, Biological Sciences BS, Biological Sciences – Eco, Evo, and Org Bio BS, Exercise Science	BS, Biological Sciences – Cell, Mol, and Dev Bio BS, Environmental Science and Technology BS, Environmental Geology – Geosciences BS, Geology – Geosciences Essential Learning
151, 151L	BS, Mechanical Engineering Technology	
300		Watershed Science Minor International Studies Minor
301, 301L	Forensic Science Minor	
311, 311L	BS, Biological Sciences – Cell, Mol, and Dev Bio	BS, Exercise Science
312, 312L	BS, Biological Sciences – Cell, Mol, and Dev Bio	BS, Exercise Science
315	BS, Biological Sciences – Cell, Mol, and Dev Bio Forensic Science Minor	BS, Biological Sciences BS, Biological Sciences – Eco, Evo, and Org Bio BS, Exercise Science
315L	Forensic Science Minor	BS, Biological Sciences BS, Biological Sciences – Eco, Evo, and Org Bio BS, Biological Sciences – Cell, Mol, and Dev Bio BS, Exercise Science
316		BS, Biological Sciences – Eco, Evo, and Org Bio BS, Biological Sciences – Cell, Mol, and Dev Bio

f. Locational and Comparative Advantages

Colorado Mesa University's competitive pricing helps to recruit students, including a significant number of non-traditional students. The latter tend to be highly motivated, add to the diversity of the student population and bring a broad range of life experiences, including military experience and work experience in the energy field.

g. Unique Characteristics

Upper division classes for majors are small and students experience a great deal of individual interaction with faculty. Additionally, nearly all members of the chemistry faculty supervise structured research involving undergraduates. (More detail is provided later in this report.) We find such interaction coupled with the independence gained from participating in research to be highly effective in developing the desired breadth of student abilities. It also creates a sense of energy and vitality that excites and motivates students.

2. Curriculum

a. Breadth/Depth of Program

The CMU Chemistry curriculum is a traditional Chemistry Bachelor's Degree program, developed with the American Chemical Society's Bachelor's Degree Guidelines in mind. Colorado Mesa University offers two Bachelor's Degrees in Chemistry, one in Chemistry and one in Biochemistry (formally, the B.S. in Chemistry-Biochemistry Concentration). A Chemistry Minor is also offered. Both the Chemistry and Biochemistry Degree programs are intended to provide a comprehensive grounding in fundamental chemistry concepts as well as applied chemistry topics that build on this conceptual background. The courses that comprise the major degree programs are organized into three categories: *foundation courses*, including physics and calculus, provide the fundamental tools necessary for a physical science student, *core courses* that consist of discipline-specific chemistry courses, while rigorous *restricted elective courses* provide additional breadth and depth in chemistry-relevant topics, as well as research opportunities (Structured Research [CHEM 397, 497]). In addition to core chemistry topics, the *core* courses also include professional development courses (such as Communicating in the World of Chemistry [CHEM 442]) which are designed to develop essential skills for students' performance as scientific professionals.

The Chemistry Program has five tenured and tenure-track faculty, all research active, and is conducting a search to hire a sixth tenure-track faculty member. The new hire will replace our previous biochemistry faculty member. Three non-tenure-track instructors are also on the faculty, as well as several rotating adjunct instructors. Our tenure-track faculty have professional training and research specialties in organic, organometallic/inorganic, physical/analytical, physical/environmental, and materials chemistry.

Over the past five years, undergraduate enrollment in CMU's Chemistry Bachelor's Programs has significantly increased, triggered in large part by the addition of our Biochemistry Concentration in 2015. Prior to 2015, ~ 70 students had declared a Chemistry major at CMU, with enrollment rising to ~100 students in AY 2018. On average, 12 students graduated with Bachelor's degrees each academic year (2013-2018). Chemistry Bachelor's students receive formal classroom and laboratory training in Organic, Analytical, Physical, and Inorganic Chemistry (with a minimum 44 credits in chemistry courses required for the Bachelor's Degree). Biochemistry is a restricted elective in the Chemistry Major sequence. Biochemistry students receive classroom and laboratory instruction in Organic, Analytical, Physical, and Biochemistry (27 credits in chemistry coursework, and 20 credits in biochemistry/biology coursework). Inorganic chemistry is a restricted elective for Biochemistry majors. Within the Organic Chemistry Lab and Instrumental Analysis Laboratory courses, students receive instruction in specialized chemistry topics, including sustainable chemistry and nanomaterials chemistry. Chemistry majors receive ~330 instructional hours in supervised laboratory classes beyond the freshman level. Upper division labs include experiments focused on the synthesis of organic molecules, organometallic complexes, determination of molecular structures, and determination of rate constants. The use of instrumentation, including: NMR, ICP-OES, Absorbance Spectroscopy, XRF, and HPLC, among others, are a point of emphasis. The Department is currently attempting to add scanning electron microscopy and fluorescence spectroscopy capabilities to our instrumental suite, as well. In addition, Special Topics courses are offered whenever possible. The most recent special topics course focused on the Analytical Chemistry of Brewing (Spring 2016). The Chemistry Minor

requires students to take one semester of Organic Chemistry, and an additional 9 credits of upper division Chemistry course work.

b. Program Currency

The primary change in the Chemistry curriculum since the prior program review has been the addition of the Bachelor's degree in Biochemistry in 2015. The addition of the Biochemistry Major has boosted overall program enrollment, better prepares pre-medical chemistry majors for the next stage of their education, and has expanded the depth of our overall chemistry curriculum. From a practical standpoint, this change has also added CHEM 316: Biochemistry II to the overall curriculum. This course is required for Biochemistry majors, and it is a restricted elective in the Chemistry major sequence.

In addition, the Department has permanently implemented the proposed curriculum changes described in the 2012 Program Review. Instrumental Analysis, the corresponding laboratory course, and Inorganic Chemistry are now offered every year. Instrumental Analysis provides students in-depth training in absorbance spectroscopy, elemental analysis (AA and ICP-OES), NMR spectroscopy, instrumental chromatography techniques, and materials analysis. The Inorganic Chemistry Course (CHEM 351) covers fundamental theories of chemical bonding, molecular structure, symmetry elements, basic group theory, coordination complexes, and ligand field theory. The one-credit Communicating in the World of Chemistry course (CHEM 442) is also offered every year as a companion course to Advanced Laboratory (CHEM 341). In CHEM 442, students receive training, experience, and feedback in professional science presentations, resume writing, job-hunting skills, and scientific writing. The Communicating in the World of Chemistry course was added to address needs highlighted in response to our institutional assessment data, and the predicted needs of our graduating students. Lastly, the Chemistry Minor requirements were changed in 2012 to the course sequence described above. The new requirements for the minor are more flexible than they had been previously, and they now better accommodate students who are majoring in other sciences, or those who have a wide range of interests. The Minor now simply requires students to take 9 chemistry upper division credit hours above and beyond the first semester of Organic Chemistry I and Organic Chemistry I Lab (CHEM 311/311L).

c. Description of Program Delivery

All chemistry courses are delivered in traditional classroom and lab settings on the CMU main campus. General Chemistry is typically taught in sections of ~70 students, while Organic Chemistry lecture sections typically have section sizes of 45 - 60 students. General and Organic Chemistry Laboratory sections are capped at 24 students and 22 students, respectively. Upper division courses have variable enrollments (typically ranging from 8-25 students) depending on demand. Upper division Laboratory courses (Analytical, Instrumental Biochemistry, and Advanced Lab) are typically capped at 16 students per section. All chemistry laboratory courses are taught as one credit courses (three hours of laboratory instruction per week), with the exception of CHEM 341 (Advanced Laboratory) which is a two-credit laboratory course (two three-hour instruction periods per week).

Instructors use a variety of delivery approaches to suit their strengths, including traditional lectures, small-group problem solving, and flipped classroom settings, as they deem appropriate. Two chemistry courses have been taught in other venues. CHEM 100 (Chemistry and Society) has been delivered online seven times and as a hybrid course six times since 2012, and has been taught in a traditional setting every spring semester since 2012 by a part-time instructor at the CMU campus in Montrose. CHEM 121, 121L Principles of Chemistry has been taught by high school teachers with CMU approval and oversight at Ridgway High School (twice) and Bridges High School (once) as part of the Early Scholars program between 2012 and 2013.

3. Analysis of Student Demand and Success

a-d. Enrollment, Credit Hours, and Graduates

Chemistry experienced a 27% increase in the number of majors, from 81 in AY13 to 103 in AY18 (Table 2, including students with provisional baccalaureate status). Sixty-four majors graduated during this period, for an average of just over ten per year (10.7/year). The number of graduates was 5, 10, 14, 15, 6, and 14 for AY13 through AY18, respectively. An average of 10.7 chemistry graduates per year for AY13 through AY18 is a significant increase when compared to the number of chemistry graduates during AY08 through AY12 (an average of 3.2 graduates per year). The number of chemistry graduates over the past six years, however, seems to be relatively stable. While there was a dip in graduates during AY17, this could arise randomly due to students taking different amounts of time to graduate. Indeed, when this year is averaged with any year or combination of years between AY15 and AY18, we still average at least 10 graduates per year. Thus, we conservatively envision about 10 chemistry graduates per year in the near future.

The number of students declaring a minor in chemistry increased from 28 to 117 over the reporting period, which is a 318% increase. In addition, the number of minors completed increased from 8 to 27 (a 238% increase) from AY13 to AY18. Over the past six years, a total of 124 students completed a chemistry minor for an average of 20.7 per year.

Table 2. Summary of Majors and Graduates by Degree Program.

Degree Program	Number of Students Declared				Annual Number of Graduates			
	Annual Average ¹	AY 13	AY 18	Percent Change AY13 to AY18	Low	High	Total	Average
BS Chemistry	84.2	80	100	+25	5	15	64	10.7
Minor Chemistry	77.2	28	117	+318	8	33	124	20.7
Prov Bacc ² Chemistry	1.8	1	3	-	-	-	-	-

¹Average over the five academic years from AY13 through AY18.

²Provisional baccalaureate status began in AY11.

While we do not expect significant increases in the number of chemistry majors and minors in the near future, our program has experienced significant growth since our last program review (AY08-AY12). This growth has put a significant strain on our department. Faculty contact hours are high

(typically 14-16 contact hours/week) and class sizes have considerably increased (current enrollment caps on General Chemistry I courses are 78 students/section). Both of these issues stem at least partly from our need to cover lab courses. Our lab courses can only accommodate 12 – 24 students, depending on the course, and each lab involves three contact hours but only counts for two faculty teaching credits.

As a result of substantial program development, our department has grown significantly over the past several years. In 2011, our department consisted of three tenured/tenure-track professors and one full-time instructor. Currently, our department consists of five tenured/tenure-track professors and three full-time instructors and we are in the process of hiring a tenure-track biochemistry professor. In addition, we have several part-time instructors teaching introductory chemistry labs. Despite the increase in faculty members, our contact hours and class sizes remain high, which is an issue for several reasons. Our program has interest in eventually offering an ACS-certified chemistry degree. Our faculty contact hours, however, are currently too high to comply with an ACS-certified degree. High contact hours take valuable time away from guiding undergraduate research, for example, which is an essential aspect of our curriculum. Large class sizes are an issue as well. They put a strain on instructors in terms of time spent helping students outside of class and grading. The extra time devoted to grading is substantial because CMU has a policy of not using teaching assistants. Large class sizes also take away from a student's education, as it is much more difficult to get individual attention and guidance in a large class. It is an important mission of Colorado Mesa University to offer intimate classes with small student to faculty ratios. This is simply not the case in our lower-level chemistry courses and even in our Organic Chemistry courses (enrollment caps of about 60 students/section) and Biochemistry course (enrollment cap of about 50 students). Lowering contact hours of tenure-track faculty and decreasing class sizes would be greatly beneficial to the function of our department and the success of our program.

Average course enrollments and student credit hours both increased by roughly 30% from AY13 to AY18 (Table 3). These enrollment numbers significantly increased when compared to our previous program review, which took place AY08-AY12. Student enrollment averages from AY13-AY18 increased by 95% when compared to average enrollments over the previous program review (AY08-AY12). On average, about 80% of the enrollment in chemistry occurred in 100-level courses during AY13-AY18. Most of this enrollment comes from other degree programs that require their majors to complete chemistry courses at this level. About 21% of chemistry enrollment (and 24% of scheduled credit hours) occurred in 300 and 400-level courses from AY13-AY18. This is a slight increase in student enrollment in upper division chemistry courses from our previous program review. Specifically, during AY08-AY12, on average about 17% of student enrollment was in upper division chemistry courses. This slight increase is due to the increased number of chemistry majors in recent years.

e. Student Successes and Recognition

Of our sixty-four graduates over the past six years, twelve enrolled in graduate school, one enrolled in medical school, two are working in the medical field and pursuing medical school, two are in pharmacy school, one is teaching high school chemistry, and one is enrolled in a post-baccalaureate teaching program. Nineteen graduates reported employment in chemistry or

Table 3. Summary of Chemistry Enrollment and Credit Hours by Level for AY13 through AY18.

Chemistry	Annual Average AY13 to AY18	AY13	AY18	Percent Change AY13 to AY18
Enrollment by student level				
Freshman	373	320	467	+46
Sophomore	686	580	759	+31
Junior	512	495	572	+16
Senior	749	642	820	+28
Non-degree	14	4	21	+4
Total	2,334	2,041	2639	+29
Student credit hours by student level				
Freshman	949	808	1190	+47
Sophomore	1778	1496	1968	+32
Junior	1332	1277	1503	+18
Senior	1917	1670	2110	+26
Non-degree	36	10	56	+460
Total	6,012	5,261	6,827	+30
Enrollment by course level				
100	1842	1668	2118	+27
200	9	55	-	-
300	451	294	481	+64
400	32	25	40	+60
Total	2334	2042	2639	+29
Student credit hours by course level				
100	4837	4371	5573	+27
200	18	109	-	-
300	1101	725	1184	+63
400	57	59	70	+19
Total	6013	5264	6827	+30

a closely related field and seven reported employment in other areas. The rest did not have an employment offer as of graduation or have not reported back on the outcome of their employment searches.

Over the past six years, thirty chemistry students presented posters and four students gave oral presentations at the CMU Student Showcase. In addition, seventeen students presented posters at national American Chemical Society (ACS) conferences across the country. Furthermore, one student presented a poster at a regional ACS meeting in Richland, WA and one student presented a poster at the International Conference on the Environmental Effects of Nanoparticles and Nanomaterials (ICEENN) in Golden, CO. The number of undergraduate research presentations dramatically increased since the last program review (AY08-AY12), during which time only one chemistry student presented a research poster.

4. Program Resources

a. Faculty

Faculty headcount, rank, and qualifications – As indicated in Table 4, the Chemistry Program has nine full-time faculty in AY19, with five (54%) being tenured or tenure-track. One tenure-track faculty has resigned in the review period (Dr. Kimberly Sperling, a biochemist), and one non-tenure-track faculty member has resigned. The program is conducting a search for a tenure-track biochemist; if successful, we will have six tenured or tenure-track faculty (67%) and three non-tenure-track faculty.

Table 4. Composition of chemistry faculty in AY13 and AY19.

	AY13	AY19
Tenured	1	4
Tenure-track	3	1
Full-time, non-tenure-track	1	4
Total	5	9

The program also has a full-time lab coordinator who teaches up to three labs per year. There are three part-time instructors employed teaching four sections of lab during the Fall 2018 semester; all three have a master's degree or equivalent. The Chemistry Program has previously used lab instructors with only a bachelor's degree in chemistry; as of Fall 2017, all lab instructors must have a master's degree in chemistry or a related field. A bachelor's in chemistry (or related field) plus 18 semester hours of graduate work in chemistry may be substituted for this requirement. Alternatively, it may be possible to fulfill this requirement with five years of work experience depending on the responsibilities involved in the employment. This policy change was a result of alignment with current Higher Learning Commission requirements for instructor qualifications.

All current tenured and tenure-track faculty have a Ph. D. in chemistry. Of the four full-time non-tenure-track faculty, three have a Ph. D. in chemistry or related field, and one has a master's degree.

A listing of full-time faculty members and their vitae are in the appendix.

The change in instructor qualification requirements in Fall 2017 had a major impact on the Chemistry Program. During AY14, 14 sections of laboratory were taught by part-time instructors. During AY18, only five sections of lower-division laboratory were taught by part-time instructors. We have very few qualified individuals living in the immediate area who are willing to teach a lab course for the offered salary (\$750 per lab section per semester for a master's degree holder). The program is fortunate that a new full-time, non-tenure-track faculty line was added in Fall 2017 so that we can continue to offer lab courses with a reduced reliance on part-time instructors.

Credit hour generation—Full-time equivalent students (FTES) and full-time equivalent faculty (FTEF) are shown for academic years 2013 and 2018 in Table 5. Full-time equivalent students increased faster than full-time equivalent faculty; the ratio of FTES to FTEF for chemistry

increased 8.7%. The numbers for AY18 and AY13 are included to emphasize change over time; a year-by-year comparison is shown in Appendix I.

Table 5. Full-time Equivalent Students and Faculty for AY13 and AY18.

	AY13			AY18			Percent Change in FTES:FTEF from AY13 to AY18
	FTES ₁	FTEF ₂	FTES:FTEF ₃	FTES ₁	FTEF ₂	FTES:FTEF ₃	
Chemistry	141.8	5.6	25.4	227.8	8.3	27.6	+8.7

¹Full-time equivalent students

²Full-time equivalent faculty

³Ratio of FTES to FTEF

Table 6 compares student credit hours generated by faculty type over the period of the review. In AY18, tenured and tenure-track faculty generated 57% of the student credit hours. The decrease between AY17 and AY18 is partially explained by the resignation of a tenure-track biochemist and her temporary replacement with a full-time temporary instructor. The percent of part-time faculty has fallen significantly. In 2014-2015, the hire of both a new tenure-track faculty member (Dr. Lohse) and a new full-time temporary instructor line reduced the reliance on part-time instructors. In 2017-2018, the hire of an additional full-time temporary faculty line further reduced this percentage. Also in 2017-2018, all instructors for labs needed a master's degree or 18 credits of graduate-level chemistry to teach labs. Even with three new full-time faculty lines since AY13, the FTES:FTEF ratio has increased due to increased demand for chemistry courses.

Table 6. Percentage of Credit Hours Generated by Each Type of Faculty, AY14-AY18.

	Total Student Credit Hours	Tenured/Tenure-Track	Full-Time Temporary	Part-Time and Lab Coordinator
2013-2014	5853	69%	17%	14%
2014-2015	5866	69%	26%	5%
2015-2016	5931	71%	24%	5%
2016-2017	6336	71%	23%	6%
2017-2018	6827	57%	40%	3%

Success and recognitions

One chemistry faculty member (Dr. Richards) has been awarded the Distinguished Faculty in Teaching award (2004).

Dr. Weinberg was awarded the 2015 Maverick Award for Academic Adviser of the Year. He chaired an oral presentation section at the Fall 2017 National Meeting of the American Chemical Society. He was awarded an ACS Petroleum Research Grant for \$50,000, most of which was used to support stipends for undergraduate researchers. Some of the grant, along with department

matching funds, was used to purchase an inert atmosphere glove box. He has sponsored five student posters at national ACS meetings. Dr. Lohse has been a co-author on 14 peer-reviewed publications, including three that contain data gathered at CMU. He has also been the author of a book chapter. Dr. Sperling was a co-author on 2 peer-reviewed publications, and she earned a research starter grant from The American Society of Pharmacognosy. Dr. Ayers was an investigator on a Smart City Air Challenge grant in Fall 2016. Although it was not funded, it was awarded an honorable mention by the EPA. Dr. D'Andrea presented his work at the American Society of Brewing Chemists national conference in 2014. All faculty have sponsored student posters in the annual CMU Student Showcase. Dr. Wolff, a full-time temporary instructor, has been awarded three U.S. Patents.

Advising—Students who decide to major in chemistry or biochemistry contact the administrative assistant in the Department of Physical and Environmental Sciences, who enters their choice into the campus-wide data base and assigns them to a tenured or tenure-track professor for advising. We accommodate student requests for a specific advisor provided that the individual is not overloaded with advisees. Otherwise, the administrative assistant makes assignments so as to keep the advising loads roughly equal. Our professors each advise roughly fifteen to thirty students, depending on the discipline and year. Students are not required to see an advisor, but the majority of our active majors do.

Service - Faculty in the Chemistry Program have been active in service to the University over the review period. All tenured and tenure-track faculty have participated in university-wide committees and chemistry search committees, with several serving in leadership positions on University committees. Dr. Richards chaired the Criterion 5 subcommittee for the recent HLC re-accreditation assurance review. Dr. Ayers has served as the faculty representative from CMU to the Colorado Faculty Advisory Council for four years. He also served as Faculty Senate Vice President for two years. Dr. Weinberg was recently elected chair of the campus assessment committee.

Measures of teaching effectiveness—Most faculty members have students fill out semester-end evaluations in all of their classes. Our campus-wide course evaluation form includes twelve positive statements, such as: “The teaching methods/techniques used by the professor are effective”; “The exams and assignments are consistent with course content”; and “The course is appropriately challenging” (Appendix II). Students assign a rating to each statement ranging from “1—strongly disagree” to “5—strongly agree”. A median response is determined for each statement, and an overall median of medians and arithmetic mean are calculated for all twelve statements.

The tenured and tenure-track professors receive mostly 5's as the median of medians for their courses, with most averages ranging from about 4.25 to 4.75. Several professors routinely receive 5's as the median of medians for all of their courses. Most of our full-time temporary instructors receive 4's as the median of medians, with averages typically ranging from about 3.75 to 4.25. Our part-time instructors tend to receive numbers similar to the full-time temporary instructors. However, some full-time temporary and part-time instructors score as well as the tenured and tenure-track professors on these evaluations.

b. Financial Information

Internal funding—The department head submits a budget request to the administration each January for the upcoming fiscal year, which begins on July 1. Inasmuch as it has been many years since we have had to endure budget cuts, our working assumption is that we will receive the same amount as in the preceding year. Requests for one-time funds or base-building increases are approved based on justification and availability of funds.

Requests may also be made outside of the normal cycle when unusual or emergency situations occur. An example of this occurred during the summer of 2018 when our nuclear magnetic resonance spectrometer experienced a catastrophic failure. The estimated cost for repair was at least \$53,000, which exceeded our budget. We requested funds from the administration to make the repair, but also suggested that a better approach would be to replace the instrument. The administration agreed to purchase a new spectrometer for \$265,000.

Chemistry does not collect lab fees for our courses. Instead, the administration allocates an amount to what would have been collected as fees based on enrollment in the preceding year.

Table 7 shows costs for each program in AY12 and AY17. Hourly compensation is for student assistants. Other current expenses include supplies, software, equipment purchase and repair, copier lease, and similar costs. Travel costs in the budget allocation category refer to faculty travel. Internal charges are for phones and phone calls.

The University has an internal funding mechanism using Faculty Professional Development Grants. These grants are for amounts in the \$1000 - \$2000 range, and they are used to buy supplies or help pay for conference travel. Four faculty members have applied for and been awarded these grants during the review period.

External funding—Members of the chemistry faculty have applied for external funding to support their research at CMU.

- Dr. Weinberg submitted an American Chemical Society Petroleum Research Fund Undergraduate New Investigator grant four times. He was awarded \$50,000 in 2014. The award was used to fund undergraduate research student stipends for 18 students, provide travel funds for students for ACS national meetings, and purchase a glove box.
- Dr. Sperling submitted NSF major research instrumentation proposals (2014, 2015) for an LC/MS system. Dr. Weinberg and Dr. D'Andrea submitted projects for these proposals. These proposals were not funded.
- Dr. Ayers was an investigator on an EPA Smart Cities grant to obtain and analyze data in a citizen science air quality project. The proposal was given an Honorable mention, but it was not funded.

Table 7. Expenditures in AY12 and AY17.

	AY12	AY17
Expenditure of Budget Allocation		
5000 Classified Wages		5,158
51460 Classified Benefits		1,187
52560 Regular Wages	264,513	421,589
52860 Part-Time Wages	54,298	100,221
54160 Benefits	90,227	141,430
Hourly Compensation	1,182	715
Other Current Expenses	18,324	23,955
Travel	456	4,307
Internal Charges	2,805	3,564
Total	431,805	702,161
Expenditure of Course Fees		
Other Current Expenses	15,990	27,814
Total	15,990	27,814
Total Expenditure	447,795	729,975
Student Credit Hours Generated	4,253	6,336
Dollars per Credit Hour	\$105	\$115

c. Library Assessment

The faculty view the strengths of our library holding to include access to SciFinder Scholar and access to recent issues of many journals. A weakness is access to older issues of many journals, including *Science* and ACS Legacy Archives. The interlibrary loan program often provides articles not held in the collection within 48 hours. While some access to these articles is commendable, this delay can greatly hinder research, grant-writing, and the composition of publications, especially since these activities commonly necessitate searching for a reference within a reference within a reference, etc.

The assessments prepared by the Tomlinson Library are shown in Appendix III along with periodical lists. An excerpt from the report is included here.

Strengths: Journals are the primary resource for CMU chemistry faculty and majors. The indexing and full-text provided by CMU's database subscriptions provide access to much current scholarship in the field strengthening the Library's resources for Chemistry research. While not extensive, the Library's reference collection supports the need for authoritative concise information. The Library's e-book collection is strong in the sciences and chemistry is well represented. E-books on both general and esoteric topics are readily available. The Library's DVD and Films on Demand collections provide many media resources. The circulating chemistry book collection receives regular use and sufficiently supports coursework for undergraduate Chemistry majors.

Weaknesses: As the circulating collection is further developed, consideration should be taken to order additional materials in areas that appear less well represented, such as biochemistry, which is one of the two concentrations offered by the program.

d. Physical Facilities

Lecture courses are distributed among all of the classroom buildings on campus. All classrooms have computers, network and internet access, document cameras, and projection screens. Laboratory work is conducted in the Science Lab Building and Wubben Hall, which are both part of the Wubben-Science Center. The labs were completed and occupied in 1997 and renovated in 2011. The chemistry laboratory facilities are on the third floor of the Science Lab wing of Wubben-Science. Chemistry facilities include:

- Two 24-student labs for general chemistry, each with six two-person fume hoods
- One 22-student lab for organic chemistry with hood space for all students and for waste
- One 16-student lab for other courses with three two-person hoods
- Two labs for faculty and student research, with four fume hoods and space for 14 people
- An instrument room housing most of the department's analytical instrumentation
- A stockroom and prep room
- A storage room on the first floor of Wubben Science for solvents

Student and faculty research space is limited. We currently have room for about 14 people with four fume hoods. We currently have five tenured and tenure-track faculty conducting research. Each faculty member has about 1 to 4 students doing research each semester; sometimes, a faculty member may have as many as eight students working in the lab during a semester. We hope to have a successful search for a tenure-track biochemist this year, and we will then have six faculty members with several students each. A non-tenure-track faculty member (Dr. Wolff) is also pursuing a research project. Assuming an average of two to three students per faculty member in a semester, we will have 21 people working in the research labs on any given day. Even if a student is not working in the lab on a given day, space is still required for their project. Space for projects, in particular hood space, is limited. Any additional growth in student numbers would significantly limit our ability to have space for student research projects. Faculty are generally collegial and willing to share the limited space, but it is a serious concern of the faculty as we move forward.

Space for upper division labs is also limited. We currently operate biochemistry, analytical, instrumental, and advanced labs out of our 16-student lab space. This lab space accommodates these diverse needs at this point in time; however, any growth will put strain on this space. Although the space is only occupied 15 hours per week in the fall and 12 hours per week in the spring, many of the projects in these upper-division labs are multi-day experiments, and significant space is required for students to keep experimental apparatus set up for several days or even weeks. If we needed to offer more sections of labs, particularly advanced lab or analytical lab, we may have trouble finding room for student experimental apparatus. We have also considered adding a physical or inorganic chemistry lab to our curriculum; however, these labs would need to share the same space, and the addition would be challenging.

Space is also limited for 100-level chemistry labs. The number of 100-level labs has grown over the review period (Table 8). These 100-level labs (and organic chemistry, CHEM 311 and 312) are typically capped in the 22-24 student range and require one of our larger labs. In Fall 2018, we currently offer 23 sections for four different lower-division laboratories. Generally, all of the sections of one lab class are set up in one laboratory room for the week. One of the classes (CHEM 151L: Engineering Chemistry Laboratory) must currently move from one lab room to another mid-week, adding to the preparation and set-up time of our laboratory coordinator. We currently use the labs almost every morning and afternoon during the week, and we use the labs several evenings, too. Because our lab spaces are close to full utilization, we anticipate having trouble meeting additional lab demand. Lab demand for CHEM 151: Engineering Chemistry will almost certainly increase as the engineering programs gain a larger foothold on campus. Demand for other labs may increase if programs requiring these labs (Environmental Science, Biology, Geoscience, Exercise Science, and Chemistry) experience increases in enrollment.

Table 8: Number of sections of lower-division and organic (CHEM 311) labs.

Course	Fall 2012	Fall 2015	Fall 2018
CHEM 121	6	6	6
CHEM 131	11	12	10
CHEM 132	2	2	3
CHEM 151	0	0	4
LOWER DIVISION TOTAL	19	20	23
CHEM 311	3	4	5
TOTAL ORGANIC AND LOWER	21	24	28

e. Instructional Resources

Both theory and experiment are essential components of any chemistry curriculum, and experimental work requires specialized scientific equipment. With complex instruments come costs for operation and maintenance. For example, the older nuclear magnetic resonance spectrometer required about \$12,000 per year in liquid helium and liquid nitrogen. We anticipate

that a new NMR may require a similar cryogen budget. The cost of bringing a service person from the manufacturer to campus for this and other instruments can easily go as high as \$2,500 or more. One of the two general chemistry labs is outfitted with computers and interfaces for computerized data collection and analysis. The program is well equipped with standard glassware and other apparatus (e.g., balances, melting point apparatus) needed in general chemistry and organic chemistry courses. The program is also very well equipped with instrumentation that is used in quantitative analysis, instrumental analysis, advanced lab, and research. Holdings include:

- An inductively-coupled plasma atomic emission spectrometer
- A high-pressure liquid chromatograph with UV-visible and fluorescence diode array detectors
- A UV/Vis spectrometer
- An ion chromatograph
- An x-ray fluorescence spectrometer
- A Fourier-transform infrared spectrometer
- A gas chromatograph with a thermal conductivity detector
- A potentiostat with electrodes for running cyclic voltammograms and controlled potential electrolyses
- Three rotary evaporators
- A supercritical CO₂ extraction apparatus

Since the last program review, we have added:

- An Ocean Optics portable UV/Vis spectrometer
- An inert atmosphere glovebox
- A Thermo Scientific ozone analyzer and ozone calibrator
- Another Fourier-transform infrared spectrometer (used)

Additionally, the CMU administration has agreed to purchase a new nuclear magnetic spectrometer that will replace an older 300 MHz NMR. The new 400 MHz instrument will have an autosampler, allowing students to program a run asynchronously. Students will also be able to work up data from their personal computers. All chemistry majors have the opportunity to use any of these instruments.

f. Efficiencies in Program Operations

We strive for efficiency in our operations. For example, equipment is shared as needed among the different courses, labs, professors, and research projects. All of the instructional labs are used for multiple courses. The ion chromatograph, inductively-coupled plasma atomic emission spectrometer, and x-ray fluorescence spectrometer housed in chemistry are shared with the environmental science program. Our chemistry lab coordinator is an instructor for up to three labs each year.

5. Student Learning Outcomes and Assessments

a. Student Learning Outcomes

In the spring semester of 2013, the chemistry faculty composed and instituted the programmatic student learning outcomes (SLOs) listed below. These SLOs were designed to contribute toward the Chemistry Program's mission and goals as well as to aid students in achieving the institution-wide SLOs. Each programmatic SLO aligns with one or two institutional SLOs; the associated institutional SLOs are listed in parentheses at the end of each programmatic SLO.

Student Learning Outcomes (SLOs) for the Chemistry Program

A student who completes the B.S. in Chemistry will have the ability to:

1. Demonstrate fluency in the concepts from the major fields of chemistry (inorganic, organic, physical, and analytical...) (Specialized Knowledge).
2. Utilize mathematics to solve chemical problems (Quantitative Literacy/Critical Thinking).
3. Employ proper experimental techniques (Applied Learning).
4. Interpret chemical information from peer-reviewed publications (Information Literacy).
5. Communicate chemical topics effectively, both verbally and in writing (Communication Fluency).

In fitting with the mission statement of the Chemistry Program, these SLOs were chosen so that Chemistry Program graduates will be well-prepared for graduate schools, medical programs, industry jobs, and a variety of other positions within the sciences. Furthermore, these SLOs are set up to give students the skills necessary for on-going independent learning beyond the classroom. The curriculum map for the Chemistry Program indicates the courses in which these SLOs are covered, and it is included in Appendix IV. The program is set up so that each student takes multiple courses associated with each SLO.

As a result of aligning the programmatic SLOs with the institutional SLOs, students gain general skills in Critical Thinking, Communication Fluency, Applied Learning, and Quantitative Literacy that prepare them for a wide variety of positions outside the sciences. In the chemistry courses that serve the University's Essential Learning Curriculum, the students are given tools to help them progress toward at least two of the University's Essential Learning SLOs: (1) Demonstrate investigative and analytical thinking skills to solve problems and (2) Select and use appropriate information or techniques in an academic project. These courses also generally cover the

University's Essential Learning SLO associated with demonstrating quantitative literacy. The chemistry courses that are part of the University's Essential Learning curriculum are CHEM 100, 121, 121L, 131, 131L, 132, and 132L.

b – d. Assessment of Student Learning Outcomes, Student Satisfaction, and Program Improvements

The SLOs are assessed via tests, specific test questions, reports, presentations, laboratory work, data analyses, and proposed procedures. These assessments, along with their results and resultant actions, are described in the Program Outcome and Assessment Report (Appendix V). Each SLO is assessed at a minimum of two levels from the Beginning, Developing, and Advanced Levels. By assessing at more than one level, we are able to get a better picture of where issues may be occurring with respect to students' attainment of the SLOs. Beyond the assessments described in the Program Outcome and Assessment Report, the Chemistry Program also assesses itself through alumni surveys and through reflection on how readily students are able to obtain positions following graduation. The Chemistry Program faculty generally receive the compiled assessment data and meet to discuss it once or twice a year. Since the beginning of 2016, a timeline has been kept of when the chemistry faculty have reviewed and discussed assessment data, and this timeline is included at the beginning of the Program Outcome and Assessment Report (Appendix V).

SLO #1: Demonstrate fluency in the concepts from the major fields of chemistry (inorganic, organic, physical, and analytical...) (Specialized Knowledge).

At the advanced level, SLO #1 is assessed using the ETS Major Field Test (MFT). This is a standardized chemistry exam for senior students that is administered at 100 – 250 self-selecting schools across the country. It assesses students' overall chemistry knowledge and problem-solving skills, and it scores them on how well they perform with respect to physical, organic, inorganic, and analytical chemistry. We require all of our senior chemistry students to take this exam during the semester before they graduate.

The results of the MFT are shown below in Tables 9 and 10. Table 9 compares our school's average scores with other schools' average scores, while Table 10 shows in what percentile our students' median scores fall. In both cases, the percentiles are shown for the overall exam and for the subsections of physical, organic, inorganic, and analytical chemistry.

From 2012 to 2016, the median scores of our students and our institutional averages were generally above, and commonly well above, the 50th percentile of schools participating in the chemistry MFT. Our percentiles dropped dramatically in academic year 2016 – 2017 and stayed lower than previously in 2017 – 2018. Our program did not undergo any major changes between the Spring and Fall of 2016, but the ETS Major Field Test was changed at that time along with the number of schools and students used for determining the percentiles. In coming up with the percentiles for 2016 – 2017 and for 2017 – 2018, there was a dramatic decrease in the number of students that participated from 8,836 students to 2,694 students, and there was also a decrease in the number of institutions from 220 to 143. This makes it likely that the change in our percentiles for academic years 2016 – 2018 as compared to 2012 – 2016 is due to a change in the schools and students participating in the exam as opposed to a change in our program. It should also be noted that the

schools participating in the MFT are in charge of which of their students take the exam, and they are also in charge of whether or not there is any reward for performing well on the exam. This could be detrimental to how well our school performs relative to other schools because we have all of our students take the exam, and we do not offer any incentives for our students to perform well. We now plan to explore alternatives to the ETS MFT in order to get a better perspective on how our senior students are performing relative to other undergraduate students.

Table 9. ETS Major Field Test (MFT) results based on national percentiles for institutional averages. These were obtained by taking the average scores of graduating CMU chemistry majors and looking at which percentiles these averages fall into relative to the averages for other participating institutions. a. Using the MFT scores for all graduating CMU chemistry majors. b. Using only the MFT scores of graduating CMU chemistry majors that have taken at least one year of physical chemistry, one year of organic chemistry, one semester of upper division inorganic chemistry, and one semester of analytical chemistry.

a. MFT Results for All CMU Chemistry Graduates

Academic Year	# students	National Percentiles for Institutional Averages				
		Overall	Physical	Organic	Inorganic	Analytical
12 to 13	6	68	70	65	56	73
13 to 14	12	60	68	55	40	69
14 to 15	11	85.5	91	82	80	84
15 to 16	14	69	87	45	52	80
16 to 17	6	17	29	21	18	10
17 to 18	15	45	59	49.5	42	45

b. MFT Results for CMU Chemistry Graduates Who Have Taken at Least 1 Year Each of Physical and Organic Chem. and 1 Semester Each of Inorganic and Analytical Chem.

Academic Year	# students	National Percentiles for Institutional Averages				
		Overall	Physical	Organic	Inorganic	Analytical
12 to 13	3	86	89	83	88	88
13 to 14	5	85	91	76	81	87
14 to 15	9	91	95.5	90	88	88
15 to 16	9	69	92	33	53	87
16 to 17	3	30	50	23	36	26
17 to 18	9	54	81	55	66	40

Table 10. ETS Major Field Test (MFT) results based on national percentiles for median students. These were obtained by taking the median scores of graduating CMU chemistry majors and looking at which percentiles these scores fall into relative to the scores of participating students nationwide. a. Using the MFT scores for all graduating CMU chemistry majors. b. Using only the MFT scores of graduating CMU chemistry majors that have taken at least one year of physical chemistry, one year of organic chemistry, one semester of upper division inorganic chemistry, and one semester of analytical chemistry.

a. MFT Results for All CMU Chemistry Graduates

Academic Year	# students	National Percentiles for Median Students				
		Overall	Physical	Organic	Inorganic	Analytical
12 to 13	6	68	70	48	52	70
13 to 14	12	56	67	60	52	56
14 to 15	11	72	70	66	66	70
15 to 16	14	66	76	33	52	64
16 to 17	6	28	41	30	23	26
17 to 18	15	39	52	44	30	49

b. MFT Results for CMU Chemistry Graduates Who Have Taken at Least 1 Year Each of Physical and Organic Chem. and 1 Semester Each of Inorganic and Analytical Chem.

Academic Year	# students	National Percentiles for Median Students				
		Overall	Physical	Organic	Inorganic	Analytical
12 to 13	3	70	76	66	78	70
13 to 14	5	80	85	66	60	64
14 to 15	9	77	81	76	78	70
15 to 16	9	63	81	40	52	76
16 to 17	3	34	52	34	23	33
17 to 18	9	39	59	34	40	41

Regardless of the issues associated with comparing our MFT scores to the scores of other schools, we can use the scores to get insight into the relative performances of our students with respect to physical, organic, inorganic, and analytical chemistry. Our students consistently performed better in physical chemistry than in the other fields of chemistry. This was observed both for our students overall and when only looking at students who had at least taken 1 year each of physical chemistry and organic chemistry and at least 1 semester each of inorganic chemistry and analytical chemistry. It should be noted that students majoring in chemistry with a concentration in biochemistry (first offered in 2015) are only required to take the first semester of physical chemistry, and they are also not required to take inorganic chemistry. The chemistry major with a chemistry concentration requires the second semester of physical chemistry and inorganic chemistry, but inorganic

chemistry was not required at all among chemistry majors until the 2013 – 2014 academic year. It can be seen that students' scores overall and in all fields of chemistry generally increased for students who have at least taken 1 year each of physical chemistry and organic chemistry and at least 1 semester each of inorganic chemistry and analytical chemistry. While increases in students' scores with respect to inorganic chemistry and physical chemistry are likely in part due to students getting additional course material in these areas, the fact that their scores increased overall is likely in part because better performing students are more likely to choose this path. Taking all of this into consideration, it seems that our students are generally performing reasonably well across all fields of chemistry, regardless of the pathway that they choose.

While the Major Field Tests assess students' fluency with respect to the major fields of chemistry (SLO #1) at the Advanced Level, this SLO is also assessed at the beginning and developing levels using final exams in CHEM 132: General Chemistry II, CHEM 312: Organic Chemistry II, and CHEM 315: Biochemistry I. In order to obtain a clear picture of how all the students at these levels are performing, a variety of statistics are used to evaluate the final exam scores. Specifically, we look at the mean, median, mean for the scores in the top 5%, and mean for the scores in the bottom 5% of students who pass the course. These scores are assessed on a yearly basis, and the results are tracked over time. Beyond that, the final exam for CHEM 132: General Chemistry II is the American Chemical Society's General Chemistry exam for the full year of general chemistry. This is a standardized exam that lets us compare the scores of students from Colorado Mesa University with the scores of students across the country.

The students' scores on the final exams for CHEM 132: General Chemistry II, CHEM 312: Organic Chemistry II, and CHEM 315: Biochemistry I seem to indicate that the students are achieving satisfactory levels of fluency in these subjects at the respective levels (Beginning and Developing) being tested. Both the average and median of our students' scores on the General Chemistry II final exam are generally close to the national averages (46th to 56th percentiles). This indicates that our students are demonstrating fluency in general chemistry topics (part of SLO #1) at a reasonable level. While the Organic Chemistry II and Biochemistry I exams are not nationally standardized exams, the average and median scores were generally between 74% and 80%, indicating satisfactory levels of fluency in these fields.

Our initial assessment of Biochemistry I in 2014 was integral with respect to our students achieving satisfactory levels of biochemistry fluency in later years. The final exam scores of Biochemistry I students in 2014 fell below an acceptable level as the students struggled with material retention. In order to improve students' fluency in biochemistry (part of SLO #1), additional reviews were incorporated into the Biochemistry I course. In subsequent years, students' average and median scores on the exam increased by over ten percentage points, indicating a dramatic increase in students' fluency with respect to biochemistry.

SLO #2: Utilize mathematics to solve chemical problems (Quantitative Literacy/Critical Thinking).

SLO #2 is assessed at the beginning level in CHEM 131: General Chemistry I and at the advanced level in CHEM 341: Advanced Laboratory I. All chemistry majors are required to take both of

these courses. At the beginning level, this SLO is assessed with a stoichiometry problem on the General Chemistry I final exam. The same problem is used in all sections of this course, every semester. The problem includes a percent yield calculation and multiple unit conversions. Every year, the majority of students have answered this question correctly. Beyond that, the majority of the students answering incorrectly gave an answer which indicated that they skipped a single step in this multi-step problem. At the beginning level, we are thus confident that students are acceptably competent in utilizing mathematics to solve chemical problems (SLO #2) after completing CHEM 131: General Chemistry I.

At the advanced level, SLO #2 is assessed in our capstone laboratory course, CHEM 341: Advanced Laboratory I. Students are required to compose journal-style laboratory reports on a rate analysis project. Their reports are assessed with rubrics on scales of 1 – 5 for their application of mathematics to determine a rate law and for their application of their results to proposing a reaction mechanism. On these rubrics, a “4” indicates the desired capstone level of achievement, and a “5” indicates a master’s degree level. In the first year (2014) of this assessment, just under half of the students performed at a capstone or master’s level. In an attempt to get more students performing at the capstone and master’s levels, Advanced Laboratory I was revised to include a review of the relevant theory. This resulted in $\geq 50\%$ of the students performing at the capstone level. In 2015 and 2016, 100% and 64%, respectively, of students achieved the capstone level; however, this dipped to about 50% in 2017 and 2018. We are in the process of considering possible strategies for improving students’ achievement of this learning outcome at the advanced level. This could involve changes to any of the courses or curriculum associated with this SLO between CHEM 131: General Chemistry I and CHEM 341: Advanced Laboratory I. In case 2017 and 2018 are aberrations, we will wait to implement any changes until after we evaluate the assessment data from the Spring of 2019.

SLO #3: Employ proper experimental techniques (Applied Learning).

SLO #3 is also evaluated at the beginning and advanced levels. At the beginning level, students in CHEM 132L: General Chemistry II are evaluated for their success in synthesizing a compound and in determining rate law constants for a reaction of this compound. The students have been highly successful with the synthesis, and the relative standard deviations for their rate constants have been good to excellent. After observing a dip in relative standard deviations during 2015 – 2017, we determined that there were issues with some of the Spec20 instruments being used. The problematic instruments were repaired or replaced, and the students’ data improved significantly in 2017 – 2018.

At the advanced level, SLO #3 is assessed in CHEM 341: Advanced Laboratory I. This assessment involves students determining a rate constant from data collected in lab. The students’ rate constants are then compared to the literature values. In every year, the students’ rate constants have closely matched the literature values, indicating that the students have excellent lab technique and that they are performing very well with respect to SLO #3. This assessment is still leading us to revise our curriculum because, in their reports, only about half the students compared their rate constants to the literature values. We have thus encouraged the instructor of this course and the instructors of lower level courses to stress the importance of comparing experimentally obtained

data to published results. Beyond that, we are looking at incorporating this assessment or a similar one into the assessment of SLO #4.

SLO #4: Interpret chemical information from peer-reviewed publications (Information Literacy).

SLO #4 is being assessed at the developing level in CHEM 316: Biochemistry II and at the advanced level in CHEM 341: Advanced Laboratory I. In Biochemistry II, the students are required to write a review paper based on a biochemical topic of their choice and citing literature research. These reviews are then assessed using a rubric on a scale of 1 to 5. The average scores on these have been high (≥ 4.2), indicating that the students are generally doing an excellent job with respect to this SLO.

In CHEM 341: Advanced Laboratory I, SLO #4 is assessed by having students develop a procedure for the synthesis of a particular transition metal complex. This requires the students to synthesize and adapt the information from at least two peer-reviewed publications. The proposed procedures are then rated using a rubric with a scale of 1 – 5. When this was implemented in 2014, a few students sought out too much help from the instructor without putting in enough effort on their own. To address this issue, the chemistry faculty were asked to spend more time in each lab course asking students to explain why they are carrying out particular steps in experimental procedures. It was thought that this would encourage students to spend more time and effort thinking about experiments on their own. This approach seemed to be helpful because in 2016 through 2018 all groups of students have been able to at least formulate the majority of the procedure independently. Furthermore, most students are developing the complete procedure without any significant errors and without any significant amount of assistance from the instructor. Almost every year, there is a student that needs a significant amount of assistance, but this is to be expected, as the students who struggle are generally performing at a “C” level in the course. Overall, the students are successful in achieving this learning outcome.

SLO #5: Communicate chemical topics effectively, both verbally and in writing (Communication Fluency).

With respect to verbal communication, students’ oral presentations are assessed at the developing level in two courses (CHEM 431: Instrumental Analysis and CHEM 316: Biochemistry II) and at the advanced level in CHEM 442: Communicating in the World of Chemistry. Written communication is evaluated at the advanced level with a journal-style laboratory report in CHEM 341: Advanced Laboratory I.

Overall, the students performed well with respect to both the verbal and written components of this SLO. In Advanced Laboratory I, Communicating in the World of Chemistry, and the last two years of Instrumental Analysis, these scores were broken down further into categories such as Organization, Content, Slides (oral presentations only), Language/Grammar/Voice (oral presentations only), Answering Questions (oral presentations only), and Spelling/Grammar/Punctuation (written reports only). With respect to the oral presentations at the developing level, students struggled the most with organization; however, there was a significant

improvement in organization at the advanced level. This improvement likely occurs because CHEM 442: Communicating in the World of Chemistry involves a lot of time discussing the best practices for organizing oral presentations and written reports. In contrast, there was a drop in students' performances with respect to accuracy and depth of content when going from the developing level to the advanced level. Students also struggled with accuracy and depth of content in their written reports at the advanced level. The decrease in quality of the content in going to the advanced level could arise due to a variety of factors. First, it is important to note that the advanced courses cover a wider range of material and spend more time focusing on the organization and formatting of presentations and reports. Next, the content is likely more complicated at the advanced level. Finally, students taking Advanced Laboratory I and Communicating in the World of Chemistry often suffer from a lack of focus and dedication due to the proximity of graduation, while at the same time, these students often have a higher workload.

Regardless of the reason(s) for the decrease in communication content scores at the advanced level, we tried to address the issue in January of 2015 by asking the laboratory instructors in all courses to spend more time in lab helping students understand the experiments and asking the students to explain the experiments in depth. From 2016 – 2018, there was a significant improvement in written communication content scores, but there did not seem to be a significant increase in the oral presentation scores associated with content. We are currently exploring more options for improving students' performances with respect to accuracy and depth of content in their oral presentations and written reports.

When assessing students' written communication skills with respect to SLO #5, students now struggle the most with spelling, grammar, and punctuation. To address this issue, all of the chemistry faculty are being encouraged to include more writing assignments that require the students to use proper spelling, grammar, and punctuation and that involve the students getting faculty feedback on this front. The chemistry faculty are also pushing for a campus-wide reevaluation of the Essential Learning writing curriculum.

General Alumni Survey Results:

The alumni survey results are included in Appendix (VI). This document is organized to compare the responses of alumni from the Chemistry Program with the responses of Colorado Mesa University (CMU) alumni in general. Chemistry alumni generally answered significantly more positively than the CMU alumni overall regarding their education. Perhaps the only area in which chemistry alumni lagged behind CMU alumni overall was annual gross income (before taxes). This is probably at least partly because a large percentage (47%) of the chemistry alumni, who responded, are currently pursuing further education.

All of the chemistry alumni stated that they were "Very Satisfied" (73%) or "Satisfied" (27%) with their undergraduate education, and all of them rated the quality of their education within the Chemistry Program as "Very High" or "High". Our chemistry faculty take pride in the personal instruction, mentoring, and research that we offer, and this was reflected in alumni responses to the question, "While an undergraduate, about how often did you have conversations with faculty outside of class?" The response reflecting the most often, "Very Often (at least once a week)," was

chosen by 86.7% of chemistry alumni; whereas this response was only chosen by 37.5% of CMU alumni overall. All chemistry alumni responded that they at least had conversations with faculty outside of class “Occasionally (3-5 times per semester).” The specific alumni comments were mainly positive with statements that faculty were supportive and that the degree prepared them well. However, there were a couple of comments that we could use more equipment and newer equipment. Also, there was one suggestion that we should incorporate some materials science into the curriculum.

Alumni Employment and Graduate Positions:

In the alumni survey, all of the chemistry alumni that responded were working for pay, and all but one were working in a position related to chemistry. The chemistry alumni all responded that CMU prepared them “Very Well”, “More than Adequately”, or “Adequately” for their current careers. Because only about 15 out of 65 graduates responded to the survey, we also surveyed the chemistry faculty to find out the current positions of chemistry alumni. Based on the survey of faculty, we determined that at least 13 former students are working in chemical industry. Beyond that, four students are employed in chemistry or science related positions.

Based on the faculty survey, at least 19 students pursued further education after leaving CMU. Of these students, 9 attended chemistry Ph.D. programs. The Ph.D.-granting institutions that they attended included University of Illinois at Urbana-Champaign, Yale, University of Washington, Colorado School of Mines, Colorado State University, University of Utah, University of Rochester, University of Texas at Dallas, and University of Houston. Beyond that, students have pursued degrees in materials science, chemical engineering, geochemistry, and biomedical sciences. Another 2 students have gone on to pharmacy school, and one student went on to medical school. Two students pursued teaching certificates with one of these students eventually becoming a science teacher at a high school in western Colorado.

Of the 10 chemistry alumni that pursued further education and responded to the alumni survey, 5 responded that CMU prepared them “Very Well”; 3 responded with “More than Adequately”; 1 responded with “Adequately”; and 1 marked “NA” (not applicable). Among these students, 6 were pursuing doctorates; 3 were pursuing master’s degrees; and 1 was pursuing a post-baccalaureate certificate. All of these students either completed their educational program (3 students) or were in the process of completing their program (7 students); none of the students had failed to complete their program.

6. Future Program Plans

a. Vision

We strive for a Chemistry Program that offers personal instruction, mentoring, and research opportunities in order to motivate and prepare students for a wide variety of careers and graduate programs. We are using the program review process to assess and bolster our efforts on this front. Based on a variety of direct and indirect assessments (Section 5), we are generally meeting our goals; however, we are actually losing some personal instruction due to increased class sizes and due to higher than preferable faculty contact hours. To continue meeting the course demands of our students, to continue offering students individual attention in critical classes, and to continue improving our program, we will probably need at least one additional tenure-track faculty member, somebody qualified to teach Biochemistry I and Organic Chemistry. We will also need the installation of additional fume hoods, repairs to fix of our leaky roof, and various instrumentation and equipment updates and repairs.

b. Strengths and Challenges

One of our Chemistry Program's strengths is the equipment and instrumentation that we purchased during this program review cycle. We are in the process of purchasing a state of the art Nuclear Magnetic Resonance (NMR) spectrometer with a dewar for low temperature experiments and an autosampler. This will allow our students to obtain high quality NMR spectra without waiting for time on the instrument. It will thus revolutionize CHEM 341: Advanced Laboratory I and allow significant updates to CHEM 431: Instrumental Analysis and to our Organic Chemistry laboratories. It will also greatly speed up research and add to the experiments that we can perform. During this program review cycle, the Chemistry Program has also obtained an inert atmosphere glove box through an American Chemical Society Petroleum Research Fund Grant and matching funds from the department; an Ocean Optics UV/Vis spectrometer; a Thermo Scientific ozone analyzer and ozone calibrator; and, a used Fourier-transform spectrometer.

We do still have instrumentation and equipment that needs to be upgraded within the next few years. In particular, we need new pH meters for our upper division laboratories, and we plan to buy them over the next few years. Instrumentation to conduct fluorescence experiments would also be helpful in several upper division labs, and we are pursuing various funding opportunities to add a fluorimeter to our instrument suite. Our GC-MS recently suffered some basic circuit board problems that rendered the MS detector inoperative. We are attempting to repair the instrument, but this GC-MS model is no longer under manufacturer warranty, and can no longer be serviced by any instrument maintenance providers in our region. As a result, we are considering how best to refurbish or replace this instrument in the near future. We are also writing an NSF instrument funding proposal in conjunction with collaborators in Physics, Engineering, and Biology to purchase and maintain a new environmental scanning electron microscope. Our ion chromatograph is relatively old, and we will likely need to replace it in the upcoming years depending on how much it is used. Currently, it is just being used by the Environmental Sciences Program, but that may change. With respect to smaller equipment, we currently have two working rotary

evaporators, but we should have three. We are thus trying to repair one of our other two rotary evaporators.

Probably our greatest strength as a Chemistry Program is the individual instruction, mentoring, and research opportunities that we offer. In our alumni survey, 86.7% of the chemistry alumni that responded indicated that they “Very Often (at least once a week)” had conversations with faculty outside of class. The remaining chemistry respondents reported that they “Often (once every two weeks)” or “Occasionally (3-5 times per semester)” had conversations with faculty outside of class. This seemed to lead students to a high degree of satisfaction with their education as all the chemistry alumni responded that they were “Very Satisfied” (73.3%) or “Generally Satisfied” (26.7%) with their undergraduate education. Personal mentoring and research opportunities have also helped our students to obtain jobs and desirable graduate positions. During this review cycle, Chemistry Program alumni have obtained graduate positions at a variety of institutions, including University of Illinois at Urbana-Champaign, Yale, University of Washington, Colorado School of Mines, Colorado State University, University of Utah, Pennsylvania State University, University of Rochester, University of Texas at Dallas, and University of Houston.

Continuing to provide this level of personal instruction will be challenging due to increasing class sizes and due to higher than preferable faculty contact hours. Our General Chemistry and Principles of Chemistry courses commonly have about 70 students per section. While most of our upper division courses involve 8 – 25 students per section, we now have about 45 students in CHEM 315: Biochemistry I and almost 60 students in CHEM 311: Organic Chemistry I. Students often struggle in these classes and need individual attention. The instructors of these courses commonly try to facilitate learning by utilizing in-class group work, but this is being hindered by the large class sizes. Furthermore, our small upper division class sizes have historically been very appealing to prospective students and their families, but now prospective students sometimes become concerned when they find out that some of their most challenging classes may have well over 45 students in them.

Adding to the issue of large class sizes is higher than preferable faculty contact hours. In the last couple of years, our faculty generally had 14 – 16 contact hours per week with multiple faculty teaching 16 or more contact hours during most semesters. The ACS (American Chemical Society) offers guidance for faculty contact hours in their ACS Guidelines and Evaluation Procedures for Bachelor’s Degree Programs. They state that faculty contact hours “*must not exceed 15 total hours per week.*” Furthermore, they say that “Fifteen contact hours is an upper limit, and a significantly smaller number should be the normal teaching obligation, particularly for faculty supervising undergraduate research.” While our degrees are not ACS certified, this can be viewed as a reasonable guideline, and we may want to move toward offering an ACS certified degree in the future. However, to earn ACS certification, we would either need to offer additional upper division lab courses or require that students take CHEM 315L: Biochemistry I Laboratory and 2 credits of research. Adding labs would exacerbate our contact hours issues in that each lab involves three contact hours but only counts for two faculty teaching credits. Requiring students to take research credits could be problematic due to the research lab space issues described below.

Even without creating additional upper division laboratory courses, we face a challenge with respect to offering enough sections of our current laboratory courses to keep up with student

demand. We generally still have space in our upper division laboratory courses except for CHEM 341: Advanced Laboratory, which is only 3 students away from reaching capacity. It is hard to know when we will reach capacity with respect to CHEM 341: Advanced Laboratory, but hopefully some students will be able to take it in the following year when that happens. Otherwise, we would not have enough personnel to accommodate an additional section.

From a personnel perspective, it would generally be hard for us to accommodate additional laboratory sections. This issue has arisen at least in part due to the increase in instructor qualifications first imposed during the Fall of 2017. Since then, we have had difficulty in finding qualified individuals living in the immediate area who are willing to teach a lab course for the offered salary (\$750 per lab section per semester for a master's degree holder). Demand for additional lab sections could arise due to increased enrollment in any of the programs that require chemistry (Environmental Science, Biology, Geoscience, Exercise Science, and Chemistry). This is particularly concerning in that we are operating at capacity or close to it for CHEM 121L: Principles of Chemistry Laboratory and CHEM 131L: General Chemistry I Laboratory. Furthermore, it is likely that enrollment in CHEM 151L: Engineering Chemistry Laboratory will increase due to changes and growth in the engineering program.

Beyond changes in enrollment, we would like to offer more upper division topics courses and begin offering a new Essential Learning course focused on the chemistry of art. Both of these changes would likely be difficult or impossible to accommodate with our current personnel. Chemistry majors and alumni have regularly requested that we offer more upper division topics courses that can count toward the restricted electives of chemistry majors. The Essential Learning chemistry of art course would be a lecture and laboratory course offered as an alternative to CHEM 100: Chemistry in Society and CHEM 121/121L: Principles of Chemistry. This course would cater to students interested in the chemistry of art. Similar courses have been popular at other schools. Unfortunately, we would likely need to first implement this course as a single lecture section and laboratory section in order to build enrollment. While some students may enroll in this class instead of CHEM 100 or CHEM 121/121L, the smaller enrollment in this course relative to our other lower division courses would likely prevent us from accommodating as many students overall.

We also face an issue with respect to accommodating additional laboratory sections due to lab space and equipment issues. Even though many of our laboratory courses have sections in the morning, afternoon, and night, we still have various laboratory rooms available at different times through the week. Unfortunately, additional utilization of these rooms would often require extra equipment to simultaneously run two sections of the same laboratory course. This would also likely require the changing of equipment and chemicals to allow the use of the room by a different course. Currently, CHEM 151L: Engineering Chemistry Laboratory switches rooms at least once a week, and some laboratory spaces are shared by two different laboratory courses each week. Additional room switching would put a strain on our lab coordinator, who is already extremely busy.

Laboratory space is particularly problematic with respect to our research laboratories. We currently have research space for about 14 people, and this includes 4 fume hoods. We currently have five tenured and tenure-track faculty conducting research, and we currently have a search open for a tenure-track biochemist. We also have one non-tenure-track faculty member conducting research.

Individual faculty members have had as many as 8 research students in a semester, and they generally average between two and three students per faculty member per semester. All of these researchers generally need space for their chemicals and equipment, even when they are not actually in the room. By using the bench space as efficiently as possible and potentially installing additional shelving or cabinets, our bench space should accommodate the tenure-track biochemist, for whom we have a search underway. Unfortunately, we may not have enough bench space to accommodate the additional tenure-track bioorganic chemist recommended in this program review.

A dearth of fume hoods for research and CHEM 341: Advanced Laboratory is an even bigger issue. We currently have 4 fume hoods being used by 4 research groups and our CHEM 341: Advanced Laboratory course. One of the hoods needs to hold 3 waste containers. While one of the research groups could move to a snorkel exhaust fume hood, there is a good chance that the incoming tenure-track biochemist will need hood space, and the tenure-track bioorganic chemist recommended in this program review would also likely need hood space. That could leave us with 5 research groups using 4 hoods. As things currently stand, 2 synthetic chemists and our CHEM 341: Advanced Laboratory course share three hoods, one of which holds at least 3 waste containers. These hoods can get particularly crowded. At one time, there have been as many as 6 research students using these hoods with the hoods also containing on-going reactions from additional students. Furthermore, there have been as many as 8 students from CHEM 341: Advanced Laboratory using the hoods in addition to research students.

The Chemistry Program actually has 2 fume hoods in storage that could be installed at any time. While this would take away bench space, their installation would dramatically improve our research space issues overall. CMU Facilities Services has quoted us about \$30,000 for the installation of a fume hood, and we will include this in our budget request for next year.

Another issue with respect to our lab space is our building's leaky roof. For many years, we have had problems with rain leaking into our labs and hallways. Within the last couple of years, there has been another liquid, possibly oil or coolant, leaking into our research lab in front of an exit. This is a potentially dangerous situation due to the risks involved in chemical research. Unfortunately, this issue has persisted for over a year even though Facilities Services has been aware of the issue throughout that time and put some work into it.

c. Use of Program Review Process to Improve Teaching and Learning

The program review process has helped us to reassess our vision for the program. This led us to the development of a program mission statement. The review process also helped us to identify our strengths and weaknesses. This is important from a planning perspective, but it is also helpful with respect to recruiting students, recruiting faculty members, and focusing our current faculty members. As an example, the results of the alumni survey seem to indicate the importance of having our faculty continue to regularly meet with students outside of class. This knowledge should help faculty members determine how to prioritize their time, and it should help them recruit and evaluate potential faculty members. Beyond that, it has helped us to reassess how many faculty

members we are likely to need. With respect to planning, the program review process has also aided us in identifying lab space, equipment, and instrumentation needs.

In the past, the program review process has been critical for assessing our student learning objectives (SLOs). This has been much less important during this cycle because we regularly assess our SLOs, analyze the results, and implement actions based on the results. Based on assessments done during the previous program review cycle, we revised the courses required and the name of the degree for our major. Based in part on this revision, we started offering CHEM 431: Instrumental Analysis and CHEM 351: Inorganic Chemistry I on a yearly basis. Based on student demand, a B.S. in Chemistry with a Concentration in Biochemistry was implemented. In order to address deficiencies in our program with respect to students' training in oral presentations, use of the chemical literature, and applying for jobs and graduate positions, CHEM 442: Communicating in the World of Chemistry was instituted as a companion course to CHEM 341: Advanced Laboratory.

Beyond the programmatic changes described above, we made numerous changes to our courses based on assessment data obtained during the current program review cycle. These are described in depth within Section 5 of this program review. While assessments resulting in individual course revisions are described only in Section 5, some of the assessments resulting in actions being taken across multiple courses are also described below.

Based on the assessment of SLOs 4 and 5 prior to 2015, all program faculty were encouraged to spend more time in lab asking students to explain experiments in depth and asking follow-up questions. The thought was that this would help students to obtain a deeper understanding of the experiments; a greater depth of knowledge could then help students to become more independent in lab. Since 2015, improvements in assessment scores have been seen for SLOs 4 and 5, possibly in part due to these actions.

Also based on the assessment of SLO #5, all program faculty have recently been encouraged to include more writing assignments with faculty feedback focusing on proper spelling, grammar, and punctuation. This assessment data has also spurred chemistry faculty to pursue a campus-wide reevaluation of the Essential Learning writing curriculum.

d. Recommendations for Addressing Challenges

In order to address the issues of large upper division class sizes and high faculty contact hours, it would seem prudent to consider hiring another tenure-track faculty member who is qualified to teach Biochemistry I and Organic Chemistry. This hire would also provide us more flexibility with respect to accommodating changes in laboratory demand, and it would allow us to consider offering an Essential Learning chemistry of art course. While we currently have a search open for a tenure-track biochemist, this person would only replace one of our temporary faculty members and therefore would not address any of the issues described above.

Our other big issues relate to lab space. We need the leaks from the roof to be fixed or contained as they pose a danger to students and faculty. It is also important for us to get additional fume

hoods installed in the research labs. We already have two fume hoods, and we just need Facilities Services to install them.

Finally, it is important to keep updating our equipment. We are in the process of obtaining additional pH meters and exploring possible routes to fixing or replacing a GC-MS and a rotary evaporator. We are working with other programs to obtain external funding for a new environmental scanning electron microscope. Given the nature of chemistry, there will unequivocally be additional equipment that needs to be purchased, repaired, or replaced during the next 6 years, and we should plan accordingly.

