FIVE-YEAR ASSESSMENT AND REVIEW OF THE CHEMISTRY PROGRAM

NATURAL SCIENCE DIVISION
SEAVER COLLEGE
PEPPERDINE UNIVERSITY

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INTRODUCTION & OVERVIEW

The chemistry department is one discipline among the seven sciences, including mathematics, in the Natural Science Division of Pepperdine University. The bachelor's degree in chemistry has been offered at Pepperdine University since 1937 (then George Pepperdine College). The current era of the chemistry major began in 1983 when the BS degree in chemistry was tailored to better meet the differing career goals of chemistry majors. This was done by the creation of two upper division sequences; one entitled the "Standard Sequence," the other called the "Biochemistry Sequence," both of which shared a common core of math, physics, and lower- and upper-division chemistry courses[1]. In the early history of the two new sequences students were required to take statistics and a computer science course, requirements that were later dropped. A third semester of calculus was required for students in the standard sequence and later added for students in the biochemistry sequence along with a net of 6 additional units in upper division chemistry courses. Students in the biochemistry sequence took a year of biochemistry plus additional courses in chemistry and/or biology. The offering of the new biochemistry sequence reflected a nation-wide trend that took into account the growing overlap between the physical and life sciences, and took advantage of our biology program's growing reputation. Since that time, the American Chemical Society has modified their requirements for certification to include at least one semester of biochemistry. In general, the standard sequence was intended for students going on to graduate school and the biochemistry sequence for those more interested in medical school, the health sciences, and teaching.

In 1992, the BA major in chemistry was added to the catalog, and in 1996, the BA degree was also split into a standard sequence and a biochemistry sequence similar to those that already existed in the BS chemistry major. These additions were made to serve those students intending to teach high school chemistry or to pursue health science careers. For example, at the time of inception, a pre-med student who is a BA biochemistry major would not have to take any additional biology classes beyond those required of the major, whereas a BS chemistry major would have to take two biology courses and a BS biochemistry major one additional biology course in order to meet the prerequisites of most medical schools. The primary differences between the BA and BS degrees follow from the differences in the calculus requirements of the two degrees, as the BA degree requires only one semester (MATH 150), while the BS degree requires three semesters of calculus (MATH 150/151/250). The BA majors take the same non-calculus-based physics sequence (PHYS 202/203) as Biology and Sports Medicine majors, while the BS majors take the same calculus-based physics sequence (PHYS 210/211) as Math, Computer Science, Physics, and 3/2 Engineering majors. BA majors take a one-semester course in physical chemistry (CHEM 380), while BS majors take a two-semester sequence in physical chemistry that requires the more in-depth math background. The standard sequence of the BS degree in chemistry continues to be the appropriate route for students going on to graduate school in chemistry.

In 2002, the chemistry minor was added. The minor requires 23-24 units of chemistry, *i.e.*, six courses, none of which are new courses to the chemistry program. Students who are premedical but not chemistry majors already must take 16 of these units, so they can complete

[1] To differentiate between these two sequences, students in the standard sequence are commonly referred to as *chemistry majors*, and those in the biochemistry sequence are called *biochemistry majors*, but for the purposes of this document, they will all be referred to as chemistry majors.

the minor by taking two additional upper division chemistry courses that are taught on a regular basis.

American Chemical Society Certification

In 2012, the Chemistry Department began the long journey to seek American Chemical Society (ACS) certification of program, bolstered in part by improvements to the chemistry program realized by division-wide improvements to the science facilities, including the Keck Science Center (2001), improved library holdings and subscriptions, larger laboratories, and increased inventory of modern instrumentation for research and teaching. Our confidence was further reinforced after the 2011 program review and the excellent external review by Dr. Eileen Spain. The criteria for certification by the ACS exceed that required by the University or WASC. The 5-year self-study completed in 2011 was, however, extremely helpful in assembling Phase I of the ACS certification.

We completed a detailed self-study of the chemistry program throughout 2013 and submitted nearly 4000 pages of the self-study and supporting information to the ACS Committee on Professional Training (ACS-CPT) in December 2013. In March 2014 professors Fritsch and Ganske met with the ACS-CPT committee in Dallas, TX, to discuss the application and hear critiques of our program. The ACS-CPT was extremely encouraging, and gave minor but reasonable critiques of the program.

The number of comments are too many to review here, but a few comments are included:

"…inventory of equipment is very good and each piece of equipment is in working order."
"…a small faculty is teaching very high quality courses…"
"…responsibilities of the faculty are very well defined. There is a concern that the individual faculty are doing so much that their level of productivity may not be sustainable."
"…students universally enjoy their classes and respect their faculty as undisputed experts in their fields…"

Among the most major of the changes requested was the conversion of Chemical Literature and Seminar (CHEM 400) to a 3 unit course and rename it to Environmental Chemistry to reflect the nature and content of the course. This change was approved by the Seaver Academic Council in 2014 and the revised course will be taught for the first time spring semester 2015.

In November 2014, we underwent a multi-day site visit by ACS-CPT representatives Dr. Bob Cave (Harvey Mudd College) and Dr. James Duncan (Professor Emeritus, Lewis & Clark College), which included meetings with faculty, staff, and administration, and interviews with current students. Their comments after the site visit were extraordinarily positive and complemented Dr. Spain's comments of 2011. ACS-CPT met again in Denver in March 2015, after which the committee requested one additional update of a program modification. The Chemistry Department was awarded ACS certification for B.S. Chemistry degree in October 2015 and students who meet the program requirements will receive certified chemistry degrees starting April 2016.

External Content

The Chemistry Department's contributions to the discipline, internally and externally

More than 80% of the chemistry majors and all of the faculty in the last 5 years have participated in a variety of curricular and co-curricular activities to serve the Pepperdine community and the community at large. These include:

- Teaching assistantships in General Chemistry and Organic Chemistry
- Grader and peer tutor positions for different chemistry courses
- Tutoring chemistry, physics, and math in the community beyond Pepperdine University
- Chemistry demonstrations for the Pepperdine community, camps held at the University and local grade and high schools in the southern California area.
- Environmental chemistry seminars and colloquia for Newbury Park High School
- More than 15 students participating in summer research since 2011 with many continuing during the academic year.
- 62 student-authored conference abstracts and presentations since 2011.
- 17 published articles in refereed journals with students as primary authors since 2011 with at least 1 additional currently in review.

Those areas listed above are in addition to two year-long courses (General and Organic Chemistry) serving the biology, nutrition, sports medicine, 3/2 engineering, and physics majors.

Mission Statement and Program Goals

The chemistry program within the Natural Science Division of Seaver College at Pepperdine University is committed to providing a modern, rigorous, and dynamic chemistry education, stimulating and encouraging the scholarship of discovery by encouraging active participation, while nurturing and advancing the professional, personal, and spiritual development of our students for lives of service, purpose, and leadership.

The principal goals of the chemistry program reflect those of Seaver College as they relate to the study and practice of the field of chemistry. The liberal arts education as defined by Seaver College emphasizes both educational breadth, through the general studies program, and depth, through the major concentration. All chemistry graduates should possess the following characteristics:

- Develop a life-long curiosity regarding the mechanisms of nature and, using the scientific method as their starting point, appreciate that there may be multiple approaches to the solution of a scientific problem.
- They will possess the ability to think logically, critically, and clearly, with the skills to design experiments to generate new knowledge independently. Allied with this goal is the graduate's ability to effectively communicate in the written and oral style.
- Consistent with their academic level, they will have sufficient expertise to communicate scientific principles and discoveries to other scientists and also to those outside of the scientific community.

PROGRAM LEARNING OUTCOMES

Upon completion of the required curriculum of the chemistry degree the graduate will have demonstrated mastery, typical of an undergraduate chemistry major, in the following 3 areas:

1. ***Critical Thinking and Problem Solving***

   Each graduate of the chemistry program should be able to successfully solve, and demonstrate to others, multistep problems in Organic, Analytical, and at least one of the other sub-disciplines of the field. In at least one case, critical evaluation of the quality or usefulness of the data presented must be evaluated and explained.

2. ***Written and Oral Communication***

   Every chemistry major will write and submit reports of independently obtained laboratory results and analyses, which must be presented in the scientific format. The effectiveness of presentation and the linguistic quality of the report will be evaluated. A seminar must be presented on a current or historical topic in chemistry in which all of the chemistry department community is invited to attend. The effectiveness and quality of presentation will be evaluated.

3. ***Technical Skills***

   Each student in the major will be evaluated on their technical competence in the laboratory with respect to operating the chemical instrumentation and properly handling apparatuses specific to certain sub-disciplines. The expectation is that the successful student will be able to transfer the knowledge and skills acquired in the laboratories to new settings after graduation, despite not using exactly the same equipment in the new setting.

At the request of an evaluator during the annual reviews, we have removed our PLO for “Service to the Community at Large,” instituted in the 2011 program review. The rationale was that the PLO was unnecessary since we have 100% participation in service to the department, division, or community through one course (Environmental Chemistry Chem 400), as well as voluntary service through the Student Affiliates Chapter of the American Chemical Society.

Alignment Map for Chemistry Department
Seaver College

Institutional Values	Core Commitments	Student Learning Outcomes from ILOs	Program Learning Outcomes (PLOs)	Course
Purpose	Knowledge and Scholarship	Demonstrate expertise in an academic or professional discipline, display proficiency in the discipline, and engage in the process of academic discovery.	**1. Critical Thinking and Problem Solving**	Chem 311 Chem 340 Chem 371 Chem 390
	Faith and Heritage	Appreciate the complex relationship between faith, learning, and practice.		
	Community & Global Understanding	Develop and enact a compelling personal and professional vision that values diversity.		
Service	Knowledge & Scholarship	Apply knowledge to real-world challenges.	**2. Written and Oral Communication**	Chem 400
	Faith and Heritage	Respond to the call to serve others.		
	Community & Global Understanding	Demonstrate commitment to service and civic engagement.		
Leadership	Knowledge & Scholarship	Think critically and creatively communicate clearly, and act with integrity.	**2. Written and Oral Communication** **3. Technical Skills**	Chem 340 Chem 400 Chem 341 Chem 371 Chem 390 Chem 440
	Faith and Heritage	Practice responsible conduct and allow decisions and directions to be informed by a value-centered life.		
	Community & Global Understanding	Use global and local leadership opportunities in pursuit of justice.		

Credit Hour Policy

This table is required for the Department of Education. It is simply a list of the chemistry courses, how many hours they meet, and how many credits they receive.

Course Number	Course Name	Credits	Hours
Chem 120	General Chemistry I	3	2.5
Chem 120L	General Chemistry I Laboratory	1	3.8
Chem 121	General Chemistry II	3	2.5
Chem 120L	General Chemistry II Laboratory	1	3.8
Chem 310	Organic Chemistry I	3	2.5
Chem 310L	Organic Chemistry I Laboratory	1	3.8
Chem 311	Organic Chemistry II	3	2.5
Chem 311L	Organic Chemistry II Laboratory	1	3.8
Chem 340	Quantitative Chemistry	3	2.5
Chem 340L	Quantitative Chemistry Laboratory	1	3.8
Chem 341	Instrumental Analysis	3	2.5
Chem 341L	Instrumental Analysis Laboratory	1	3.8
Chem 370	Physical Chemistry I	3	2.5
Chem 370L	Physical Chemistry I Laboratory	1	3.8
Chem 371	Physical Chemistry II	3	2.5
Chem 371L	Physical Chemistry II Laboratory	1	3.8
Chem 380	Introduction to Physical Chemistry	3	2.5
Chem 380L	Intro to Phys Chem Laboratory	1	3.8
Chem 390	Inorganic Chemistry	3	2.5
Chem 390L	Inorganic Chemistry Laboratory	1	3.8

Chem 400	Environmental Chemistry	3	2.5
Chem 430	Bioorganic Chemistry	3	2.5
Chem 440	Advanced Analytical Chemistry	4	7.2

MEANING, QUALITY, AND INTEGRITY OF THE CHEMISTRY MAJOR

By the very nature of science, honesty and integrity are at the core of the process. One cannot be a successful practicing scientist without a keen awareness of the consequences of dishonesty. Beyond that basic premise, however, is our universally accepted commitment to instill values and pose ethical questions in our courses. For example, the research in several of the chemistry laboratories is focused, beyond contributing to the body of chemical knowledge, on reducing the impact of chemical use on the environment, human health, or economy. In the classes and class laboratories, questions of scientific ethics are frequently posed, both formally in the form of free-response exam questions and informally in the form of discussion. Those who pose questions such as these on exams require the students to defend their position in some tangible way, thus spurring critical thinking and self-reflection.

Every faculty member in the chemistry department shares a similar and complementary faith-walk while coming from different faith cultures, but all openly declare the harmony of faith and science. The faculty take their knowledge into the community to share this harmony, often inviting students to participate. The tradition of service exemplified by the University since its inception, is further illustrated in Chem 400 where students go to a local high school to teach modern chemistry and chemical principles and, further, the Student Affiliates Chapter of the American Chemical Society (aka, "Chem Club") where the students and faculty make science accessible through demonstrations, chemistry-themed social events outside of the chemistry department, and involvement in campus-wide events such as Blue and Orange Madness during Waves Weekend.

The Chemistry Curriculum

The curriculum for the BS degree in chemistry meets the requirements for certification established by the American Chemical Society[2]. The course offerings for our four chemistry degree routes are typical for a small liberal arts college, given the breadth of the general education requirement. As specified by the ACS, at least 3 of the traditional chemistry disciplines (analytical, biochemistry, inorganic, organic, and physical chemistry) must be represented in the chemistry major sequence, and must include not fewer than four one-semester courses. Foundation course work builds on the introductory chemistry experience. The curriculum must also have at least 12 semester hours of in-depth course work. An in-depth course builds on prerequisite foundation course work.

[2] *Undergraduate Professional Education in Chemistry*, American Chemical Society, 2008

With the required 2 semester courses in analytical, organic, and physical chemistry courses, one semester of inorganic chemistry, and the elective biochemistry courses our students satisfy and, in fact, exceed the requirements of the ACS for foundation and in-depth courses. Students also have advanced elective courses in analytical chemistry, biochemistry, and bio-organic chemistry, and research to further fulfill the "in-depth" requirements.

The ACS specifies 400 hours of laboratory experience beyond the introductory chemistry laboratory in at least 4 of the 5 foundation and in-depth areas of chemistry. Laboratory experiences must include synthesis, measurement of chemical properties, structures, hands-on experience with modern instrumentation, and computational data analysis. In the Bachelor of Science tracks, our chemistry majors will attend more than 420 hours of lab; more, if the student participates in the chemistry research program. Chemistry majors are required to understand the operation and theory of modern instruments and use them to solve chemical problems as part of their laboratory experience. They receive training and hands-on experience with a variety of instruments, including spectrometers (including NMR, FT-IR, and UV-visible spectroscopy), chemical separations instruments (including GC, GC-MS, and HPLC), and electrochemical instrumentation.

Course sequencing in the chemistry major is pyramidal in structure. Figure 1 shows a typical course sequencing for a B.S. Chemistry major in the Biochemistry track. Not shown in the sequence are the details of the math and physics corequisites. It is clear from the sequence that, in most cases, progress through the major curriculum requires competency in one or more prior course groups. The Physical Chemistry sequence and Inorganic Chemistry course are offered on a regular biennial schedule in alternating years.

Chemistry, as one of only two majors in the physical sciences offered at Seaver College, plays an essential role in passing an understanding of the composition and nature of the physical universe onto our students be they chemistry, biology, sports medicine, nutritional science and/or pre-health professionals. The chemistry major is fundamentally strong, and it attracts and graduates a number of Seaver College's most academically gifted students. It is incumbent on the chemistry faculty to continue to maintain a modern and challenging program.

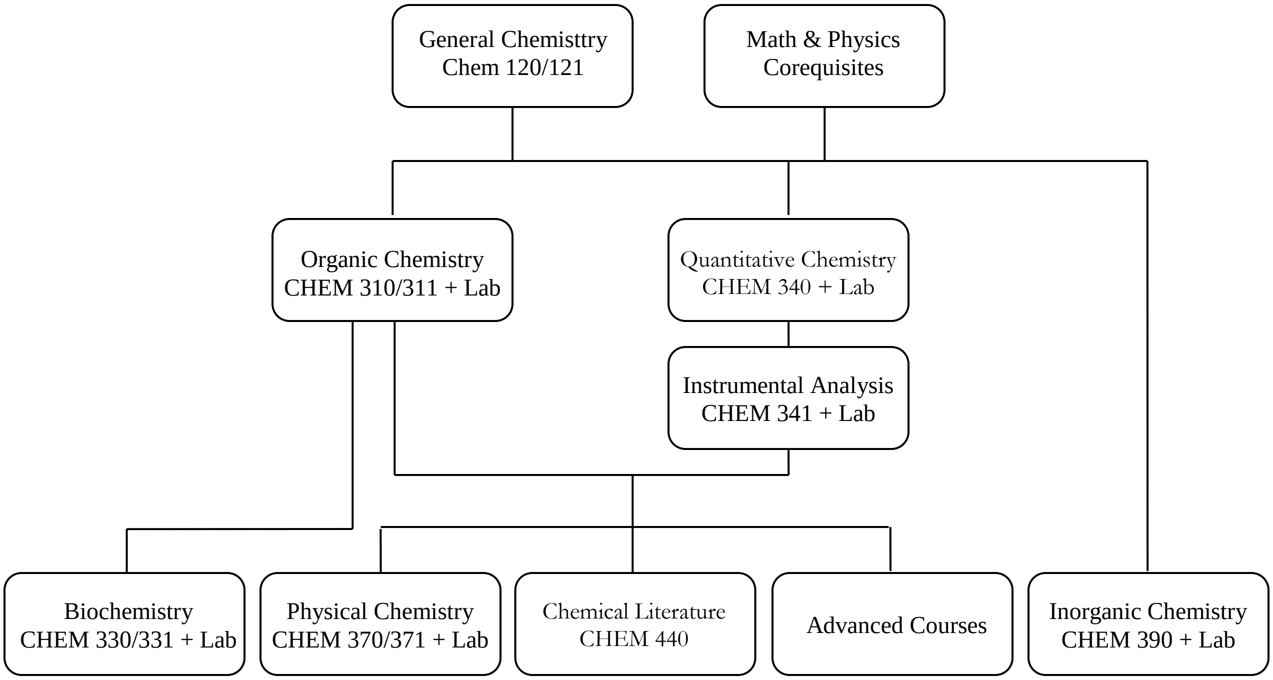

Figure 1. Basic course sequencing for the B.S. Chemistry degree

Following a long tradition of formal and informal self-assessment, we look at each of the goals and objectives and superimpose our curriculum matrix (seen below) upon them to ensure that each objective is being focused upon in the current state of the program. Many, in fact most, of the objectives are addressed in multiple courses in progressively increasing depth.

For example, PLOs 1 and 3 are necessarily a primary focus in almost every chemistry course. The physical and chemical principles underpinning atoms, molecules, structures, and bonding are introduced in the first year course (CHEM 120/121) and built upon or utilized in nearly every subsequent course. The basic knowledge base of these chemical principles has relatively strict rules and must obey certain natural laws, so assessment of the knowledge base is straightforward. In the Organic Chemistry sequence (CHEM 310/311), most of the more advanced topics covered in the depth appropriate for this level could not be mastered without adequate competency in the earlier courses. A deep quantum mechanical treatment of these example topics culminates in the Physical Chemistry sequence.

The chemistry curriculum has a very strong writing component (PLO 2). This objective is first addressed in the General Chemistry laboratory, where students work in small groups (2 or 3) to present their laboratory results in a modified American Chemical Society journal format. During their 26 weeks of laboratory in the first year course, the students will submit 20 detailed laboratory reports. The students' writing skills are refined in the Quantitative/Instrumental sequence where students will perform at least 20 laboratory investigations. The results of their work are presented in one of three formats:

- Journal manuscript format
- Scientific monograph format
- Journal note

Each of these formats is common in the chemical literature and the format selected for a particular investigation is determined by type of laboratory work performed. Each report is graded using a rubric that includes:

- Scientific accuracy
- Statistical accuracy of analyzed results
- Writing style and fluency
- Format and syntax
- Quality of bibliographic citations

The expectation is that as the student progresses through the major curriculum their writing skills will continually improve. In addition to a broad writing requirement, each student augments their presentation skills in the form of oral presentation (PLO 2) which is formally introduced in the Environmental Chemistry course (CHEM 400).

A matrix of program learning outcomes and the courses that address each learning outcome is presented below. Because of the highly integrated nature of our courses at the Chem 340 level and beyond and the variable sequencing available to the students, occasionally demonstrated mastery of a PLO is assessed in an earlier course with utilization of the PLO demonstrated in higher level courses. This is a characteristic of most technical programs that are designed more like an inverted pyramid, where there are a few introductory courses that establish the necessary basic skills onto which a very wide knowledge base and skill set can be built. This inverted pyramid scheme also clarifies the rationale for not having a single capstone course but, rather, allowing students to have multiple opportunities in their highest level courses and the research program to explore projects of their own design and implementation.

Matrix of Program Learning Outcomes in relation to the Chemistry curriculum

Program Learning Outcomes[a]	120	121	310	311	340	341	370	371	380	390	400	430	440
1. Critical Thinking and Problem Solving Successfully solve multistep problems in Organic, Analytical, and a third sub-discipline of the field. In at least one case, critical evaluation of the quality or usefulness of the data presented must be evaluated and explained.	I	I	P	D	D	P	P	D	P	D		P	P
2. Written and Oral Communication Reports of independently obtained laboratory results and analysis must be presented in the scientific format. The effectiveness of presentation and the linguistic quality of the report will be evaluated. A seminar must be presented on a current or historical topic in chemistry in which all of the chemistry department community is invited to attend. The effectiveness and quality of presentation will be evaluated.	I	I			D	P	P	P	P		D		P
3. Technical Skills Each student in the major will be evaluated on their technical competence in the laboratory with respect to operating the chemical instrumentation and properly handling apparatus specific to certain sub-disciplines.	I	I	P	P	P	D	P	D	P	D	P		P

[a] I = introduced; P = practiced or utilized; D = Demonstrated assessed mastery

Comparison of the Chemistry Department to Peer Institutions

Three institutions were selected for comparison based on reputation, a strong liberal arts focus and religious roots. Founded in 1887 near what is now downtown Los Angeles, Occidental College encourages religious and spiritual growth but itself does not subscribe to or promote any particular faith walk. Nevertheless, Occidental College ranks 43 in the 2015 edition of Best Colleges in National Liberal Arts Colleges. Westmont College is Christian liberal arts institution in Santa Barbara. Founded around the same time as Pepperdine College, it ranks 93 in the 2015 edition of Best Colleges in National Liberal Arts Colleges. Finally, Whittier College (1887) has a strong Quaker heritage and ranks 127 in the same poll. Pepperdine is ranked 52 in the 2015 edition of Best Colleges is National Universities, which is in a different category but, like the peer institutions, ranks highly in its class.

Comparing our program to the other programs listed in the table below shows that the chemistry program at Pepperdine University is of breadth comparable, and in fact broader across the sub-disciplines in some cases, to other similar universities, although the selection of upper-division courses varies somewhat. This is not entirely surprising since all but Westmont College in the comparison are ACS certified, so the minimum requirements for their degree are specified by the American Chemical Society. What was somewhat enlightening and, moreover, encouraging is that our unit requirement exceeds our peer institutions, with the only exception being our B.A. Biochemistry Sequence compared to Westmont College and Whittier College.

The recent certification of the B.S. Chemistry degree at Pepperdine University is further evidence of excellence compared to other certified institutions when the breadth and depth of the degree are considered.

Comparison of the chemistry curriculum to peer institutions

Comparison of Chemistry (B.S.), Standard Sequence, curriculum or equivalent program across peer institutions.

Institutions	Units Required for Degree	Calculus	Physical Chemistry	Analytical Chemistry	Instrumental Analysis	Inorganic Chemistry	Upper Division	Lab Courses	Other
Pepperdine University	26/66	3/12	4/8	1/4	1/4	1/4	17/36	11	ACS Cert.
Occidental College	17/59	2/8	4/10	0/0	0/0	1/4	9/30	10	ACS Cert., BA
Westmont College	21/65	3/12	4/8	1/5	0/0	1/4	12/35	11	
Whittier College	19/58-59	2/8	3/7	1/5	1/4	1/4	9/26	11	ACS Cert., BA

Listed as number of courses/number of units

Comparison of Chemistry (B.S.), Biochemistry Sequence, curriculum or equivalent program across peer institutions.

Institutions	Units Required for Degree	Calculus	Physical Chemistry	Analytical Chemistry	Instrumental Analysis	Biochemistry	Upper Division	Lab Courses	Other
Pepperdine University	25/64	3/12	4/8	1/4	1/4	2/8	16/34	12	
Occidental College	19/65	2/8	2/5	0/0	0/0	2/10	8/21	13	BA
Westmont College	20-22/66-67	2/8	2/5	1/5	0/0	1/4	11-12/33	12	
Whittier College	21/63-65	2/8	2/7	1/5	0/0	4/8	10/27-28	12	BA

Listed as number of courses/number of units

Comparison of Chemistry (B.A.), Standard Sequence, curriculum or equivalent program across peer institutions.

Institutions	Units Required for Degree	Calculus	Physical Chemistry	Analytical Chemistry	Instrument al Analysis	Inorganic Chemistry	Upper Division	Lab Courses	Other
Pepperdine University	22/55-58	1/4	1/4	1/4	0/0	1/4	15/35-38	10	
Occidental College	17/59	2/8	4/10	0/0	0/0	1/4	9/30	10	ACS Cert.
Westmont College	14-15/46-47	2/8	2/4	1/3	0/0	0/0	7/21	7	
Whittier College	19/58-59	2/8	3/7	1/5	1/4	1/4	9/26	11	ACS Cert.

Listed as number of courses/number of units

Comparison of Chemistry (B.A.), Biochemistry Sequence, curriculum or equivalent program across peer institutions.

Institutions	Units Required for Degree	Calculus	Physical Chemistry	Analytical Chemistry	Instrumental Analysis	Biochemistry	Upper Division	Lab Courses	Other
Pepperdine University	19/53-54	1/4	1/4	1/4	0/0	2/8	12/33-34	11	
Occidental College	19/65	2/8	2/5	0/0	0/0	2/10	8/21	13	
Westmont College									
Whittier College	21/63-65	2/8	2/7	1/5	0/0	4/8	10/27-28	12	

Listed as number of courses/number of units

Curriculum Changes Since 2011

The chemistry curriculum is a mature and well-designed program based on (and superseding in many aspects) the requirements established by the American Chemical Society[3]. Having completed the process to obtain certification by the American Chemical Society, several characteristics of the department were highlighted: 1) we were scored highly for exposing students to modern instrumentation and methods, 2) we were praised for excellent teaching practices as described by our submitted teaching materials and borne out during direct interviews with our majors, 3) a collegial faculty both internally and Division and University-wide and an accessible faculty to the students, and 4) for research productivity demonstrated by students' publications and presentations.

As a direct result of recommendations by the ACS, we have modified and renamed one course (*Environmental Chemistry*, Chem 400) to better reflect the content of the course and the trend in chemistry education to more overtly present this branch of chemistry in systematic and formal manner.

General Chemistry (CHEM 120/121)

The results of our annual assessments underscored only a small number of necessary curricular changes. For example, in General Chemistry (Chem 120), the introduction of more demonstrations with handouts for data collection in the thermochemistry section of the course has resulted in greater student learning on the topic over the previous practices of lecture only or lecture supplemented by demonstrations. The handouts have provided organizational ease for student use allowing them to focus on the topics at hand instead of organizing the data for themselves. As a result, there have been rising student survey results of learning as they self-assess.

Quantitative Chemistry (CHEM 340) as the Writing Intensive Course

Perhaps among the most significant was the discovery that students who adapted facilely to writing in the scientific format early in their academic career, tended to improve at the expected rate throughout their academic career (Annual Review 2014-15). Students who wrote poorly early in the curriculum, improved slightly, not at all, or withdrew from the major before graduation. In some cases it was clear that improving their writing skills was not a priority for the students regardless of their scores, available resources, and feedback. This observation has led to modifications in Quantitative Chemistry (Chem 340, the writing intensive course); specifically, 1) inclusion of additional primary literature as models of successful manuscripts, 2) annotated inferior and superior manuscripts written by students as exemplars of course expectations, and 3) improved written instructions to authors and dedication of a complete laboratory period to writing in the scientific style.

It was interesting to discover that the best student authors in Quantitative Chemistry over the four-year study also engaged in undergraduate research and published their work in a scientific journal or presented their work at a regional or national conference. One student in the 2012 manifold was one standard deviation below the average and presented her research at the ACS conference at UC San Diego in 2014, thus clearly showing that exceptions exist between writing aptitude and ability to complete and present original research. We discovered a weak correlation

[3] *Undergraduate Professional Education in Chemistry*, American Chemical Society, 2008

indicating that mastery of writing in the scientific content and style is a proxy measurement for success in the major.

Inorganic Chemistry (CHEM 390)

Since the 2011 review, an innovation in the Inorganic Chemistry (Chem 390) curriculum has been the implementation of a greater number of handouts and a field trip to the University of California, Los Angeles Crystallography Laboratory. The more frequent use of well-designed handouts has resulted in greater clarity and higher student performance on topics like crystal field theory, nomenclature, and group theory. Students scored higher on the rubric-based assessment of nomenclature and crystal field theory as a result. Beginning in 2013, Dr. Fritsch began taking students to the Crystallography Laboratory to meet with Dr. Saeed Khan who presents to the students the practice of this important technique to the field. Students have been energized by the trip and had their career vision of chemistry expanded through interaction with staff scientists at a research university. In particular, the 2015 trip to UCLA revealed additional employment roles for chemistry graduates in field and the value of graduate studies in chemistry.

Organic Chemistry (CHEM 310/311)

Several changes have taken place in the lecture portions of the two-semester sequence in organic chemistry (CHEM 310/310P/311/311P). One is that all lectures are recorded and downloaded to Google Drive, and students enrolled in these courses are given access to them. This allows students who miss lecture to still hear the lecture, although it hasn't reduced attendance. It also allows students who attended lecture to review selectively course material in preparation for exams. Written comments from student evaluation and other anecdotal evidence of the courses is positive, *i.e.*, students like having the lectures recorded.

The other change is that, beginning with the fall of 2015, Dr. White is writing an extensive problem set for each lecture handout in CHEM 310 to provide students with additional problems to practice prior to exams. For each lecture there was already a comprehensive lecture handout that contained problems for students to do on their own. The solutions to the problems in the lecture handouts are provided at the end of the lecture handouts. The new problem sets are questions that closely mimic literature and exam questions. Keys to these problems are not provided, but instead are solved during problem sessions during the week in a classroom. Attendance to the problem sessions is voluntary on the students' part, but provide one-on-one to one-on-few time much in the same way as formal office hours. Students can bring their problems completed or solve the problems during problem sessions. In this way, the professor can catch concepts that students did not understand well enough to apply, but didn't realize they didn't understand well enough, and go through how to solve the problems. The students are overtly told that the purpose of the problem sets and problem sessions is to allow mistakes in a low-threat environment before the exam, not on the exam. The average on the first exam for each of the two sections of CHEM 310 in the fall of 2015 was about five points higher than the average on the first exam in the one section of CHEM 310 that was taught in the fall of 2014. The exams in 2015 were not the same as the exam in 2014, and there is always some variation year-to-year in averages, but the remarkable observation was that there were very few low grades in 2015 compared to 2014. Out of 49 students who took the first exam in the fall of 2015 there were only 2 'C's, 3 'D's and 1 'F.' In contrast, out of the 30 students in CHEM 310 section in the fall of 2014 there were 5 'C's, 4 'D's and no 'F's. To put it more succinctly: 6 out of 49 (12%) made a C or lower on the first exam having done problem sets and problem sessions in the fall of 2015, and 9 out of 30 (30%) made a C or lower on the first exam the previous year without the problem sets and problem sessions.

Biochemistry (CHEM 330/331)

The use of an online homework system (Sapling Learning) for CHEM 330 Cellular Biochemistry was tested in the Fall 2013 semester. Based on the results of surveys, it was determined that the online homework was beneficial to the students. Students reported that they found the online homework system to be beneficial and most recommended that it be used in the future. An additional consideration was that the purchase of access to the online system by the students allowed them to save money by purchasing an older edition of the textbook. Therefore, the use of the online homework system allowed students to decrease the cost of their course materials as needed.

In the summer of 2013 Dr. Joyner attended a National Science Foundation sponsored Chemistry Collaborations, Workshops, and Communities of Scholars mini-workshop on the topic of Development & Implementation of Case Studies in Undergraduate Chemistry Courses at the University of California, Riverside. From this workshop, Dr. Joyner was able to develop a case-study on the topic of public health concerns over the use of the antibiotic triclosan. Dr. Joyner implemented this case study CHEM 331 Advanced Cellular Biochemistry in the Spring 2015 semester.

Wiki Surveys

In the Spring 2015 semester, Dr. Joyner collected survey data in CHEM 301 Elementary Organic Chemistry at multiple time points throughout the semester. These surveys allowed information about student learning and satisfaction to be measured throughout the course. The results of these surveys indicate that the students in this class felt they were learning as much or more than they were in similar classes at Pepperdine and that although the work load for the class increased toward the end of the semester this increase in difficulty was matched with an increase in how much the student's perceived they were learning (Figure 1). The surveys also indicated that the students found the teaching methods used in the class to be effective throughout the semester. These surveys are representative of the type of measures of effectiveness collected by Dr. Joyner in all of his classes.

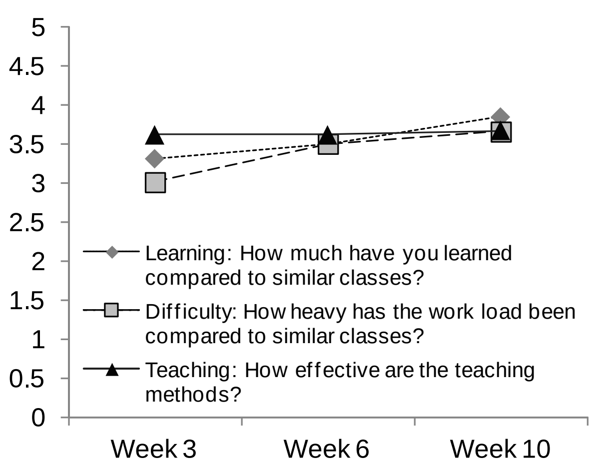

Figure 1

Dr. Joyner has also utilized the American Chemical Society Biochemistry standardized exam in his CHEM 330 Cellular Biochemistry course. Many colleges and universities across the country use this exam as part of their biochemistry curriculum which allows the performance of Pepperdine students on this exam to be compared to that of students at other institutions. Examination of the performance of Pepperdine students over the past three years shows that the majority (71%) of our students score above the 50th percentile on this exam compared to students across the nation (Figure 2). These results indicate that the Chemistry program is achieving excellence in preparing our students for success in their upper-level courses.

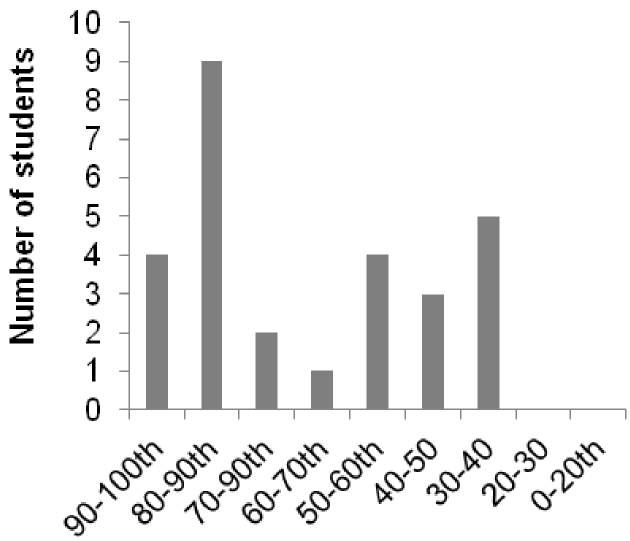

Figure 2. Students performance on American Chemical Society Biochemistry exam grouped by national percentile ranking (*n* = 122).

Long-Term Assessments of Curricular Changes and Pedagogy

One recurring theme in the improvements in the courses is providing the students more primary and secondary material to supplement the textbooks. Even the most modern of the chemistry textbooks are often lacking the most modern discoveries in the related field. In addition, supplemental information isolates and clarifies difficult material. Students can then go back to the textbook or primary literature and make better and faster connections between classroom material and the literature.

Despite being a robust curriculum, even minor changes to the system can have significant downstream effects – both positive and negative. Perturbations in the feedback loop must necessarily be carefully considered. When we have made substantial changes too quickly, we have often found the return to equilibrium to be slow, resulting in discouraged students with a perception of a department with unreasonable expectations. We point to sweeping changes to the General Chemistry curriculum in the late 1990s that required several years and a return to our traditional values to recover. Because of our many decades of combined experience, successful changes in our curriculum have been incremental, considering both the students' response and difficulty in implementation.

Core Competencies

Graduates from the chemistry department must demonstrate mastery in the 5 core competencies, as defined in the OIE handbook: written communication, oral communication, quantitative reasoning, critical thinking, and information literacy.

As stated elsewhere in this self-study, students are required to write in the scientific style starting in the first semester of General Chemistry. Exemplar manuscripts are provided on the instructor's website, as are aids for the content and style of the manuscripts. The students advance to Quantitative Chemistry (Chem 340), where the expectations on the quality of the writing increase. Extensive feedback is given and improvements in the quality of the students' manuscripts is assessed. Since high quality writing is a critical component of every laboratory course at and beyond the Chem 340 level, the students and faculty both have ample opportunity to evaluate the students for improving writing skills.

Oral communication is evaluated by the professor and peer-evaluated by the students in Environmental Chemistry (Chem 400). In addition, feedback from the high school teacher is used to further evaluate the students after returning from the service component of this course. Research students present multiple short seminars during research group meetings during their tenure in the laboratory. These are informally evaluated by the faculty and other research students and immediate feedback is given during the question-and-answer period following the seminars. At the conclusion of group meetings, the faculty meet to discuss the quality of the students' presentations and offer suggestions, as necessary, for improvements. Almost every research student in the chemistry program will attend a conference where they must present their work to other students and professionals. Finally, 8 students in the last 5 years have written honors theses and presented their work to the Pepperdine community in the form of a seminar. These students then defended their work in front of a faculty panel of their committee in an oral examination.

Quantitative reasoning and critical thinking in the scientific field is difficult to decouple and are at the very heart of the scientific endeavor. Alumni surveys, results of independent projects, and research presentations and articles all indicate that our students are functioning at the highest level of Bloom's taxonomy expected for a student graduating with a bachelor's degree. Feedback from the graduate advisors suggests that many of our students are operating beyond this expectation even in their first year of graduate school.

When our students enroll in Environmental Chemistry (Chem 400), each one is expected to obtain a university-sponsored account for accessing the abstracting databases provided through SciFinder Scholar. Many students obtain their account well in advance of enrolling in Chem 400. As early as Chem 340 (although not required at that level), students learn to search the chemical abstracts for research articles that are relevant to their reports and research. By the time a student graduates, they have learned how to access chemical information using paper, network, and database searching tools. Through one-on-one and classroom exercises, students also learn how to critically read research articles for relevant and useful information, and discard articles that do not provide the desired information. Informal surveys of graduates indicate that knowing how to find information quickly is among their greatest assets in their first year of graduate school. In fact, it was this very skill that allowed one graduate to obtain a professional position at the Chemical Abstract Services.

QUALITY

Examples of Practices that enrich the Learning Experience

Service learning

The department encourages our students to utilize their gifts in the sciences in service to the broader community through a variety of outreach events including science nights at local elementary and high schools. We are one of few departments which also have a required service learning component to our major. Each chemistry major must complete Chemistry 400 (recently renamed *Environmental Chemistry*), which has traditionally included a service project. In the last five years, each chemistry major has presented a lecture to high school Chemistry IB students on a current topic of interest to the atmospheric/environmental science community. In spring 2014, each student was also required to offer a critique on the high school students' environmental field projects. The effectiveness and quality of the Pepperdine student presentations is evaluated in nine areas including accuracy and clarity. Prior to the request to remove this assessed PLO, this requirement was assessed each time it was taught.

Research opportunities

In the past five years, 45 students have graduated with a major in chemistry. Nearly 73% of those graduates were active in our chemistry undergraduate research program, participating for at least one semester or one summer of research, and most extending their research to a year or more. During the spring 2015 semester, ten chemistry majors presented their research findings at the national American Chemical Society meeting in Denver, CO, accompanied by four chemistry faculty members. This constituted the largest group of chemistry research students presenting at one time at a conference since the inception of the formalized chemistry research program in 1986. The national American Chemical Society meetings are the largest scientific professional conferences in the world, drawing from 15,000-25,000 chemistry professionals.

During summer 2015, nine students were engaged in research in our summer undergraduate research program, and most are continuing their projects this fall. Our research programs continue to expand, offering a gamut of opportunities in chemical ecology, natural products isolation, environmental chemistry, photocatalysis, biodegradable polymer chemistry, and the genetic analysis of soil bacteria.

These numbers tell of only one year of the chemistry research program. The program is robust, active, and cross-disciplinary with biology, physics, nutrition, Payson Library, and the UCLA Department of Chemical Ecology and Evolutionary Biology.

Internships

The chemistry faculty encourages students who are not engaged in our own research program to gain experience in the chemical industry during the summer months. Most recently, three of our chemistry majors have procured summer or semester internships at HRL laboratories, Malibu, CA. We have maintained active collegial liaisons with HRL over the years and senior scientists there continue to request our students for internships and full-time positions. Other chemistry majors have secured internships at Amgen Corporation and The Getty.

High-impact practices

One high impact practice central to the success of the chemistry program is a laboratory assistantship program which formally trains 15-20 chemistry majors/minors each term as teaching assistants in the general and organic chemistry laboratories or as a member of the General Chemistry Tutoring program. Each student invited to be a laboratory teaching assistant undergoes weekly orientation and training in freshman/sophomore laboratory instruction and serves as a paid in-lab assistant to a faculty member responsible for that section. We believe that this program encourages the mentorship of younger peers and is a highly-efficient and practical means of retaining our STEM majors. Further, it prepares our graduates for M.S. and Ph.D. programs in chemistry which generally require students to serve as teaching assistants.

A second high-impact practice unique to our program includes the student-spearheaded activities of our Student Affiliates chapter of the American Chemical Society (SAACS). Our SAACS chapter has received national commendation repeatedly in the last five years for its innovative role in bringing science to the larger student body at Pepperdine and greater Malibu community. In particular, chapter members and faculty advisors of SAACS have implemented activities exploring nanotechnology, polymer chemistry, non-Newtonian fluids, cryogenics and textile chemistry. These pursuits are certainly integral to the mission of the university enterprise in their attempts to foster an increased understanding of our physical world.

Co-Curricular Integration

Academic and career advising programs and resources

The Chemistry program conducts academic and career advising independently of the Department of Student Affairs. Every faculty member in the department advises majors for academics, career advice, and formal or informal spiritual counseling.

Each student who enters the Chemistry program is personally advised by one of the tenured or tenure-track Chemistry faculty members. With the help of his or her advisor, each student develops a 4-year plan that maps out the specific courses that need to be taken in each semester and identifies different options regarding elective or optional courses.

Tutoring, supplemental instruction, and teaching assistants

The Chemistry program provides free tutoring for all students enrolled in the CHEM 120/121 sequence. The tutors are hired from a pool of candidates who have already completed these courses and demonstrated proficiency and success. This system benefits the students who need tutoring since they can receive help at no personal monetary cost and it benefits the students who are hired as tutors because their work reinforces their mastery of concepts and skills covered in their prior classes.

Teaching assistants are hired to help the Chemistry faculty prepare for and administer the laboratory sections for General Chemistry I and II (CHEM 120/121), Organic Chemistry (CHEM 310/311), Elementary Organic Chemistry (CHEM 301), and Cellular Biochemistry (CHEM 330). Teaching assistants prepare supplies for lab experiments, set-up equipment, clean-up after lab periods, grade lab reports and provide general assistance to student enrolled in these courses. The TAs work from 2-12 hours each week, depending on the course and provide essential help and support to the Chemistry program. The TAs are hired from a pool of students who have already completed these courses and demonstrated proficiency and success.

Orientation and transition programs

The Chemistry program participates in student orientation each year by meeting with incoming first-year students who have declared a chemistry major and discussing the academic and extra-curricular opportunities available through the program.

Financial support for obtaining scholarships, fellowships, teaching assistantships, etc.

The Chemistry program has been awarded a matching grant from the Stauffer Foundation that will provide financial support for students who conduct research with the Chemistry faculty during the summer months. It is anticipated that these funds will eventually support 10-12 students during the summer months and will provide them with housing, meals, stipends and funds for research supplies. Except for this limited funding, the Chemistry Department has little control in funding scholarships.

The majority of the chemistry faculty have applied for the Undergraduate Research Fellowship on behalf of their research students for support during the summer research program. Many have also applied for and have been awarded Academic Year Undergraduate Research Initiative funds for their research students.

Tutors and teaching assistants have historically been supported by the Natural Science Division for nearly every position available. When the Division did not support a student, one faculty member has procured support from funding sources outside of the Division.

Support for engagement in the campus community

The Chemistry program primarily participates in the co-curricular experiences offered by the Department of Student Affairs through the activities of the Students Affiliates of the American Chemical Society (Chemistry Club). The Chemistry Club has participated in the many activities coordinated by student affairs. We list below only a couple:

- Blue and Orange Madness (2 years)
- Relay for Life

Additionally, the Chemistry Club frequently organizes events for students on campus, such as making Dippin' Dots in coordination with other campus activities and the Periodic Table of Cupcakes to celebrate National Chemistry Week each year.

Spiritual development programs and opportunities

One faculty member regularly engages one or two students per semester in the Spiritual Mentorship program offered through the Convocation Series office. Most faculty members have regularly hosted or participated in "Club Convo" or alternative chapels.

Study Abroad

The Chemistry program has participated in the Study Abroad programs by offering Organic Chemistry at the Buenos Aires and London campuses. Dr. White has also been appointed as the faculty-member in residence in the London program in three separate academic years.

Profile of the Chemistry Majors

In the past five years, 45 students have graduated with a major in chemistry, with 53% being female. The majority of our graduates chose to pursue post-graduate education with 41%

admitted into graduate programs (chemistry and biochemistry) and 25% admitted into health professional schools. Of the health professional schools, medical school was the top choice, followed by osteopathic and pharmacy school. The large remainder of our graduates (16%) entered the chemistry workforce, some of whom intend to pursue graduate study after securing experience in industry. One student (2%) entered law school, completing her J.D. and passing the bar exam.

The gender demographic of the chemistry major (combined BA and BS majors) is summarized for the previous 5 years in Table 3.

	5 year average
Male (percentage)	21 (47%)
Female (percentage)	24 (53%)
Total	45

Table 3. Gender demographic of the chemistry major

Our demographic is only mildly different from the 6-year national average of 49.9% of all bachelor's degrees in chemistry awarded to women[4]. Our gender numbers have fluctuated alternately slightly above and below the national average during the same period.

Ethnic diversity in the chemistry program is less consistent with the national averages. Table 4 summarizes our demographic comparing majors who specify their ethnicity as white/Caucasian and those among the ethnic minority groups. The number of students declaring themselves a member of an under-represented group is down to 16% from a two-year average of 38% in 2009 and slightly lower in 2011.

	5 year average
White/Caucasian	84%
Ethnic minority	16%

Table 4. Ethnic demographic of the chemistry major

The ethnicities represented in the minority group of Table 4 include American Indian and Native Alaskan, Pacific Islander, Asian, and Latino and Hispanic students. Contrasting our demographics with national averages, it is reported by the American Chemical Society (ACS) that the breakdown of bachelor's degrees awarded in 2007 were to 76% white candidates and the remaining 24% to the combined minority groups.[5]

Students choose the chemistry major because they realize from a high school or freshman-level class that they possess both an aptitude and a passion for this challenging field. The chemistry major draws strongly from other Natural Science Division disciplines including mathematics, sports medicine, and biology. As such, the successful chemistry major requires a broad mastery of other scientific fields.

Alumni and Student Survey Results

[4] *Chemical & Engineering News* November 23, 2009 Volume 87, Number 47

[5] *Chemical & Engineering News* September 17, 2007 Volume 85, Number 38

Students and alumni feel that they have been very well-trained in the discipline as demonstrated in the metrics of the OIE Alumni Survey. Chemistry ranks very well in the Natural Science Division in the provided data on the 38 criteria measured. Chemistry ranks number 1 among the science disciplines in 16 categories (42%), second for 9 categories (24%), third for 8 categories (21%), fourth for 2 categories (5%), and fifth for 4 categories (11%). Of particular note, respondents noted how well they were trained in the scientific method (3.85/4), their ability to express ideas clearly (3.71/4), and draw conclusions from mathematical graphs (3.74/4). In addition, they noted, with distinction, the emphasis that research plays in the chemistry department (3.50/4) and their continued connection to the chemistry program. Surprisingly, these measures of quality did not translate as strongly as for other programs in the desire to re-enroll at Pepperdine. Areas where the program was ranked lower than its peer science disciplines in the survey were in professional development through study abroad (2.36/4) and application of American history and institutions to existing issues (2.76/4). Due to the sequential and cumulative nature of chemistry courses, students in the chemistry program will struggle to participate in International Programs without adjustments to the periodicity of course offerings.

Research, Publications, Awards and Recognition, and Professional Accomplishments

Student research is an important component of the undergraduate experience in the chemistry program. During the past five years, there have been 17 peer-reviewed publications with student co-authors. There have been 62 presentations by students or with student co-authors at professional conferences, most commonly the national meetings of the American Chemical Society, but also including regional meetings of the American Chemical Society, the American Chemical Society Conference on Undergraduate Research in Chemistry and Biochemistry, the Southern California Conferences on Undergraduate Research (SCCUR), and numerous symposia. In addition, there have been 8 honors theses by students in chemistry during the past 5 years. This strong undergraduate research experience has translated to 14 Undergraduate Research Fellowships, 3 students being awarded the Outstanding Research Graduate of the Natural Science Division, and 6 students being awarded Graduate Research Fellowships by the National Science Foundation during their graduate studies in the past 5 years alone. These are in addition to the research fellowships awarded to many of our alumni as they enter graduate school.

Are graduates achieving the learning outcomes at the expected level?

Graduates from the Chemistry program are meeting and exceeding the learning outcomes for knowledge and expertise in chemistry as established by the program and benchmarked with the American Chemical Society (ACS) standards for certified programs. The successful review of the chemistry program by the ACS Committee for Professional Training (CPT) resulted in the program becoming 1 of only 43 schools in California with a certified program. During the review process, each course's lecture and lab syllabi and exams were reviewed for rigor of content and breadth of topical coverage. Among California peer and aspirational schools, Pepperdine joins Harvey Mudd, Claremont McKenna, Pitzer & Scripts Colleges, Occidental College, Loyola Marymount, Whittier College, Pomona College, and University of San Diego and University of San Francisco. Beyond this external validation of excellence in the training of our graduates, the OIE alumni survey of graduates showed that 100% of our graduates are engaged in full-time employment or graduate and professional school studies. As a result, it is clear that our graduates are meeting and exceeding the standards of the field and are desirable to employers and other institutions.

Meeting the standards of performance that the major has established

The standards of performance in the major are established by the combination of (1) the benchmarked standards of the American Chemical Society, (2) the expertise of each faculty member in their discipline, and (3) up-to-date innovations in the field and current chemistry education pedagogy. Student performance is assessed against these standards throughout their courses both in their intellectual performance on exams and in their technical abilities in the laboratory. Due to the time-intensive nature of the discipline, students not meeting the standards in early courses self-select for other majors in the sciences or, perhaps, among majors outside of the Natural Science Division. Students confronted by the limitations of their abilities may select a Bachelor of Arts degree instead of a Bachelor of Sciences degree as a better fit for their academic and career goals. These choices lead students to accurately assess their abilities and motivation and select either full-time employment or graduate and professional studies after graduation in which 100% of our graduate respondents are engaged in.

SUSTAINABILITY

The Chemistry Major

According to a 2009 ongoing national survey by the American Chemical Society[6], the number of bachelor degrees awarded in chemistry in the US from 1989-2009 went through several cycles of waxing and waning. In 1996-97, 10,644 degrees conferred, then steadily declined to 9,493 bachelor degrees in 2000-01, and peaked again in 2006-07 at almost 14,000. The number of students majoring in chemistry at Seaver College mirrored this trend from 1997 to 2005 but remained relatively static through 2011. Anecdotally, the upswing in chemistry majors starting in 2001 coincided with the opening of the new Keck Science Center.

Since 2011, the market for chemistry graduates (bachelor degrees as well as masters and doctoral) has been growing and, despite an otherwise weak economy, unemployment for chemists seeking jobs is very low. As of March 2014, 91.9% of chemists reported being employed full-time. A mere 2.9% of member chemists reported they were unemployed but looking for a job as of the date of the last survey, down from 3.5% March 2013, 4.2% in 2012, and a peak of 4.6% in 2011.[7]

According the 2015 OIE Alumni Survey Report for the Natural Science Division, 100% of graduates that responded to the survey were either employed or in graduate or professional

[6] *Chemical & Engineering News*, November 23, 2009.
[7] *Chemical & Engineering News*, November 3, 2014.

school. Of the respondents, nearly 70% indicated that they were extremely well prepared for their career path and only a single respondent indicated less than reasonably well prepared. The statistics for the Chemistry Department exceed the Division average and have the highest employment average overall, except for Computer Science graduates. Our statistics are comparable to (and actually exceeding) the national averages.

The Classroom and Laboratory Facilities

The Natural Science Division at Seaver College is housed in two main areas, the first to fourth floors of the Keck Science Center (KSC) and the first floor of the Rockwell Academic Center (RAC). The total space allocated to the division is 39,037.5 ft^2, and square footage within this space includes offices for faculty and staff, storage areas, support facilities, research and teaching laboratories, and classrooms.

Of the space allocated to the Natural Science Division, 943 ft^2 is used for the main office, stockroom, and tech support. There is approximately 1,401 ft^2 that includes space for office equipment, a break room, adjunct office space, a conference room, and the lobby with storage space consisting of 1,159 ft^2. In addition, approximately 1,751 ft^2 is used for a vivarium, autoclaves, the stockroom, a cold room, chemical storage, and washroom.

Classrooms for all courses taught by programs in the division are scheduled by the Office Administrator of the Natural Science Division. Currently, the division has access to 9,801.5 ft^2 that is used as classroom space, with classrooms distributed throughout the RAC, KSC, CAC (Cultural Arts Center), and the Plaza. In addition, PLC102, a classroom adjacent to the Payson Library, is used to teach several classes in mathematics. The following is a list of classrooms by student capacity: 1) 50 students – Plaza 188 and KSC 130; 2) 30 students – CAC 124, CAC 125, and RAC 175; 3) 24 students – KSC 100, KSC 110, RAC 170; 4) 16-22 students – KSC 210, KSC 300, KSC 320, KSC 360, RAC 138, RAC 178. Five of these rooms (KSC 210, KSC 300, KSC 320, KSC 360, KSC 430) are used as teaching laboratories, as well as classrooms.

Faculty members have assigned laboratory space that is used for both research and teaching. Programs which most of the laboratory space include Biology, Chemistry, Physics, and Sports Medicine. Collectively, this amounts to approximately 9,788 ft^2. Laboratory space utilized primarily for teaching includes 14,956 ft^2.

Office space for faculty is located in the RAC and totals 4,240 ft^2.

Facilities Specific to the Chemistry Program

a. Classroom space

Given that we see it as desirable that the courses we teach (general chemistry, organic chemistry and biochemistry) that support multiple majors not be large, our classroom space is adequate, as it limits the size of a class to about 50 students. With the growth in the number of students majoring in the sciences, this has meant teaching more sections of general chemistry, including teaching one section in a smaller classroom because the larger classrooms that seat 50 students were not available.

b. Laboratories

Chemistry has three laboratories for conducting the laboratory portion of courses in the chemistry curriculum: one for General Chemistry (KSC 420), one for Organic Chemistry (KSC 450), and one for all of our other upper division courses (KSC 430). The biochemistry labs are taught in another lab in space assigned to biology. Given the greater space needed per student, laboratories by nature are more limited in the maximum number of students allowed per section compared to a lecture. For example, the maximum number of students possible in a General Chemistry lab section is 20, and the maximum number of students possible in an Organic Chemistry lab section is 16 (CHEM 310L/311L). As long as there are enough time slots available to teach the requisite number of lab sections, laboratory space is adequate. Occasionally one of our laboratory courses taught in KSC 430 has more students than can be accommodated in one section, so two sections are taught. This is undesirable from the point of view of increasing the total number of units we have to cover with limited faculty, and it has happened 3 times in the preceding 5 years.

c. Student study space

There is no formal study space for chemistry students. However, students have desks in their dorm rooms, Payson Library has many areas for students to study, and there are various locations in RAC and KSC where students study, *e.g.*, the RAC lobby, the Advanced Laboratory (KSC 430) when unoccupied, and on benches next to windows in KSC.

PROFILE OF THE CHEMISTRY FACULTY

The chemistry department employs five tenure or tenure track faculty members (* indicates tenured status):

Joseph M. Fritsch*, Associate Professor of Inorganic Chemistry (2008 Seaver Fellow in Natural Science)
Jane A. Ganske*, Professor of Physical Chemistry (2002 Frank R. Seaver Professor of Natural Science)
David B. Green*, Professor of Analytical Chemistry and Instrumentation Specialist
P. Matthew Joyner, Assistant Professor of Biochemistry
James B. White*, Professor of Organic Chemistry

Each faculty member holds an earned Ph.D. in their subdiscipline. The faculty are represented by only one woman and currently have limited ethnic diversity. Three are members of the Churches of Christ and all are active in a church. The terms of employment at Pepperdine, at the time of this review, range from 5 years to 29 years. Each has published research and/or education articles in their field since their appointment at Pepperdine. The individual field-expertise of each faculty member is critical to the program's excellence in that every specialty course is taught by a recognized specialist in the field. In addition, every faculty member in the chemistry department possesses sufficient breadth that they can teach outside of their specialty. The chemistry faculty are all involved in research and, in many cases, their research interests are brought to the chemistry laboratories in the form of modern laboratory investigations and experiences. Some of these investigations have been published in the chemistry education journals (*Journal of Chemical Education* and *Chemical Educator*).

The chemistry faculty meet together at least once a year to discuss the curriculum and ensure critical topics are introduced and reiterated in later courses, where necessary. Using the American Chemical Society curriculum as the template reduces the necessity to meet more frequently to discuss curricular matters. The chemists also meet either directly or electronically frequently to discuss students' progress through the curriculum and other advising issues. In addition, some of the faculty meet informally weekly to discuss pedagogical approaches to improve student retention and content delivery.

Concern for pedagogy is well-demonstrated by the time and resources invested by each chemist to present their discipline partially or fully unencumbered by textbooks linked to current trends or not designed for the educational model utilized in the chemistry department. The following is an abbreviated list of resources produced "in-house," designed for pedagogical flexibility and appropriateness for our students. These resources are not intended to be published externally since, by their design, they would not be as effective outside of the Pepperdine University chemistry department.

Green, Ganske, Fritsch: *Laboratory Investigations and Experiments in General Chemistry* (in 3rd edition, CHEM 120L/121L)

Green: *Laboratory Manual to Accompany Quantitative Chemistry and Instrumental Analysis* (CHEM 340L/341L/440L)

White: Organic Chemistry notes. Replaces the traditional and limited organic chemistry textbook. (CHEM 310, 311)

Ganske: Laboratory investigations in Physical Chemistry. A series of monographs specifically for the physical chemistry laboratories (CHEM 370,371, 380)

Fritsch: Laboratory investigations in Inorganic Chemistry. A series of monographs specifically for the inorganic chemistry laboratories (CHEM 390)

Green: *Analog Electronics: A Primer*. A primer designed for semi-independent experiments in analog electronics (CHEM 492)

With the small faculty complement characteristic of the chemistry department, mentoring of new faculty is shared by all members without any formal assignment of duties. Each member is encouraged to attend field- and discipline-specific workshops and meetings as frequently as practical. The chemistry faculty have attended conferences and workshops at meetings including regional and national meetings of the American Chemical Society, the Gordon Research Conferences, PKAL, National Conference on Undergraduate Research, and others.

Qualifications and Achievements of the Chemistry Faculty

The five tenured and tenure-track faculty in the chemistry program each have their Ph.D. (terminal degree) in the discipline that they teach. Among the visiting and adjunct faculty in the program over the past 5 years, 60% have their terminal degrees and 40% have their master's degrees. The five major disciplines of chemistry each have a tenured/tenure track faculty member on staff to apply their expertise and provide expert instruction to students.

Research with a faculty mentor is an important component of the chemistry program, and the vast majority of students in the chemistry program are able to participate in discovery research.

Faculty and students conduct research primarily (at least 40 h/week) during the summer during a 12 week period and to a lesser extent during the academic year (~4-10 h/week). Success in these research projects translates into presentations, publications, and honors theses.

Faculty Member	Chemistry Discipline	Peer-reviewed Publications (5 y)	Presentations with student co-authors at professional conferences (5 y)	Student Honors Theses (5 y)
Fritsch	Inorganic	6	22	4
Ganske	Physical	1	5	1
Green	Analytical	9	25	2
Joyner	Biochemistry	1	10	1
White	Organic	0	0	0

External awards were made to:
Bucciarelli, G., Green, D.B., Kats, L.B.; "Characterization, evaluation, and control of invasive species in Los Angeles watersheds" ($50,000) from Virgenes Municipal Water District.
Drs. Fritsch and Green for a 400 MHz NMR spectrometer ($239,639) by the Ahmanson Foundation (2011) as part of a larger grant to the Natural Science Division.
Dr. Ganske for a GC-MS ($98,475) by the Parsons Foundation (2010).

Participation in professional development research opportunities is as follows:

	Year of last sabbatical	Location
Fritsch	Spring 2014	Imperial College, London
Ganske	1997-1998	UCI
Green	1999	HRL, Malibu
Joyner	ineligible	
White	Spring 2005	UCSB

Due to the teaching loads and dependence on each faculty member to be actively teaching in the department, the chemistry faculty have had limited opportunity to participate in professional development activities, like sabbatical. Despite being eligible for sabbatical for 9 and 10 years, respectively, David Green and Jane Ganske have not availed themselves of this form of professional development due to the demands of teaching and the difficulty of finding replacement visiting faculty.

Faculty information in a capsule

a. Number of full-time faculty

There are five tenured/tenure track faculty members, one visiting faculty member and one adjunct (as of 2015) employed in chemistry. In terms of credit hours covered, tenured/tenure-track faculty members cover 70-75% of the load, and the visiting faculty member and adjunct(s) cover the remainder.

b. Student-faculty ratio

The student-to-faculty ratio has varied from 24-38% since 2011, which is essentially unchanged since the 2011 program review. The tables summarize the student-to-faculty ratio since 2011 and is disaggregated by lecture and laboratory. The three largest lecture courses, which also serve multiple majors, are listed as well.

Average Student-to-Faculty Ratio for all chemistry lectures and for service courses.

	Student-to-Faculty Ratio				
Year	Fall	Spring	General Chemistry (Fall/Spring)	Organic Chemistry (Fall/Spring)	Biochemistry
2011	24	27	53/47	33/22	47
2012	38	22	53/35	48/36	43
2013	33	24	42/35	42/35	50
2014	26	29	36/35	36/43	41
2015	25	25	33	27	39

Average Student-to-Faculty Ratio for all chemistry laboratories.

	Student-to-Faculty Ratio	
Year	Fall	Spring
2011	12	15
2012	16	14
2013	17	14
2014	12	15
2015	13	14

The simple algorithm of the ratio of the total number of students taught by the total number of faculty was used for each of the averages. The student-to-faculty ratios are higher when the ratio of student-contact-hours per faculty-load-hours is utilized, due to the laboratory component of courses being evaluated at a lower load hours than contact hours.

c. Faculty Workload

Each faculty member carries between 11.5-13 units of compensated load. One faculty member regularly teaches an additional advanced course each year without compensation to provide advanced courses required for graduation. Some faculty members receive a one-course release, either because they are untenured or because they have applied for release time. For the 2015-16 academic year, those receiving a course release covered on average 20.2 contact hours, and those without a course release covered 23.9 contact hours. The visiting faculty member covered 31.25 contact hours, and 10 contact hours were covered by an adjunct.

d. Faculty review and evaluation processes

Faculty members are evaluated by the students in their lecture and laboratory courses each semester. The Divisional Dean of the Natural Science division does an annual review of each faculty member, and faculty members are evaluated by RTP for tenure, promotions and five-year reviews.

e. Professional development opportunities and resources (including travel and research funds)

Funds are available through the Natural Science division for travel to national/regional meetings at least once a year. Grants for carrying out research with undergraduate students during the fall and spring semesters and during the summer are available through the offices of the Dean and the Provost. In addition, funds are available from an endowment for supporting research in chemistry.

f. Sufficient time for research, program development

We have teaching loads equal to or greater than our peer institutions. This makes doing research during the academic year difficult, but not impossible. It also means that the most productive time for research is during the summer. Likewise, there is limited time for program development, but it is carried out during the academic year and the summer.