# Department of Chemistry and Biochemistry
# 2022 Assessment Report

*All areas shaded in gray are to be completed by the department/program.*
*This document will be posted online and must be accessible electronically (including appendices).*

## MISSION STATEMENT

The mission of the Department of Chemistry & Biochemistry is to create new knowledge about the molecular sciences and to convey these discoveries, as well as the discoveries of other molecular scientists throughout history, to the scientific community, students, and the public.

## DEPARTMENT ALIGNMENT WITH PRIORITIES FOR ACTION

After listing each departmental objective, indicate which of the five Priorities for Action the objective supports. In this section, you may also briefly describe any innovative or noteworthy programs/initiatives that support the Priorities for Action.

1. **Provide quality instruction in the foundations of the chemical sciences to majors and non-majors**. The courses and majors in chemistry or biochemistry provide training for students planning careers in the chemical sciences and also for those whose interests lie in related fields such as physics, biology, health sciences, earth sciences, engineering and secondary education. The Department delivers approximately 8,000 student credit hours each year, and approximately 92% of those are to students in majors other than Chemistry or Biochemistry. A substantial fraction of the total UM undergraduate population will, at some stage of their degree program, take a course in the Department of Chemistry and Biochemistry and the curriculum is designed to satisfy the diverse needs of all these students. *This objective aligns closely with 1. Place Student Success at the Center of all we do, and 2. Drive Excellence and Innovation in Teaching, Learning and Research.*

2. **Provide unique advanced and experiential learning opportunities for Chemistry and Biochemistry majors and graduate students.** Each chemistry graduate will have completed a rigorous program which includes foundational and in-depth course work in chemistry. Bachelor's and graduate options emphasize laboratory experience and the development of professional skills. Advanced coursework and educational activities outside the traditional classroom, such as independent research and internship opportunities provide students the opportunity to develop practical skills, conduct individual research projects or participate as a member of a team. Many undergraduate students also benefit from taking one or more advanced graduate courses in specific fields of chemistry. The Department also provides students opportunities to review and advance their knowledge of chemistry by serving as tutors, peer leaders, learning assistants or teaching assistants. Nearly all graduate students and many undergraduate students serve as teaching assistants for a semester or more. Many of our undergraduate students also participate in the Chemistry Peer Leading Program or the UM Learning Assistant Program where they gain experience leading workshops and recitations. The Department of Chemistry & Biochemistry has also converted a computer lab into the Chemistry and Biochemistry Learning Center (CBLC), where Teaching Assistants are assigned to hold office hours and to be available to assist and tutor students. The CBLC is also used extensively by students in informal study groups or who meet to work on projects together. *This objective aligns closely with 1. Place Student Success at the Center of all we do, 2. Drive Excellence and Innovation in Teaching, Learning and Research and, 4. Partner with Place.*

3. **Students of chemistry, and chemistry majors at graduation, will have a set of fundamental competencies that are knowledge-based, performance/skills-based, and affective practices.** Students develop these skills through a structured curriculum based on national norms that is certified by the American Chemical Society (ACS). Each course in the curriculum introduces and/or reinforces particular competencies (see attached Curriculum Mapping Template for Chem/Biochem). The competencies are defined in Departmental Objectives 4-6 below, and the associated courses and assessment measures are presented in Table 1. The effectiveness of each course is reviewed and assessed through student evaluations and most of the courses are also measured objectively and quantitatively using American Chemical Society subject exams. Many chemistry programs in the United States use these standardized ACS exams as an assessment tool, and national performance statistics are available for the exams. These standardized exams thus allow comparison of UM student learning outcomes to accepted national norms and also provide a means to track changes in program and student performance over time. For more information about the ACS exams, please visit the webpage: https://www.acs.org/content/acs/en/education.html *This objective aligns closely with 1. Place Student Success at the Center of all we do, and 2. Drive Excellence and Innovation in Teaching, Learning and Research.*

4. ***Knowledge-Based Competencies*** Students and graduates will be able to:
   a. Master a broad set of chemical knowledge concerning the fundamentals in the basic areas of the discipline (organic, inorganic, analytical, physical, environmental and biochemistry).
   b. Solve problems competently by identifying the essential parts of a problem and formulating a strategy for solving the problem. They will be able to rationally estimate the solution to a problem, apply appropriate techniques to arrive at a solution, test the correctness of the solution, and interpret their results.
   c. Use computers in data acquisition and use available software as a tool in data processing and analysis.
   d. Employ modern library search tools to locate and retrieve scientific information about a topic, chemical, chemical technique, or an issue relating to chemistry.
   *1. Place Student Success at the Center of all we do, and 2. Drive Excellence and Innovation in Teaching, Learning and Research.*

5. **Performance/Skills Based Competency**

1. Understand the objective of their chemical experiments, properly carry out the experiments, and appropriately record and analyze the results.
   b. Use standard laboratory equipment, modern instrumentation, and classical techniques to carry out experiments.
   c. Know and follow the proper safety procedures and regulations for safe handling and use of chemicals.
   d. Communicate the concepts and results of their laboratory experiments through effective written and oral communication skills.
   *1. Place Student Success at the Center of all we do, and 2. Drive Excellence and Innovation in Teaching, Learning and Research, 4. Partner in Place and 5. Proudly tell the UM story.*

2. ***Effective Outcomes***
   All graduates will be able to successfully pursue their career objectives in advanced education in professional and/or graduate schools, in a scientific career in government or industry, in a teaching career in the school systems, or in a related career following graduation. (Education for the Global Century and Partnering for Student Success). *This objective aligns closely with 1. Place Student Success at the Center of all we do, 2. Drive Excellence and Innovation in Teaching, Learning and Research and 4. Partner with Place and 5) Proudly Tell the UM Story.*

## STUDENT LEARNING GOALS and MEASUREMENT TOOLS

| Student Learning Goals | Student Feedback | Student Evaluations | Faculty Evaluation | ACS Exams | Capstone Performance |
|---|---|---|---|---|---|
| **CHMY 104** This is a preparation for college chemistry course designed to prepare students for success in CHMY 141/3. This addresses goals in 1, 4a and 4b above. | √ | √ | √ | | |
| **CHMY 121/3** This general, organic and biochemistry course sequence is for students not majoring in the chemical or physical sciences and addresses goals 4a, 4b and 4c. | √ | √ | √ | | |
| **CHMY 122/4** These are the laboratory courses associated with 121/3 and address goals 4a-c and 5a-d | √ | √ | √ | | |
| **CHMY 141-4** This is the college chemistry sequence for students majoring in the natural, physical and chemical sciences. The sequence is both lecture and laboratory and addresses goals 4a-c, 5a-d | √ | √ | √ | √ | |
| **CHMY 221-4** This is the organic chemistry sequence of lecture and lab courses for physical and natural science majors and addresses and reinforces goals 4a and 5a-d | √ | √ | √ | √ | |
| **CHMY 311** This quantitative analytical chemistry lecture/laboratory course is for chemistry, biochemistry and related majors and addresses and reinforces goals 4a-c, 5a-d | √ | √ | √ | √ | |
| **CHMY 373/371** This physical chemistry sequence is completed by chemistry and biochemistry majors and addresses and reinforces goals 4a-b. | √ | √ | √ | √ | |
| **CHMY 401** This inorganic chemistry course is taken by chemistry and biochemistry majors and addresses and reinforces goals 4a-b | √ | √ | √ | | |

| Student Learning Goals | Student Feedback | Student Evaluations | Faculty Evaluation | ACS Exams | Capstone Performance |
|---|---|---|---|---|---|
| **CHMY 402**<br>This inorganic chemistry laboratory course is completed by chemistry majors and addresses and reinforces goals 4a-c, 5a-d | √ | √ | √ | | |
| **CHMY 421**<br>This instrumental analysis course is completed by chemistry and biochemistry majors and addresses and reinforces goals 4a-c, 5a-d. | √ | √ | √ | | |
| **CHMY 490**<br>Undergraduate research is an upper division elective for chemistry and biochemistry majors. More than half of undergraduate chemistry majors conduct undergraduate research, and of those nearly half author or co-author a publication describing their research results. goals 4c-d, 5a-d, and 6. | √ | | | | √ |
| **CHMY 498**<br>Internships are upper division electives for all chemistry and biochemistry majors. Chemistry majors in the Forensic Science Option are required to complete either research or an internship. Internships reinforce goals 4a-d, 5a-d, and 6 | √ | | | | √ |
| **BCH 481/2**<br>This advanced biochemistry sequence is completed by chemistry and biochemistry majors and addresses and reinforces learning goal 4a. BCH 482 also satisfies 1/3rd of the Advanced Writing Gen Ed for both Chemistry and Biochemistry majors. | √ | √ | √ | | √ |
| **BCH 486**<br>This laboratory course develops students skills in biochemistry research techniques and is completed by biochemistry and some chemistry majors. The course addresses and reinforces learning goals 4a-d, 5a-d and 6. BCH 486 also satisfies 2/3rd of the Advanced Writing Gen Ed for both Chemistry and Biochemistry majors. | √ | √ | √ | | √ |

| Student Learning Goals | Student Feedback | Student Evaluations | Faculty Evaluation | ACS Exams | Capstone Performance |
|---|---|---|---|---|---|
| **Undergraduate Electives** Chemistry majors are required to complete variable amounts of elective credits in chemistry depending on their degree option. Electives are selected in consultation with the adviser to reinforce goals 4a-b,d and 6. | √ | √ | √ | | √ |
| **Graduate Coursework** A full complement of graduate level courses are offered in six disciplines of chemistry: Analytical, Environmental, Organic, Inorganic, Physical and Biochemistry | √ | √ | | | √ |

## RESULTS and MODIFICATIONS

| Learning Goal results | Modifications made to enhance learning |
|---|---|
| CHMY 121N: Introduction to General Chemistry. The 120 series of Chemistry courses (of which 121 is the first in the sequence) is a service course that serves Allied Health, Forestry/Wildlife Biology and Environmental Sciences majors. As well, this course has a Natural Science Gen Ed designation and many students satisfy their 'N" designation with this course. Overall, the 120 series comprises ~40% of the SCH taught in the Chemistry and Biochemistry department.<br>Starting in Spring 2019 we hired an instructor for this positon with the goal of increasing Completion Rates in the 120 series. The results have been significant with completion rates increasing from ~ 70% to the low 80% range up to 2020. Covid and the resulting remote learning approaches were not helpful in this trend however and significant new challenges to Learning Goals have arisen from poorly prepared freshman. | The instructor for this course has made extensive use of undergraduate Learning Assistants in the class (~ 30 in the last two years alone). To help attain Learning Goals, a one hour recitation course has been added with multiple sections to lower the number of students to a more manageable size. Normal lectures have ~250 students while the recitation has been pared down to ~40 students. 40 is still a large number of students for a single TA or instructor so undergrad LA's have been extensively used to increase instructor:student ratios. This has been found to be quite effective and has also served to reinforce chemical concepts with the LA's. Overall it is a valuable teaching tool to enhance learning but it needs a lot of work by the instructor as well as a lot of resources by the University and the Department. |
| CHMY 122: Introduction to General Chemistry Lab. This is a discovery-based laboratory course to accompany CHMY 121. This laboratory course is primarily taken by students in the Pre-Nursing program. The Chem and Biochem department has taken over this course from Missoula College starting in Fall of 2020. Labs have been designed to give students practice in careful "hands-on" scientific measurements/error determination as well as to develop the students quantitative skills and reinforce critical thinking skills. | The Learning Goals of this course have been enhanced by consistent teaching since it has moved into the purview of the Chem and Biochem Dept. Previously this course was staffed by adjuncts that differed from year to year. This has changed along with a more consistent curriculum and learning goals. |
| CHMY 123: Introduction to Organic and Biochemistry. This is a course taken primarily by Allied Health and Forestry/Wildlife Biology Majors. As with CHMY 121 above, an instructor was hired to increase completion rates and increase the numbers of students continuing on from 121 into 123. Both of these have been successful as shown with continuation between courses rising ~ 10% (it should be noted that not all students who take CHMY 121N need CHMY 123 for their major). | Significant modifications have been made to the CHMY 123 and 124 sequence. This includes updated recitations with lowered course capacities and the involvement of undergraduate Learning Assistants (much like CHMY 121N above) along with graduate Teaching Assistants. This has taken a significant investment in resources by the department of Chemistry and Biochemistry but, by all accounts, it has been paying off with higher completion rates. In |

<table>
<tr><th>Learning Goal results</th><th>Modifications made to enhance learning</th></tr>
<tr><td></td><td>particular, the Learning Assistant Program has seemed to have significantly benefited learning outcomes of the students by having more one-on-one time between instructor and student.</td></tr>
<tr><td>CHMY 124: Introduction to Organic and Biochemistry Lab.<br>This is a discovery-based laboratory course to accompany CHMY 123.</td><td>The instructor for the CHMY 123 series has been put in charge of the 124 lab that accompanies the course. This has led to relevant modifications to the lab that translates into closer ties to the lecture. One particular are of learning enhancement has been the incorporation of modern analytical instrumentation into this lab. The current 124 instructor has students using state-of-the-art High Performance Liquid Chromatography and UV-Vis Plate Readers to take data and determine compound purity. By all accounts the students really enjoy using this equipment and getting to see real world research instruments.</td></tr>
<tr><td>CHMY 141<br>CHMY 141N: College Chemistry I Goals 4a-b<br>ACS Exam Scores:
<table>
<tr><td>Semester</td><td>AU 2012</td><td>SP 2013</td><td>AU 2013</td><td>SP 2014</td></tr>
<tr><td>Median %tile</td><td>79</td><td>53</td><td>70</td><td>58</td></tr>
<tr><td>Semester</td><td>AU 2014</td><td>SP 2015</td><td>AU 2015</td><td>SP 2016</td></tr>
<tr><td>Median %tile</td><td>77</td><td>N/A</td><td>74</td><td>63</td></tr>
<tr><td>Semester</td><td>AU 2016</td><td>SP 2017</td><td>AU 2017</td><td>SP 2018</td></tr>
<tr><td>Median %tile</td><td>81</td><td>N/A</td><td>84</td><td>59</td></tr>
</table>
<table>
<tr><td>Semester</td><td>Au 2018</td><td>SP 2019</td><td>AU 2019</td><td>SP 2020</td></tr>
<tr><td>Median %tile</td><td>79</td><td>53</td><td>70</td><td>58</td></tr>
<tr><td>Semester</td><td>Au 2020</td><td>SP 2021</td><td>Au 2021</td><td>SP 2022</td></tr>
<tr><td>Median %tile</td><td>70</td><td></td><td>78</td><td></td></tr>
</table>
CHMY 141 and CHMY 143 are taught using an innovative Peer Leader program in which student peers are trained to lead in-class problem solving activities and workshops with groups of 8-12 students.<br>As noted earlier in this report, the American Chemical Society (ACS) Examinations Institute provides nationally-standardized exams that are used by many institutions to evaluate and normalize student outcomes in traditional undergraduate chemistry courses. The national median percentile is, by definition 50% (pre-Covid).<br>ACS Exam percentile scores for CHMY 141 at UM, presented above, indicate that students in this course, particularly those who complete the course in the fall semester, are outperforming their peers across the nation. Autumn scores have shown substantial and significant improvements since 2016. Scores are significantly lower for the off sequence cohorts who take the course in the spring semester.</td><td>We have initiated a program by which students who do not perform well in CHMY 141 during the first five weeks of the semester may transfer to CHMY 104 along with a preparatory math program without fees and without the drop/add showing up on their transcripts. This allows students to receive adequate preparation and continue into CHMY 141 in a later term. Students who make the transfer earn on average a B- in CHMY 104., and approximately half of those students do repeat CHMY 141 earning on average a C+ in their second attempt.<br><br>Future Plans:<br>The instructor intends to continue to revise the curriculum. We plan to revise the textbook with a particular focus on improving the homework sets. Lectures, homework assignments, and lecture workbook will continue to be revised based on student feedback. We also have a plan to improve workshop leader training by changing the emphasis on a number of factors, such as how to convince students to do the homework</td></tr>
<tr><td>CHMY 142: College Chemistry I Lab<br>This is a discovery-based laboratory course to accompany CHMY 141: College Chemistry I</td><td>Beginning in Autumn 2018 the instructor of record for the lab course will be the same as that for the lecture course (Dr. Mark Cracolice). The laboratory is to be rescheduled and reworked, and new laboratory exercises introduced, so that it follows more closely</td></tr>
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<table>
<tr><th>Learning Goal results</th><th>Modifications made to enhance learning</th></tr>
<tr><td></td><td>the material presented in lecture. This is also one of the first classes where significant scientific writing skills are introduced and analytical skills reinforced.<br>We plan to enhance both the writing and analytical skills by continuing the inquiry based learning approach to the lab.</td></tr>
<tr><td>CHMY 143<br>CHMY 143N: College Chemistry II Goals 4a-b<br>ACS Exam Scores:<br><table><tr><td>Semester</td><td>SP 2013</td><td>SU 2013</td><td>SP 2014</td><td>SU 2014</td></tr><tr><td>Median %tile</td><td>81</td><td>72</td><td>81</td><td>72</td></tr><tr><td>Semester</td><td>SP 2015</td><td>SU 2015</td><td>SP 2016</td><td>SU 2016</td></tr><tr><td>Median %tile</td><td>81</td><td>70.5</td><td>70</td><td>67.5</td></tr><tr><td>Semester</td><td>SP 2017</td><td>SU 2017</td><td>SP 2018</td><td>SU 2018</td></tr><tr><td>Median %tile</td><td>76</td><td>84</td><td>79</td><td>N/A</td></tr><tr><td>Semester</td><td>SP2019</td><td>SU 2019</td><td>Sp 2020</td><td>SU 2020</td></tr><tr><td>Median %tile</td><td>85</td><td>N/A</td><td>84</td><td>N/A</td></tr><tr><td>Semester</td><td>SP 2021</td><td></td><td></td><td></td></tr><tr><td>Median %tile</td><td>N/A</td><td></td><td></td><td></td></tr></table>Students in this class are performing well above national norms, with all cohorts scoring above national norms and only one autumn semester cohort in the past six years scoring below the 76th percentile. As with 141, however, students in the off-sequence summer session course generally do not perform as well as those in the spring semester course, but the most recent summer cohort scored at about the same level as autumn cohorts</td><td>Textbook and curriculum were revised to introduce thermodynamics earlier; this is the first step in an effort to interweave thermodynamics throughout the curriculum.<br>The workshop leader training program was revised.<br>Future Plans:<br>CHMY 143 instructors will continue to revise the course and leader training regimen based on student and peer leader feedback.</td></tr>
<tr><td>CHMY 144: College Chemistry II Lab<br>This is a discovery-based laboratory course to accompany CHMY 143 College Chemistry II</td><td>Beginning in Spring 2019 the instructor of record for the lab course will be the same as that for the lecture course (Dr. Mark Cracolice). The laboratory is to be rescheduled and reworked, and new laboratory exercises introduced, so that it follows more closely the material presented in lecture.</td></tr>
<tr><td>CHMY 221: Organic Chemistry I Goals 4a-b<br>ACS Exam Scores:<br><table><tr><td>Semester</td><td>AU 2010</td><td>AU 2011</td><td>AU 2012</td><td>AU 2013</td></tr><tr><td>Median %tile</td><td>62</td><td>65</td><td>53</td><td>50</td></tr><tr><td>Semester</td><td>AU 2014</td><td>AU 2015</td><td>AU 2016</td><td>AU 2017</td></tr><tr><td>Median %tile</td><td>65</td><td>59</td><td>41</td><td>48</td></tr><tr><td>Semester</td><td>AU2018</td><td>AU2019</td><td>AU2020</td><td>AU2021</td></tr><tr><td>Median %tile</td><td>47</td><td>45</td><td>N/A</td><td>40</td></tr><tr><td>Semester</td><td>AU2022</td><td></td><td></td><td></td></tr><tr><td>Median %tile</td><td>27</td><td></td><td></td><td></td></tr></table>Exam scores over the past 8 years have averaged 55 +/- 9 %tile. In general, with the exception of 2016 and the most recent 2022 results, the scores indicate that students are</td><td>Beginning with the fall semester of 2018 the exams for this course were given on-line through Moodle and completed outside of class time.<br>This was to permit more time for students and the professor to meet in lecture. Students had more than one opportunity to complete the exams satisfactorily. Pending successful implementation of this approach, the course may progress toward a skills mastery approach in which students demonstrate mastery of content though online examinations. There is still significant tweaking going on with this delivery method and we are closely monitoring results.<br>Given the continuing drop in median %tile the current Professor for this class has decided to move back to the in class exams and increasing the % that the final</td></tr>
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<tr><th>Learning Goal results</th><th>Modifications made to enhance learning</th></tr>
<tr><td>performing at or above their peers nationally. Scores appear to have decreased significantly over the past four years. 2014 scores notwithstanding, the trend toward lower performance may extend as far back as 2012. Instructor of record Nigel Priestley has been making significant changes to the course in recent years in an attempt to improve learning outcomes and reduce DFW rates. The 2022 low %tiles likely reflect the overall lower chemistry skills of the Covid cohort.</td><td>(ACS) exam is worth. Hopefully this will enhance student learning in the critical core course.</td></tr>
<tr><td>CHMY 222: Organic Chemistry I Lab<br>Student learning is hampered to an extent by the lack of access to state of the art instrumentation such as Nuclear Magnetic Resonance and Gas Chromatography-Mass Spectrometry.</td><td>New IR instruments have been effectively incorporated to provide qualitative analysis.<br>Incorporated 3D printing of crystal structures to teach symmetry and NMR spectroscopy in Lab 7..<br>Future Plans: Add a specific dish washing guide.<br>Reword postlab quiz 5 as it is too difficult.<br>Purchase more UV lamps. Continue implementing 3D printing in the labs. Integrate more Thin Layer Chromatography into the lab. Shorten Lab 4 or 6 by one day. Extend Lab 7 by one day. Provide further resources for keeping a better lab notebook.<br>Incorporate some mechanism drawing in the lab.</td></tr>
<tr><td>CHMY 223: Organic Chemistry II Goals 4a-b<br>ACS Exam Scores:<table><tr><td>Semester</td><td>SP 2013</td><td>SP 2014</td><td>SP 2015</td><td>SP 2016</td></tr><tr><td>Median %tile</td><td>60</td><td>56</td><td>56</td><td>48</td></tr><tr><td>Semester</td><td>SP 2017</td><td>SP 2018</td><td>SP2019</td><td>SP2020</td></tr><tr><td>Median %tile</td><td>47</td><td>56</td><td>58</td><td>41</td></tr><tr><td>Semester</td><td>SP2021</td><td>SP2022</td><td></td><td></td></tr><tr><td>Median %tile</td><td>33</td><td>54</td><td></td><td></td></tr></table>Exam scores for the past six years have averaged 54±5 %tile with the exception of SP2021 (following the remote AU2020 covid class). After a brief decline in scores in 2016 and 2017, there was a recovery in 2018 and hopefully a continued improvement in 2022. Students at UM are performing at or just above national norms on this exam. The instructor has indicated that a classroom more conducive to group problem solving may help students to participate and better learn the concepts.</td><td>In spring of 2017 the curriculum was revised to have somewhat less material on NMR, allowing for more comprehensive coverage of other material.<br>In spring of 2018 The “molecule of the day” content was not focused upon as the course fell a little behind in covering the required content.<br>Future Plans: Highlight one “molecule of the day” as it relates to the topic being covered in class. Reduce the number of generic examples of each reaction and spend more time on one relevant example per reaction.<br>Many of these plans were interrupted by Covid remote learning and reintroduction of them is now necessary.</td></tr>
<tr><td>CHMY 224: Organic Chemistry II Lab<br>Student learning is hampered to an extent by the lack of access to state of the art instrumentation such as Nuclear Magnetic Resonance and Mass Spectrometry</td><td>New IR instruments have been effectively incorporated to provide qualitative analysis.<br>Future Plans:Implement GC/MS techniques and methods for visualizing molecules</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CHMY 311: Quantitative Analysis, Goals 4a-c, 5a-d<br><br>ACS Scores:<table><tr><td>Year</td><td>2012</td><td>2013</td><td>2014</td><td>2015</td></tr><tr><td>Median %Tile</td><td>71.5</td><td>67</td><td>60</td><td>79</td></tr><tr><td>Year</td><td>2016</td><td>2017</td><td>2018</td><td>2019</td></tr><tr><td>Median %Tile</td><td>53</td><td>53</td><td>67</td><td>53</td></tr><tr><td>Year</td><td>2020</td><td>2021</td><td>2022</td><td></td></tr><tr><td>Median %Tile</td><td>47</td><td>N/A</td><td>36</td><td></td></tr></table>Between 2012 and 2016 there appears to have been a significant decline ACS test Scores, levelling off (with the</td><td>On-line homework system through Sapling Learning has been in use since 2014, and was modified in 2015 to allow students to work and rework the on-line homework problems several times without significant penalty, encouraging students to persist until they figure out the problems.<br>Adopted active learning strategies to improve student engagement and to improve student learning of the material. Students have been enthusiastic about the active learning approach.<br>Lecture was moved from 8AM to 2 PM.<br>Future Plans: Further adopt on-line text and homework system through Achieve (formerly Sapling), balancing cost against accessibility and quality of the text material.</td></tr>
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<tr><th>Learning Goal results</th><th>Modifications made to enhance learning</th></tr>
<tr><td>exception of 2018) at 53%tile. The course was moved to meet at 8 AM in 2016. The lecture was moved back to 2 PM in 2020. Active learning strategies were adopted in lectures in 2018, were further developed in 2019, and were continued in 2020. 2020 was impacted by Covid-19 with over half of students attending lectures remotely. It is not yet clear whether the remote learning environment impacted learning outcomes in 2020 but the continued poor scores in 2022 show that a cohort of chem/biochem students have lowered analytical skills. The instructor is well aware of these deficiencies and is planning strategies to address them.</td><td>Improve instruction in those areas where students demonstrated particular misconceptions on the ACS exam: 50% vs 95% confidence, paired t-test, and significant figures based on std deviation</td></tr>
<tr><td>CHMY 371: <u>Physical Chemistry; Quantum Mechanics and Spectroscopy</u><br>ACS Exam Scores:<br><table><tr><td>Semester</td><td>2015</td><td>2016</td><td>2017</td><td>2018</td><td>2019</td><td>2020</td></tr><tr><td>Median %tile</td><td>85</td><td>85</td><td>86</td><td>81</td><td>92</td><td>N/A</td></tr></table>This course is very effective and students are demonstrating that they are mastering this challenging advanced chemistry material, with ACS exams scores that are more than 30 points above national norms. Half of the UM students in CHMY 371 are performing better than 81% of the students across the country on this standardized exam. However, this is a small class number and this course is not taught every year.</td><td>The course is tailored to meet the needs of each year’s class. One change that was implemented was reduction of coverage of the subject of “basic postulates of quantum mechanics”.<br>Future Plans: Reducing fundamental quantum mechanics and lecturing more on spectroscopy may benefit chemistry students more.</td></tr>
<tr><td>CHMY 373: <u>Physical Chemistry; Kinetics and Thermodynamics</u><br>ACS Exam Scores:<br><table><tr><td>Year</td><td>2011</td><td>2012</td><td>2014</td><td>2015</td><td>2016</td></tr><tr><td>Median %tile</td><td>56.5</td><td>56</td><td>84</td><td>93</td><td>85.5</td></tr><tr><td>Year</td><td>2017</td><td>2018</td><td>2019</td><td>2020</td><td>2021</td></tr><tr><td>Median %tile</td><td>96</td><td></td><td>8720</td><td>N/A</td><td></td></tr></table>This course has been very effective since 2014 and students are demonstrating that they are mastering this challenging advanced chemistry material, with ACS exam scores that are more than 30 points above national norms. Half of the UM students in CHMY 373 are performing better than 84% of the students across the country on this standardized exam for the past three years. This exam was not administered in several of the Covid years.</td><td>In 2016 one lecture on applying the second law of thermodynamics to drug design was removed. Instead, I spent more time deriving and explaining equations.<br>Future Plans: Extensive reviews from various angles may help students to learn better.</td></tr>
<tr><td>CHMY 401: <u>Inorganic Chemistry</u>, Learning Goals 4a-b</td><td>Made use of more structural models in class to aid students with 3D visualization of the diversity of Inorganic Structures. Increased the amount of Biological Inorganic Chemistry at the end of the course to provide more relevance to Biochemistry majors. Reduced the number of quizzes from 9 to 3 (from weekly to one between each midterm). Decided 9 quizzes was too much in an upper division course and it reduced student flexibility in allocating time to other courses. In 2017, increased the number of</td></tr>
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| Learning Goal results | Modifications made to enhance learning |
|---|---|
| | quizzes to 4 from 3. In particular, had two quizzes before the first midterm to give the students more feedback before the first midterm. |
| CHMY 402: Inorganic Chemistry Lab, Learning Goals 4a-c, 5a-d | The course introduced new and additional focus on crystal structures the students made. This generated a lot of interest and discussion.<br>Students taking CHMY 402 will use the X-Ray diffractometer to analyze crystal structures of various compounds. The students will also have access to a 3D printer that is used to print the structure for the purposes of analyzing bond lengthening. The premise of implementing this sort of technology into this class is for the reason that 70% of the students in this class will work in laboratory research in the future. This is a great method to prepare students for hands-on research that will be expected of them at the professional or graduate student level. |
| CHMY 421: Instrumental Analysis Goals 4a-c, 5a-d | Homework assignments could be improved as students tend to get the solution from online. Also Grading breakdown could also be improved to increase the portion of homework to 10% (currently 5%) and reduce the final exam to 10% (currently 15%) |
| CHMY 442: Aquatic Chemistry – Advanced Elective Goals 4a-b,d | Asked the students to break into small groups to solve problems at the white board.<br>Students did a round robin discussion of research papers for effective learning. |
| CHMY 465: Organic Spectroscopy, Advanced Elective Goals 4a-b,d Students need to demonstrate a better understanding of spectroscopy data. | Changes were made to accommodate unusually large classes. A new objective was added to the course which entailed identification of unknown compound. Once the students were able to figure out the structure, they would give a small presentation to the class. Then they would get another unknown to work on. This type of hands on knowledge really helped students refine their understanding of spectroscopic data |
| BCH 481/482. The Biochemistry Program received Full accreditation by the American Society for Biochemistry and Molecular Biology (ASBMB) in 2019 after a lengthy evaluation process. We are the only biochemistry degree program in Montana accredited by ASBMB.<br>Both Chemistry and Biochemistry students need the BCH 48X series of classes to graduate. As Biochemistry is a more and more important part of Chemistry as a whole, a good understanding of this area of Chemistry is important. We have added more tutorials and quizzes into the lecture series to enhance assessment and to reinforce areas of weakness that are identified by the ASBMB standardized test. | Accreditation by the ASBMB allows our majors and minors to take a certification exam. The Department of Chemistry and Biochemistry covers the fee of $45 for all majors or minors who want to take the exam because the program does not have an independent operating budget. During this two-year assessment period, 19 biochemistry majors/minors took the certification exam. 11 passed (58% pass rate; national pass rate was 49%) 4 of these students passed with distinction (21%; national rate of pass with distinction was 15%). Thus, our majors outperform national averages on the ASBMB certification exam. Recent exam results (Spring 2022) have maintained our slight increase in the % of students who are passing with distinction with ~20% and an overall pass rate of ~60%. |

| Learning Goal results | Modifications made to enhance learning |
|---|---|
| | The ASBMB certification exam has 11 questions. 4 are at a low Bloom's level (Knowledge, Comprehension, Application) and 7 are at a high Bloom's level (Analysis, Synthesis, Evaluation). Thus, our program is producing graduates with highly developed critical thinking skills relative to national averages. |
| CHMY 466/566: NMR Spectroscopy – Advanced Elective Goals 4a-b,d<br>The new practicum is working in that it demonstrates that students are able to use the instruments to obtain good data in practice. | An end of the year practicum was introduced wherein students have 1 hour to demonstrate that they can run the instrument after all of the parameters have been altered. The written exam was eliminated.<br>There are now three projects during the last 4 weeks whereby students have to do a full work up of three molecules, run all the specs (H1, C13, DEPT, COSY, HSQC, HMBC, NOESY) , process the specs and assign them. |
| CHMY 490: Undergraduate Research<br>More than half of Chemistry and Biochemistry majors conduct research during their undergraduate career at UM. Of these, more almost half co-author papers describing their research results. Undergraduate research is mentioned and noted by our students as the most valuable and effective learning experience that they have had at UM. | We seek to enhance undergraduate research going forward by re-instating the Lien Fellowship from our Foundation Accounts that pays undergrads a modest amount to work in a PI's lab over the summer. This is consistently seen by the students to be the most rewarding part of their education in Chemistry and Biochemistry. Enhancement of this program will occur as funds become available. |
| CHMY 498: Internships, Goals 4a-d, 5a-d, and 6<br>These capstone experiences were completed by several students during the past two years.<br>A significant portion of students in the Forensic Chemistry Option have participated in Internships with the State of Montana Crime Lab: All Crime Lab interns received an "excellent" evaluation of their work from the internship mentors. Overall the internship program is very successful and demonstrates that our students are prepared to be productive in the workplace and are in high demand for employment after graduation. | The Department of Chemistry and Biochemistry will continue to seek and place upper division students in relevant internships and to evaluate their performance and employment outcomes |
| CHMY 544: Applied Spectroscopy – Graduate course and Advanced Elective, 4a-b,d | Deemphasized lectures in this course to allow for more open discussions of technical papers focusing on technologies and applications. The papers focused on areas that were not typically covered in undergraduate courses. |
| CHMY 562: Organic Structure and Mechanism – Graduate course and Advanced Elective, 4a-b,d | New exam material was introduced and an additional/new implementation of computational chemistry was introduced. Updated research papers to include new material on hydrogen bonding.<br>Future Plans: Continue to add new relevant papers from modern literature, and consider expanding discussion of computational chemistry |
| CHMY 595: Mass Spectrometry – Graduate Course and Advanced Elective, Goals 4a-d, 5a-d | This was a new course taught for the first time in Fall of 2017. The course included lecture and practical laboratory exercises in Mass Spectrometry, an important analytical tool in chemistry and biochemistry |

| Learning Goal results | Modifications made to enhance learning |
|---|---|
| | |
| CHMY 652: Original Research Proposal – Graduate Course<br>The course has mixed success in encouraging students to complete the original research proposal graduate requirement in a timely manner. | The Chemistry graduate program was revised to include this new requirement that is meant to place students on a fixed schedule to complete graduate requirements. |
| Tracking graduates<br>Of 34 BS graduates in Chemistry and Biochemistry between Spring of 2020 and Spring of 2022, we have been able to track 17. Of these, 9 went to graduate school, and 8 took jobs in a chemistry-related industry. Our graduates continue to have great success in pursuing careers in chemistry, biochemistry or related professions.<br>All recent MS and PhD graduates in Chemistry or Biochemistry have gone on to work in chemistry or biochemistry. | Chemistry and Biochemistry had implemented a system in an effort will track graduates for up to five years after graduation. This system has allowed us to track approximately 50% of graduates over the past several years although the Covid years have had a negative impact on our ability to track. The department will redouble efforts to obtain this information, including through the use of social media, as the current response rate makes use and interpretation of the data difficult. FERPA rules and UM Foundation rules make following these graduates difficult. |

## FUTURE PLANS FOR CONTINUED ASSESSMENT

In the future we plan to continue our monitoring of assessment through student and faculty evaluations as well as the standardized exams from the American Chemical Society (ACS). These exams are the best indicator of how our program is progressing compared to the rest of the nation. Overall these exams show that we are performing well above average compared to other Chemistry and Biochemistry Departments in the nation. One particular problem is for assessment is our large enrollment 120 series that do not have standardized exams. In this case we will continue to monitor completion rates and continuation rates in this series as well as continue to use the Learning Assistant Program and the Internal Feedback Assessment on all Exams. More recently the University has implemented better data tracking and the CHMY 12X series instructors have been using this to track success rates and other parameters for student outcome (see appendix 1 for details).

Other Material. See Attached Appendix with example outcome tracking in the CHMY 12X series.

Appendix 1. Modifications to Enhanced Learning and Increase Feedback on Student Outcomes in the CHMY 12X series.

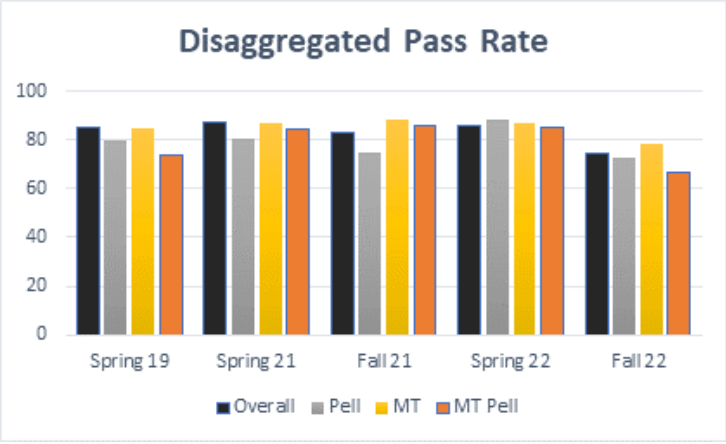
1. **Communication practices (e.g., wise feedback, effective student outreach, psychologically attuned language use) were implemented to enhance student success in the course(s)?**

Students in a failing demographic (less than 60% in each of the first two mid-terms) were specifically invited to the first "special" or "extra" office hours as an "invitation only" event after the second mid-term. Upon arrival students were given a copy of the document "You Can Grow Your Intelligence" that was provided as part of the FLC course material. Students were given 5 minutes to read the article and then – without any comment – we moved on to the student-based questions. With one exception, students in this group continued to come to "extra" office hours through Mid-Term 3. ON the next mid-term, this targeted group moved from underperforming to performing at the same level of the class as a whole.

| | Mid-Term One | Mid-Term Two | Mid-Term Three |
|---|---|---|---|
| Class Average | 72.7% | 69.8% | 69% |
| Intervention Group Average | 58.9% | 58% | 67 % |

Due to the scheduling of breaks including Thanksgiving, attendance dropped off – as did Mid-Term 4 performance for this group.

2. **Enhanced Data Collection approaches to Determine Student Cohorts of Success in the CHMY 12X series (specifically CHMY 123 for this set).** Access to new data collection software has allowed us to start identifying cohorts of students at risk of failing our CHMY 123 Chemistry courses. Pell (economic status) has shown a rough correlation with pass rate. Further use of these kinds of data analysis tools may prove useful in the future.



# UM Curriculum Mapping Template
# Chem and Biochem Degree

| Required Course (Name and Number) | Scientific Reasoning | Develop Chemical Lab Skills | Apply Analytical Skills | Teaching of Chemical Laws and Models | Scientific Writing Skills |
|---|---|---|---|---|---|
| CHMY 141: Gen Chem I | I, A | | I, A | I, A | |
| CHMY 142: Gen Chem I Lab | I | I | I | I | I |
| CHMY 143: Gen Chem II | I, A | | I, A | I, A | |
| CHMY 144: Gen Chem II Lab | I | I | I | I | I |
| CHMY 221: Organic Chem I | D, A | | D, A | D, A | |
| CHMY 222: Organic Chem I Lab | D | D | D | D | I |
| CHMY 223: Organic Chem II | D, A | | D, A | D, A | |
| CHMY 224: Organic Chem II Lab | D | D | D | D | I |
| CHMY 311: Quantitative Analysis | M, A | M, A | M, A | M, A | D |
| CHMY 401: Inorganic Chem | D | | D | D | |
| CHMY 402: Inorganic Chem Lab | D | M | D | D | D |
| CHMY 421: Instrumental Analysis | M | M | M | M | M |
| BCH 480: Biochem I | D | | D | D | |
| BCH 482: Biochem II | M | | M | M | M |
| BCH 486: Biochem Lab | M | M | M | M | M |

**KEY:**

I = Introduced

D = Developed/reinforced, with opportunities to practice

M = Mastery

A = Assessment evidence collected