Program: BS Chemistry

Department: Chemistry

Number of students enrolled in the program in Fall, 2011: 150

Faculty member completing template: Linda Roberts Date: 12/14/2011

Period of reference in the template: 2006-07 to present

Please note: The same learning outcomes and assessment instruments apply to all of our undergraduate programs, therefore please forgive the repetitiveness. I have highlighted differences where relevant.

1. Please describe your program’s learning-outcomes trajectory since 2006-07: Has there been a transformation of organizational culture regarding the establishment of learning outcomes and the capacity to assess progress toward their achievement? If so, during which academic year would you say the transformation became noticeable? What lies ahead; what is the next likely step in developing a learning-outcomes organizational culture within the program?

Chemistry’s assessment plan was developed and approved by the department with submission to the Office of Assessment in 2000. The plan details the types of assessment the department will do, and identifies three tools for carrying it out. In 2005, Chemistry implemented the assessment process in its current form (which is featured as a model by the Office of Assessment in its Spring 2012 newsletter) as a two-pronged approach involving 1. use of the American Chemical Society’s standardized exams in three upper division courses (ensuring all majors will take at least one ACS exam) and 2. evaluation of capstone course poster projects using a common department rubric (all majors are evaluated by this process in at least one capstone course). We have collected data using these two instruments for the past five years and, as noted in the 2010-2011 annual report, feel this is a good time to review the cumulative data and decide if changes are needed.

2. Please list in prioritized order (or indicate no prioritization regarding) up to four desired learning outcomes (“takeaways” concerning such elements of curriculum as perspectives, specific content knowledge, skill sets, confidence levels) for students completing the program. For each stated outcome, please provide the reason that it was designated as desired by the faculty associated with the program.

The list given below is a subset of the learning outcomes in our Assessment Plan. Since a successful scientist needs multiple kinds of skills, there is no priority ranking in this list of outcomes.
a) **Problem-solving and critical thinking skills.** Chemistry, by its nature, proceeds through posing or identifying problems to solve, devising ways to solve them, and evaluating the quality and validity of the solution. Problem-solving skills range from simple quantitative calculations to developing sophisticated methods to test and evaluate hypotheses. In our curriculum, students experience multiple approaches and levels of problem-solving, beginning with the first class, CHEM 1A. Problem-solving begins in the curriculum with straightforward textbook word and quantitative problems and culminates in capstone poster projects where students drive the process from posing of the problem to evaluating its solution using sophisticated instrumental, computational and mathematical techniques. Students in the BS Chem degree experience the most extensive and rigorous exposure to the scientific process through upper division independent capstone project work in four of the five sub-disciplines of Chemistry (Physical, Inorganic, Organic, Analytical), noted in Table 1 below.

b) **Library and Scientific Information and Literacy.** All scientific work rests on a foundation built by others. It is essential that students be able to access, utilize, and comprehend multiple sources of information, much of this involving computer-aided searches and analysis. Students in Chemistry are expected to be able to search scientific databases, comprehend scientific information from multiple types of sources, and utilize information retrieved from databases and sources. In particular, students are expected to become proficient in searching and evaluating scientific research literature. The BS Chem students get the most experience in utilizing sources to prepare capstone poster presentations.

c) **Communication.** Science thrives through communication via scientific meetings and the scientific literature. Students learn to write formal laboratory reports early in the curriculum, starting with CHEM 1B and continue to develop these skills through additional courses. In upper division classes, laboratory formal reports are formatted according to primary scientific research literature using American Chemical Society journals as the model. Students become proficient at recognizing and writing in the style of standard journal sections (e.g. abstract, methods, etc.). In addition to written reports, students also communicate their learning through posters in laboratory capstone classes and through oral presentations in lecture courses and laboratory capstone courses.

d) **Laboratory skills.** Chemistry is still largely an experimental science and it has broad application to many fields requiring proficiency with experimental design and instrumentation. Our program has a very strong focus on developing students laboratory skills. This ranges from basic manipulation of laboratory glassware, to preparation of solutions and reagents, devising experimental set-ups, and operating sophisticated equipment.

3. **For undergraduate programs only, in what ways are the set of desired learning outcomes described above aligned with the University’s Baccalaureate Learning Goals? Please be as specific as possible.**

**Competence in the Disciplines:** The ability to demonstrate the competencies and values listed below in at least one major field of study and to demonstrate informed understandings of other fields, drawing on the knowledge and skills of disciplines outside the major.

Our rigorous BS Chemistry degree ensures that students are competent in the discipline in regard to content, practical and work-related skills, scientific literacy, and scientific analysis as it relates to chemistry. Both the ACS exam, which primarily addresses content, and the Capstone Poster Project
Assessment, which addresses communication, problem-solving and other skills as described below, allow us to gauge competency in the discipline.

**Knowledge of Human Cultures and the Physical and Natural World** through study in the sciences and mathematics, social sciences, humanities, histories, languages, and the arts. Focused by engagement with big questions, contemporary and enduring.

In the BS Chemistry degree, one major focus is in learning the concepts and tools of the discipline, which includes both the Physical and Natural World. Because of the extensive content and the high level of math and analytical skills required in the discipline, there is not much time within our curriculum that is devoted to big questions in the societal sense. However, our students learn the most time-tested, rigorous method for grappling with such questions: the scientific method.

**Intellectual and Practical Skills, Including:** inquiry and analysis, critical, philosophical, and creative thinking, written and oral communication, quantitative literacy, information literacy, teamwork and problem solving, practiced extensively, across the curriculum, in the context of progressively more challenging problems, projects, and standards for performance.

The BS Chemistry provides students with ample experience and practice in all areas listed for this BLG and our program outcomes are most relevant to these skills. Through capstone projects, students gain extensive experience in inquiry and analysis. Creative thinking comes into play through defining a project and then creating the experimental conditions for the project. Although students will start these projects by reading the literature, the framing, design, and execution of the project requires novel thought and input. Students communicate the results in both written and oral formats. Chemistry, by its nature, requires quantitative literacy and critical evaluation.

Information literacy comes into play through the execution and dissemination of the capstone project. Teamwork is not a formal component of our assessment program.

**Personal and Social Responsibility, Including:** civic knowledge and engagement—local and global; intercultural knowledge and competence*, ethical reasoning and action, foundations and skills for lifelong learning anchored through active involvement with diverse communities and real-world challenges.

The courses in the BS Chemistry degree do not include specific components related to civic engagement, local or global. However, students do get some exposure to ethics in science through their exposure to the scientific literature. Students learn some rudiments in that when they handle and evaluate data, students are confronted with the prospect of bias and how to handle outliers. By communicating their own project results, they are faced with conveying to both technical and general audiences (both are present at the departmental event) the quality or "goodness" of data. Because our program is highly experiential, we believe it builds life-long learning skills.

**Integrative Learning**, Including: synthesis and advanced accomplishment across general and specialized studies.

Students in the BS Chemistry degree must synthesize a lot of information in order to successfully complete capstone projects. Furthermore, the process of learning chemistry is integrative by nature. Fundamental concepts are learned at early stages and these are revisited in new and more complex settings as the curriculum progresses. Moreover, the BS Chemistry degree requires students to synthesize multiple types of skills (e.g. problem-solving, communication, laboratory, etc.) into independent laboratory capstone projects. Because our curriculum goes beyond content acquisition and "cookbook" (i.e. 100% directed) laboratory study, our students have advanced laboratory and analytical skills and we are known in the region for this.
4. For each desired outcome indicated in item 2 above, please:

**Learning Outcome: Problem-solving skills**

a) Methods of evaluation

1. **ACS exam.** This exam, while our principle tool for examining content, does contain questions that probe student's basic problem-solving skills. The exam is administered in three courses, two of which are taken by the BS Chemistry students (Table 1).

2. **Capstone poster projects.** Our main method for evaluating students' problem-solving skills is in the design, execution, and dissemination of at least one independent research capstone project. Posters are disseminated in a department-wide event at the end of each semester. Faculty use a common rubric to evaluate these posters. As a result of its rigorous, laboratory-oriented curriculum, the BS Chemistry students are evaluated in four capstones (Table 1).

<table>
<thead>
<tr>
<th>Course</th>
<th>Semester</th>
<th>Enrollment per section</th>
<th>Total enrollment per semester</th>
<th>Assessment instrument</th>
<th>Semesters evaluated</th>
<th>BS CHEM assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CHEM 124</strong> Organic Chemistry Lecture II</td>
<td>F, S</td>
<td>72</td>
<td>144</td>
<td>ACS exam in Organic Chemistry</td>
<td>10</td>
<td>Y</td>
</tr>
<tr>
<td><strong>CHEM 160B</strong> Metabolism and regulation</td>
<td>S</td>
<td>40</td>
<td>40</td>
<td>ACS exam in Biochemistry</td>
<td>5</td>
<td>E</td>
</tr>
<tr>
<td><strong>CHEM 110</strong> Inorganic Chemistry Lecture</td>
<td>F</td>
<td>10-20</td>
<td>10-20</td>
<td>ACS exam in Inorganic Chemistry</td>
<td>5</td>
<td>Y</td>
</tr>
<tr>
<td><strong>CHEM 125</strong> Advanced Organic Laboratory</td>
<td>F, S</td>
<td>12</td>
<td>12-24</td>
<td>Capstone poster rubric</td>
<td>7</td>
<td>Y</td>
</tr>
<tr>
<td><strong>CHEM 110L</strong> Advanced Inorganic Lab</td>
<td>F</td>
<td>12</td>
<td>12</td>
<td>Capstone poster rubric</td>
<td>5</td>
<td>Y</td>
</tr>
<tr>
<td><strong>CHEM 133</strong> Chemical Instrumentation</td>
<td>S</td>
<td>12</td>
<td>12</td>
<td>Capstone poster rubric</td>
<td>5</td>
<td>Y</td>
</tr>
<tr>
<td><strong>CHEM 141</strong> Physical Chemistry Lab</td>
<td>F, S</td>
<td>12</td>
<td>12</td>
<td>Capstone poster rubric</td>
<td>6</td>
<td>Y</td>
</tr>
<tr>
<td><strong>CHEM 164</strong> Advanced Biochemistry Lab</td>
<td>S</td>
<td>12</td>
<td>24</td>
<td>Capstone poster rubric</td>
<td>5</td>
<td>N</td>
</tr>
</tbody>
</table>

Table 1. Courses included in Chemistry Department Program assessment
b) Sample of students
For both the ACS exam and the capstone poster evaluation, the student sample is the students enrolled in the course.

c) Assessment instruments
ACS exam. For security reasons, we cannot append this document for review. The various ACS exams are used nationally and only infrequently updated, necessitating that the same exam be used every semester over a period of years. Within the department, it is administered under tightly controlled conditions. ACS does not provide sample exam questions, except in the context of study guides that can be purchased but which the department does not possess or provide to students. Capstone project rubric. The rubric used in capstone poster projects is attached at the end of this document.

d) Analysis.
ACS exam. Data are scored using a scantron key and compared to national norms. Capstone projects. The results of faculty poster evaluations are tabulated by the departmental administrative staff and given to the Department Chair for the annual report. Annual assessment results are disseminated for discussion at the annual department retreat in August. Table 2 shows how the questions in this rubric are tied to the learning outcomes. Note: our annual assessment report gives the quantitative and qualitative details of the outcomes measured by these instruments.

Table 2 - Capstone project rubric and learning outcomes

<table>
<thead>
<tr>
<th>Learning outcome</th>
<th>Rubric questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem-solving skills</td>
<td>4, 5, 7</td>
</tr>
<tr>
<td>Scientific information literacy</td>
<td>6, 7, 8</td>
</tr>
<tr>
<td>Communication skills</td>
<td>1, 2, 3, 6, 8</td>
</tr>
<tr>
<td>Laboratory skills</td>
<td>4, 5, 9</td>
</tr>
</tbody>
</table>

Learning Outcome: Library and scientific information literacy
Library and scientific information and literacy are evaluated only in capstone projects using the Department poster rubric. The student sample, assessment instruments and analysis are as given under problem-solving skills.

Learning Outcome: Communication skills
Communication skills are evaluated only in capstone projects. The student sample, assessment instruments and analysis are as given under problem-solving skills.

Learning Outcome: Laboratory skills
The methods, student sample, assessment instruments and analysis are as given under problem-solving skills.

5. Regarding each outcome and method discussed in items 2 and 4 above, please provide examples of how findings from the learning outcomes process have been utilized to address decisions to revise or maintain elements of the curriculum (including decisions to alter the program’s desired outcomes). If such decision-making has not yet occurred, please describe the plan by which it will occur.

ACS exam

Given our diverse population and the range of preparation of students entering our program, the faculty have been generally satisfied with the ACS exam scores. In general, students score at or above the national average. Students in CHEM 110 score much higher than average on the Inorganic Exam, suggesting that BS Chemistry students overall (who make up most of the population of this course) may do better as a group. We have not evaluated performance on the ACS exam according to the degree tracks (except for the two Biochemistry degrees) or by major (Biology majors take the ACS exam in CHEM 124). It would be worth doing this analysis in all cases for past and future data.

The ACS exam allows us to assess rudimentary problem-solving and laboratory skills because we can identify and categorize questions in these areas. The information pertaining to problem-solving skills is limited to generally lower level, quantitative and/or word problems. Information on laboratory skills pertains to familiarity with laboratory methods but does not test, for example, a student's understanding of experimental design. As yet, assessment of laboratory skills has been done only with the Biochemistry ACS exam but can be applied to all three ACS exams.

The ACS exam is limited in that it mainly tests content. Despite this, we will retain the ACS exam for two reasons. First, it allows us to compare our students' performance to a national norm. Second, it allows us to easily relate national exam performance to student attributes such as transfer status, GPA, where prerequisite courses were taken, etc. Currently, this is only being done for the biochemistry degrees (BS Biochemistry and BA Chemistry with Biochemistry Concentration). That analysis produced a wealth of highly useful information, including data relating to graduation rates, therefore we are working towards implementing the same extensive analysis to the other degrees.

Capstone projects

We believe capstone projects fully and deeply engage students in all four learning outcomes. Therefore, assessment of our capstones is where we gain the most information on our learning outcomes. Our rubric contains 10 questions addressing different aspects of the capstone project (see Table 2 above). The scoring of these questions has shown some trends. For example, in some semesters, it appears that student performance improves sequentially through multiple capstone classes. However, this trend has not been consistently observed and needs systematic evaluation. Overall, the scores from this rubric indicate faculty generally feel students are exhibiting the skills we desire to see developing in capstones. While our rubric is giving us some information about
overall quality but the questions are rather broad and don't address specific elements within the learning outcomes well. For example, laboratory skills pertains to a host of activities ranging from the simple (e.g. manipulating pipets) to the complex (e.g. operating sophisticated instruments and proposing experimental design). The next phase of our assessment will be to a. define the learning outcomes in terms of more specific, measurable learning and b. to redesign the rubric to better measure this learning. As this level of assessment is difficult to develop, it will not be simple and may take some time.

6. Has the program systematically sought data from alumni to measure the longer-term effects of accomplishment of the program’s learning outcomes? If so, please describe the approach to this information-gathering and the ways in which the information will be applied to the program's curriculum. If such activity has not yet occurred, please describe the plan by which it will occur.

Although our program has grown considerably in the last five years, we still strive to maintain contact with our students. We are particularly successful doing this with research students because we form close and long-standing connections with them. While individual faculty have long tracked their research students' post-graduate destinations, we have only recently been doing this in a systematic way at the department level. In Fall 2011, we started keeping track of students' planned destinations at graduation through a graduation survey developed by Dr. Crawford. This information is disseminated to faculty at a department meeting just prior to graduation for final verification. In past years, we have mailed alumni a newsletter soliciting information, but this hasn’t been done in a long time. I intend to revive this activity in AY 2012-2013. In addition, we have redesigned our webpage as the first stage in reaching out to alumni electronically. Future stages will involve an electronic alumni newsletter and regular spotlighting of alumni. These activities are intended to strengthen ties with all graduates which will support longitudinal tracking. Finally, we have a highly active and successful Chemistry Club with its own Facebook page which has potential for tracking students. Discussions on how we might do this are at a preliminary stage.

7. Does the program pursue learning outcomes identified by an accrediting or other professional discipline-related organization as important? Does the set of outcomes pursued by your program exceed those identified as important by your accrediting or other professional discipline-related organization?

The BS Chemistry degree is an American Chemical Society (ACS) approved degree. It meets all the criteria that this body requires, including curriculum, laboratory hours, and faculty contact hours (although we are perpetually on the precipice of losing our certification due to overage on contact hours). ACS is an organization that plays a leadership role for chemists worldwide in research, career development and secondary and post-secondary education. Meeting the ACS standard is highly desirable because it communicates to the outside world the high quality of our program. It aids in recruitment of students and faculty and signals employers to expect a high level of preparation in our graduates. Currently, the BS Chemistry degree is the only one that meets ACS
approval. The fact that we offer an ACS approved degree elevates the status of our department as a whole.

8. Finally, what additional information would you like to share with the Senate Committee on Instructional Program Priorities regarding the program’s desired learning outcomes and assessment of their accomplishment?

Due to the hard work of previous Chairs Jim Hill and Susan Crawford, Chemistry is a recognized leader on campus in developing and implementing an assessment process. I had the good fortune beginning back in the late 90’s to work with both Chairs, particularly with Jim Hill on the development of an assessment plan in Chemistry. Our next phase is to move from implementation to improvement as discussed here. In the 2010-2011 annual report, I identified several items which would improve our process and my overall intent is to move our program into a phase that better elicits the data on outcomes we really want to have, as discussed in question 5 above. Specifically, we will:

1. Relate ACS exam performance to student attributes for all three exams
2. Revise capstone rubric to better elicit data on specific elements within learning outcomes
3. Analyze capstone data according to specific learning outcomes and degree path
4. Relate past and future data from both instruments to retention and graduation rates
Original Poster Project Assessment  (Chemistry Department Spring 2011) PLEASE ASSESS 5 POSTERS

Course__________________   Evaluator_______________________

Overall the student’s presentation shows that the student:

1. demonstrates effective organization of their poster (shows effectively the problem and how problem was attacked and solved)
   
   | SD | D | A | SA | NA |

2. demonstrates effective use of graphs and other visual aids

   | SD | D | A | SA | NA |

3. uses effective writing (good grammar, spelling, coherent writing, clear exposition)

   | SD | D | A | SA | NA |

4. shows an ability to use instrumentation useful in solving or doing problem

   | SD | D | A | SA | NA |

5. collected reasonable data useful in solving or doing the problem

   | SD | D | A | SA | NA |

6. uses literature properly in presentation

   | SD | D | A | SA | NA |

7. supports their generalizations and conclusions with adequate and sound evidence

   | SD | D | A | SA | NA |

8. uses technical vocabulary correctly

   | SD | D | A | SA | NA |

9. demonstrates effective learning of several laboratory skills

   | SD | D | A | SA | NA |

Key

**SD**: Strongly Disagree  **D**: Disagree  **A**: Agree  **SA**: Strongly Agree  **NA**: Not Applicable

10. Overall impression of the poster presentation. Please rate your overall impression

   | 1 (poor) | 2 (fair) | 3 (average) | 4 (good) | 5 (outstanding) |

Additional Comments: