I. Introduction:
The chemistry department is a department characterized by a relatively young faculty, most of which have been hired in the past 10 years. The department is divided into sub-discipline specialties including: analytical chemistry, biochemistry, inorganic chemistry, organic chemistry and physical chemistry. The department also has a faculty member who specializes in science education. Additionally, the chemistry department offers American Chemical Society certified Bachelor degrees in chemistry. To maintain accredited status, the department must adhere to the guidelines and evaluation procedures established by the ACS Committee on Professional Training. Learning outcomes and assessment practices are addressed within these guidelines. Last year we submitted our five year program review report to the ACS. Although we have not yet obtained the results of this review, we anticipate a favorable analysis. During the 2009-2010 academic year, the chemistry department continued its major assessment of capstone projects through the departmental poster session. During the spring semester, 44 posters were assessed. We also utilized American Chemical Society standardized exams in CHEM 110, CHEM 124, and CHEM 160B.

Undergraduate Assessment:

II. Learning Goals:
Students are expected to develop their competence in eight skill areas. Five of these are transferable skills taken from general education courses and three are more specifically aimed at students majoring in Chemistry.

- Effective Writing
- Effective Oral Communication
- Critical Thinking (logic and rhetoric)
- Problem Solving and Critical Thinking
- Quantitative Analysis
- Library and Scientific Information Literacy
- Computer literacy
- Laboratory Skills
III. Specific Learning Outcomes:

A. Laboratory Knowledge and Skills.

Students obtaining a baccalaureate chemistry degree should have upon graduation:

1) the basic analytical and technical skills to work effectively in the various fields of chemistry.
2) the ability to perform accurate quantitative measurements using modern chemical instrumentation, interpret experimental results, perform calculations on these results and draw reasonable conclusions.
3) the ability to synthesize, separate and characterize compounds using modern methodologies and instrumentation.
4) knowledge and understanding of the issues of safety regulations in the use of chemicals in their laboratory work.

B. Computer, Library and Information Skills.

Students obtaining a baccalaureate chemistry degree should have upon graduation:

1) the ability to make effective use of the library and other information resources in chemistry, including the primary literature, tabulated data, and secondary sources such as the internet.
2) the ability to make effective use of computers in chemistry applications using standard and chemistry specific software packages.
3) the ability to perform and interpret simple molecular modeling or chemical computations using standard software.

C. Oral and Written Communication Skills in Chemistry.

Students obtaining a baccalaureate chemistry degree should have upon graduation:

1) adequate skills in technical writing and oral presentations.
2) the ability to communicate scientific information in oral and written formats to both scientists and nonscientists.

D. Quantitative Reasoning Skills.

Students obtaining a baccalaureate chemistry degree should have upon graduation:

1) ability to accurately collect and interpret numerical data.
2) ability to solve problems competently using extrapolation, approximation, precision, accuracy, rational estimation and statistical validity.
3) proficiency in the scientific method (formulating hypothesis and arriving at appropriate answers and conclusions.)
E. **Knowledge of Chemical Principles and Facts.**

Students obtaining a baccalaureate chemistry degree should have upon graduation:

1) a working knowledge of chemical principles appropriate to a chemistry degree program to include thermodynamics, equilibrium, kinetics, quantum mechanics, structures of materials, reactivities of substances, and synthesis.

2) a mastery of a broad set of factual chemical knowledge concerning the properties of substances, molecules and atoms.
IV. Assessment Methods:

The degree path in the chemistry degree is a linear program in which content material and complexity of material is strongly dependent on previous and pre-requisite courses. As a result, the majority of the learning goals stated in section II are introduced in lower division courses and expanded upon in the subsequent courses as the student’s knowledge and skill base increases. Although assessment of learning goals is performed in each course in the chemistry curriculum through grading of written and examination materials, the chemistry department has elected to perform an in-depth broadly-based assessment at two points in the major, one at the midpoint and the other toward the end of the degree.

A. Assessment of Capstone Projects. Examination of the above stated learning goals indicates that goals can be effectively assessed utilizing laboratory-based Capstone Projects. Capstone Projects involve developing experimental design, establishing the protocol, and executing the laboratory project in collaboration with a faculty mentor. Students present the methods, analysis and findings in a scientific poster presentation. Items A-D are assessed through departmental assessment of the posters by the full-time chemistry faculty. Each faculty member is responsible to assess 4-5 posters utilizing a common rubric. The assessment rubric is identified only by the course are collected and tabulated for analysis. During the 2009-2010 academic year the following courses included capstone projects for assessment: CHEM 110L (Inorganic Chemistry Laboratory), CHEM 125 (Advanced Organic Chemistry Laboratory), CHEM 133 (Chemical Instrumentation), CHEM 141 (Physical Chemistry Laboratory), and CHEM 164 (Advanced Biochemistry Laboratory).

Rubric for Assessment of Capstone Posters

Overall the student’s presentation shows that the student: (ratings: strongly disagree, disagree, no opinion / not applicable, agree, or strongly agree).

1. demonstrates effective organization of their poster (shows effectively the problem and how problem was attacked and solved)
2. demonstrates effective use of graphs and other visual aids
3. uses effective writing (good grammar, spelling, coherent writing, clear exposition)
4. shows an ability to use instrumentation useful in solving or doing problem
5. collected reasonable data useful in solving or doing the problem
6. uses literature properly in presentation
7. supports their generalizations and conclusions with adequate and sound evidence
8. uses technical vocabulary correctly
9. demonstrates effective learning of several laboratory skills
10. overall impression of the poster presentation. (ratings: poor, fair, average, good or outstanding.

B. American Chemical Society Standardized Testing. Although Learning Goal E, Knowledge of Chemical Principles and Facts, may also be assessed within the Capstone Assessment Activity, we elected to administer standardized exams in three courses during the 2009-2010 academic year. We elected to administer the American Chemical Society exam covering the full year (two semester sequence)
of organic chemistry as the final exam in CHEM 124 (Organic Chemistry Lecture II). This course is taken by all chemistry majors irrespective of concentration and represents a lecture course taken at the midpoint of the chemistry degree. During the 2009-2010 academic year, the department administered the ASC standardized exam in CHEM 110 (Advanced Inorganic Chemistry lecture) as a comparison for student content knowledge at a point at the end of their academic career. This course is taken predominately by students seeking the BS Chemistry degree. It is extremely rare for a biochemistry or forensic chemistry major to take this course. In order to evaluate the Biochemistry BS and BA students near the end of their academic career, the standardized ACS exam in Biochemistry was administered to students in CHEM 160B (second semester biochemistry lecture) as the final exam for the course.

V. Assessment Results:

A. Capstone Poster Results. During the 2009 – 2010 academic year, 44 capstone posters were assessed using the common rubric. The rubric is provided as an attachment and contains ten assessment ratings that are linked to the departments learning goals. The assessment scale ranges are Strongly Agree, Agree, No Opinion, Disagree, Strongly Disagree. In analyzing the data, numerical scores were assigned to the assessment scales, where 5 corresponds to Strongly Agree and 1 corresponds to Strongly Disagree. Using the assigned numerical scores, averages were obtained and are provided in Table 1 below:

<table>
<thead>
<tr>
<th>Question</th>
<th>CHEM 125</th>
<th>CHEM 133</th>
<th>CHEM 164</th>
<th>CHEM 141</th>
<th>CHEM 198</th>
<th>CHEM 110</th>
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<td>4.8</td>
</tr>
<tr>
<td>Average</td>
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<td>4.4</td>
<td>4.0</td>
<td>4.7</td>
<td>4.9</td>
<td>4.7</td>
</tr>
</tbody>
</table>

B. American Chemical Society Standardized Exam Results.

1) Organic Chemistry CHEM 124. Three sections (one during the fall semester and two at the conclusion of the spring semester) of CHEM 124 were given the American Chemical Society Comprehensive Test in Organic Chemistry. The exam covers
material from the two semester organic chemistry sequence. Table 2 contains the
results of the exams.

2) **Inorganic Chemistry CHEM 110.** One section of CHEM 110 was given the
American Chemical Society Comprehensive Test in Inorganic Chemistry. The exam
covers material from the one semester course in inorganic chemistry, although
considerable content gained in the three physical chemistry courses taken prior to
CHEM 110 would be represented on the exam as well. CHEM 110 is typically taken
by BS Chemistry majors during their last semester in the program prior to graduation.
Table 3 contains the results of the exam and comparison to the national average.

3) **Biochemistry CHEM 160B.** One section of CHEM 160B was given the American
Chemical Society Comprehensive Test in Biochemistry. The exam covers material
from the two semester course sequence in biochemistry which is required of all
biochemistry BA and BS students. Occasionally, BS chemistry students opt to take
this sequence in order to fulfill elective requirements. Table 4 contains the results of
the exam and comparison to the national average.
Table 2. Results of Standardized Exam in Organic Chemistry (CHEM 124)

<table>
<thead>
<tr>
<th>Section</th>
<th>Students</th>
<th>Average Score</th>
<th>Percentile</th>
<th>National Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Fall)</td>
<td>22</td>
<td>42</td>
<td>59%</td>
<td>38</td>
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<tr>
<td>1 (Spring)</td>
<td>39</td>
<td>39</td>
<td>51%</td>
<td></td>
</tr>
<tr>
<td>2 (Spring)</td>
<td>46</td>
<td>37.1</td>
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Table 3. Results of Standardized Exam in Inorganic Chemistry (CHEM 110)

<table>
<thead>
<tr>
<th>Section</th>
<th>Students</th>
<th>Average Score</th>
<th>Percentile</th>
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</thead>
<tbody>
<tr>
<td>1 (Fall)</td>
<td>16</td>
<td>40</td>
<td>93%</td>
<td>28</td>
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</tbody>
</table>

Table 4. Results of Standardized Exam in Biochemistry (CHEM 160B)

<table>
<thead>
<tr>
<th>Section</th>
<th>Students</th>
<th>Average Score</th>
<th>Percentile</th>
<th>National Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Fall)</td>
<td>30</td>
<td>33.1</td>
<td>53%</td>
<td>32.9</td>
</tr>
</tbody>
</table>

VI. Discussion of Assessment Results:

General Comments. Examination of both the Capstone Poster Project assessment results and the results of the standardized American Chemical Society exams establishes that the Chemistry Department is a) effectively meeting the its learning objectives and b) comparing at level or above when compared to other chemistry departments in the nation who took part in the standardized testing.

A. Capstone Project Results. Closer examination of the Capstone poster project results shows that in all classes considered, students are meeting the learning objectives defined by the department. It is interesting to compare the CHEM 125, CHEM 141 / CHEM 110L, and CHEM 198 results. The data shows an increasing trend as students progress from CHEM 125 to CHEM 141/ CHEM 110 and then CHEM 198 using a common rubric. In the chemistry program, there is typically a semester or more between these laboratory courses as students progress linearly through this series. For example, students take CHEM 125 a minimum of one semester prior to CHEM 141 / CHEM 110L and again typically prior to taking CHEM 198. It is clear from the data that the students improve significantly as a function of progressing through the program. This is to be expected since the students in CHEM 125 are at the sophomore or early junior level standing, compared to late junior or early senior level status of CHEM 141 students. CHEM 198, senior research is typically one of the last courses students take in pursuit of the BS Chemistry degree. Student experience in CHEM 125 is likely a first experience in completing and presenting independent experimental chemical work for many students. It is the first course in which independent critical thinking is expected in the context of the laboratory environment. Students in this course are not all performing the same experiment simultaneously and as a result are unable to rely on their neighbor to help them in their own experiment.
These students have little prior experience using the scientific literature, writing in a scientific fashion, and a considerably less accomplished "scientific vocabulary" compared to the CHEM 141 / CHEM 110L students. Students gain a considerable amount of scientific maturity in these two courses. CHEM 198 students have typically spent a semester (typically longer) working in a faculty research lab working alongside graduate students and the faculty PI. The chemistry experiences leading up through this last cumulating experience clearly shows the students meeting the learning objectives set forth by the department. Use of the scientific literature is a main learning objective in CHEM 141.

Examination of the results from the CHEM 164 capstone projects shows that these students scored lower using the common rubric compared to the CHEM 141/CHEM 110L / CHEM 198 students. Although an average score of 4.0/5.0 shows that CHEM 164 students are clearly meeting the learning objectives set forth by the department, these senior level students are scoring a full 0.5 or more points below their CHEM 141 / 110L / 198 peers. Most notably, these students scored lower in their technical writing and use of the scientific literature. A major difference between these two groups of students involves the number of laboratory courses containing independent capstone components that each set experiences throughout their curriculum. The students following the general BS chemistry curriculum track are required to take CHEM 125 / CHEM 133 / CHEM 141 / CHEM 110L. Most of these go on to take CHEM 198 (senior research). In comparison, the CHEM 164 students are only required to take CHEM 162 (Biochemistry I laboratory) prior to taking CHEM 164. Although CHEM 162 contains scientific writing components, it is only one course compared to the four lab course sequence required of the general chemistry group. Additionally, CHEM 162 was increased in size to accommodate 18 students per section as compared to 12 students per section (previous enrollment cap) which necessitated a reduction in the amount technical writing feedback the instructor could provide. It will be interesting to examine how the BS Biochemistry students perform on the CHEM 164 capstone since this newly approved major requires its students to take the CHEM 125 / CHEM 141 / CHEM 164 sequence. A correlation of higher scores within this biochemistry subset would clearly support the department's long held philosophy that advanced independent laboratory experiences with significant technical writing components is the most effective way to meet the department's defined learning objectives.

B. Standardized Test Results. Examination of the standardized ACS test results shows that our students compare at or above the national average using the same exams. Interestingly, while our sophomore students are at the national average, our senior level students (CHEM 110) perform much higher than the national average. We cautiously attribute this success to the intensive laboratory experiences provided to our students through formal coursework and research experiences. We will be revising our "blind" assessment model in order to examine this correlation more fully in the future. In explanation, it will be useful to identify other features of the students' backgrounds in analyzing the results of
our assessment. We may be able to accomplish this by including a student questionnaire evaluating a student's course and laboratory background to their scores on the standardized exam. Both our lower division and upper division courses are currently meeting the learning objectives of our certifying agency and the chemistry department.

**CHEM 124 (Organic Chemistry) Faculty Comments:** This was the third year that the American Chemical Society standardized exam was administered in CHEM 124. The exam covers the two semester sequence of material covered in CHEM 24 and CHEM 124. Our results this year are slightly lower than those of last year with the average performance approximately 1.5 points lower than that of the previous two years. Although the significance of this dip is unclear, there is some concern that faculty furloughs this academic year negatively impacted student learning. In explanation, CHEM 24 (first semester organic lecture) completed 1.5 chapters less than is usually covered in the course. Although students were given extra work outside of class in order to make up for furlough day loss, they were unable to accomplish this independent work and the instructors needed to "backtrack" and lecture on the material anyway. This resulted in less material covered. As a result, CHEM 124 needed to cover the extra 1.5 chapters along with the course's already demanding content. The students had an extremely difficult time keeping up with the pace and performed less well in the course as a result. Since the ACS exam is administered at the conclusion of CHEM 124 and covers CHEM 24 / CHEM 124 material, it isn't surprising that the average score appears lower than in the past two years. Student performance continues to compare with the average performance at the national level on the same exam. Two faculty members note that our students continue to perform well on the spectral analysis and reaction mechanisms. They also continue to perform well on questions related to the selection of reagents for reaction completion. High performance in these areas is to be expected since our program places emphasis on the practical application of organic chemistry. Our students struggled most with material taught during the first semester course and on topics that traditionally are most challenging for all organic students. The organic faculty will now evaluate the two year exam results in order to determine if course or teaching modification is warranted.

**CHEM 110 (Inorganic chemistry) Faculty Comments:** Students in Chem 110 scored higher than the National Norm (2002 Exam: 28.38 ± 8.10) on the 2009 ACS standardized exam. The average exam score for our course was 40.75. The highest score on the exam was a 52, which corresponds to the 99 percentile range when compared to the 2002 national scores.

Subject areas that were challenging for students were Bioinorganic, Catalysis and Solid-State chemistry. These topics are typically covered towards the end of the course and less time is devoted towards these areas.
Topics that students scored well on were Group theory and Molecular symmetry, Molecular orbital theory, Term symbols, and Spectroscopy of Inorganic complexes. Students also did well in Organometallics. Scores were particularly high in these areas because more time was spent discussing this material in lecture. Furthermore, the laboratory component of the course emphasizes the synthesis and spectroscopy of coordination compounds, which reinforced concepts taught in lecture.

A comparison between students whom were enrolled in just the lecture portion of the course compared to those who were also simultaneously enrolled in the laboratory component (CHEM 110L) showed only a 2% difference in their average standardized test results. The students not taking the laboratory portion of the course scored lower than those who were also enrolled in lab. However, although a 2% difference seems slight, it should be noted that all of the students scoring 70% or higher on the standardized exam were also enrolled in the laboratory portion of the course. The student scores which brought our department average significantly above the national norm, were exclusively obtained by students who were also enrolled in the laboratory course as well as the lecture. At this point it is premature to draw strong conclusions regarding the clear benefit of the lab component due to the small number of students since a few outlying low scores can influence the averages significantly. We believe that future CHEM 110 and CHEM 110L classes, when examined in totality, may more clearly illuminate our perceived benefit of lab reinforced concept understanding in this course.

Additionally, the instructor believes the course could be greatly improved if there was more time to devote to Bioinorganic and Main Group Chemistry. Because this class is one semester, topics such as Metalloenzymes- Structure and Function and Descriptive Chemistry can not be covered in detail. Additionally, scheduling in the laboratory portion of the course requires students to rotate through experiments in a staggered fashion which results in some students performing particular experiments prior to having the associated material presented in lecture. It might be interesting for the department to consider a separation of the lecture from the lab components in such a way that students would take the laboratory course the semester following the lecture course instead of concurrently. However, considering that our students perform higher than the national average on this standardized exam, we are confident that we are effectively preparing our students in this subarea of chemistry and an immediate consideration for change seems unwarranted.

**CHEM 160A/B (Faculty Comments)**  
Student performance in the year-long biochemistry sequence CHEM160A/B was assessed in 2010 for the second time using the American Chemical Society Exam Institute Biochemistry 2007 Exam. In 2010, 30 students took the 60 question, two-hour exam as the course final. The mean score in 2010 (33.1) was not significantly different than the mean score in 2009 (31.9, n=36), so the data from both years were combined and analyzed to
identify factors that contribute to student performance. Although the total data set of 66 exam scores is not exceptionally large, analysis of student performance on the exam can provide a preliminary indication of overall student performance in the biochemistry program.

The overall mean and standard deviation for scores of CSUS students (32.42 ± 7.18) were similar to those for the national scores (32.9 ± 8.92). The most often missed questions were from a range of subject areas, although three of the seven most missed questions were from areas that were purposely de-emphasized in the lecture course. The questions most often correctly answered were also from a range of subject areas. Thus, results from this examination suggest that CSUS students perform similarly to students across the nation and are not exceptionally deficient or proficient in any particular subject area within biochemistry.

To determine whether completion of other courses within the biochemistry curriculum, the student’s course of study (undergraduate major or post-baccalaureate student), or the student’s transfer status (native CSUS student, community college transfer or 4-year university transfer) impacted performance on the exam, students were surveyed to identify which of 18 biochemistry-related courses they had completed or were concurrently enrolled as well as their major and transfer status. Stepwise regression analysis was first performed to identify related courses that significantly impacted student scores. The only course that was significantly associated with exam performance was participation in an independent undergraduate research course (CHEM 189 / CHEM 198). As shown in Figure 1, students who had participated in independent study projects scored an average of 5 points higher on the exam than those who did not. This association may either be causative (students supplement learning through the independent research experience) or correlative (students that participate in independent research experiences may be more academically motivated in general). No other course was associated with exam performance once participation in a research experience course was taken into account.
Figure 1. Mean ACS Exam scores of students who were \( n=17 \) and were not \( n=49 \) participating in independent student research courses. Error bars represent 95% confidence intervals for differences between the means.

Eight questions in the ACS exam address skills emphasized in our biochemistry laboratory course, CHEM162, which is not a co-requisite of the course. Interestingly, stepwise regression analysis did not identify participation in CHEM162 as a significant factor in student performance on either the total score or the score on the specific lab-related questions.

Similar analysis was performed to establish whether student course of study (undergraduate major or post-baccalaureate student) or student transfer status (native CSUS student, community college transfer or 4-year university transfer) was associated with exam performance. None of these variables was significantly associated with exam performance.

In summary, these results suggest that performance of students in the CSUS program is similar to that of other biochemistry students who have taken the examination nationwide, and students did not perform particularly well or particularly poorly in any specific subject area within biochemistry. The correlation and possible influence of undergraduate research on exam performance is recognized, and participation in undergraduate research should continue to be encouraged. The influence of the biochemistry laboratory course CHEM162 on exam performance should continue to be monitored, and changes in the curriculum of that course may be warranted to better reinforce fundamental biochemical concepts and laboratory skills.
VII. Future Plans:

A. The current chemistry department assessment plan is well-developed to assess the learning outcomes of the BS chemistry program. In this regard we believe the program in clearly meeting the high standard of student learning the chemistry department and the American Chemical Society have established as desirable. We will discuss the assessment outcomes in a fall department meeting. In contrast, our current plan is less well-suited for application to the BS and BA biochemistry degrees. Although we have implemented the use of the ACS biochemistry standardized exam to assess student performance in lecture content material and we include CHEM 164 (second semester biochemistry lab) posters in our capstone assessment, we need to examine more closely our stated learning goals associated with the biochemistry majors. Although the department intended to work on this during the last academic year, the implementation of furloughs and the associated workload reduction placed a barrier to progress in this area. Additionally, our current plan does not address learning goals and assessment of our MS graduate programs in Chemistry and Biochemistry. We have begun some discussion of graduate student performance using our standard placement exams in organic and physical chemistry to evaluate student competence entering the program, faculty evaluated literature seminar, research thesis and defense. The graduate committee has modified its graduate policy to include these assessment items and will begin drafting an addendum to the department's assessment plan during the fall semester. The modified assessment plan will be presented to the department for considered adoption spring 2011.

B. Department discussion involving utilization of alumni survey data in learning outcomes assessment. The department is working with the college of NSM to develop a graduating senior exit seminar and alumni survey to provide data for our program assessment.