ASSESSMENT OF STUDENT LEARNING

CHEMISTRY PROGRAM

A. Learning goals

What are the particular levels of knowledge, skills, and abilities that our students attain as a result of their experiences with the Chemistry Program curriculum? In response to this question, during Spring 1999, the program came up with a list of skills/outcomes we wanted our students to have/meet when they graduated. The categories were: Basic Laboratory Techniques, Intermediate Lab Techniques, Instrumental Skills, Chemical Concepts, Quantitative (Science) Skills, Technical Communication, and Decision Making Skills. This comprehensive list can be found in Appendix 1.

These goals were primarily intended for our majors (Chemistry [CHEM] and Biochemistry/Molecular Biology [BCMB]) and were in need of further deliberation. However, we made no further progress as a program and instead individual faculty experimented with classroom assessment techniques. With the advent of the institutional assessment of student learning initiative, in spring 2003 the program decided to charge a committee/workgroup with (1) identifying a set of learning goals that would be applicable to a broader student population and (2) formulating an assessment plan. The committee members are Kelly Keenan, Kristen Hallock-Waters, Shanthi Rajaraman, Bob Olsen, Ada Casares and Brian Rogerson.

The committee identified eight broad learning goals that need to be assessed:

1. Data Analysis Skills (graphing, data interpretation)
2. Molecular Representation
3. Basic Measurement Skills
4. Knowledge of Intramolecular and Intermolecular Forces
5. Recognizing the Properties of Substances: Structure/Properties Correlation
6. Knowledge of Solutions
7. Understanding How to Separate Compounds
8. Understanding Atomic, Molecular and Macromolecular Sizes.

This list is not meant to be comprehensive; it simply constitutes a reasonable starting point. There is also no suggestion of relative importance at this stage. Each of these broad goals was expanded into a subset of concepts that are described in detail in Appendix 2. This expansion resulted in some degree of overlap across the main learning goals. Furthermore, discussions with program faculty led to the recognition that this overlap was not only necessary but desirable as it may help student learning and also help us achieve our desired learning outcomes. It should be noted that since assessment of student learning will always be a work in progress, these goals will be subject to constant modification, particularly as a result of feedback from assessment instruments, or because of changing pedagogical interests of Chemistry Program faculty, and at yet other times because of programmatic changes in the curriculum.
A preliminary discussion concerning appropriate assessment instruments to measure these learning outcomes resulted in the narrowing of the scope of our initial assessment effort. The assessment workgroup submitted a recommendation that we initially assess two basic qualitative goals and two basic quantitative goals:

**Qualitative:**
1) Understanding what chemical formulas mean and how to properly represent the corresponding chemical structures.
2) Understanding how to separate compounds.

**Quantitative:**
1) Understanding what the calculations required for the preparation of a solution are (using written protocols).
2) Plotting data and interpreting graphed information.

These four goals are described in more detail in Appendix 3 and have been approved by the Program. The workgroup suggested that these four concepts be used to model the assessment process because they are among those amenable to assessment across the chemistry curriculum. The idea is to evaluate how the understanding of the concept matures as the student progresses through the curriculum. Informally, we have always made the claim that students “learn something” by the time they graduate. Our intention then, is to provide direct evidence that this is actually the case.

**B. Assessment instruments for measuring the learning outcomes of our majors**

We then considered how the learning goals would be assessed, which student populations would be assessed, and at what stage(s) in their college education they would be assessed. Our thinking has come full circle in at least one respect. We started out wanting to assess student learning in our majors, but then broadened the effort to include a number of majors that we serve, such as Biology, Environmental Studies and Marine Science. However, we are focusing once again on our majors. One reason is to keep assessment manageable. Another is that our majors tend to be very consistent about the sequence in which they take their courses. For example, a very limited survey of the transcripts of 2004 and 2005 BCMB graduates shows that ~75% took CHEM I, II, III and IV in sequence (while ~13% each took the I, IV, II, III and the I, II, IV, III sequences). CHEM I and IV correspond to the first and second semester of general chemistry, while CHEM II and III correspond to the first and second semester of organic chemistry. A third reason we wish to focus on our majors is that it is easier to track the progress in student understanding when following students who continue to take more chemistry courses, and these, of course, are our majors.

As a way to monitor student learning, the assessment workgroup has decided to use embedded questions to assess the progress of student understanding of the two qualitative and two quantitative learning goals described earlier. Student understanding will be assessed as they progress through the Chemistry Program curriculum. We wish to test the idea that multiple exposure to a particular concept in different course contexts results in a better understanding of the concept. The idea is to assess global programmatic influences (rather than individual faculty
influences) on students. For instance, questions about plotting data and interpreting graphs will be placed in the CHEM I → CHEM II → CHEM IV → BIOCHEM → BLM (Biochemistry Laboratory Methods) course sequence, because it is in these courses where students are plotting data and interpreting graphs. Furthermore, the questions will be course-specific, with expectations higher in the more advanced courses.

These instruments will be assembled this summer (2006). We have asked all interested faculty to identify candidate questions in their tests for this purpose. At this point we are not concerned about format, just identifying questions that meet the spirit of the assessment. As a way to assuage any fears, we have pointed out that whether a student does well (or poorly) on an embedded question while in a particular class (i.e. with a particular teacher) is not what should concern the Program. Rather, what matters is whether students show consistent progress over time in their understanding of the concept and hopefully by the time they graduate. Again, what is being addressed is the influence of the program as a whole. The hypothesis is that exposure in different contexts (i.e. different courses) is the key to fully understanding a concept or mastering a skill. If a particular student does not “get it” while in a particular course, they may do so in the next course. Students have different ways of learning and faculty have different ways of teaching, so it should be obvious that it is our joint effort (and not our isolated efforts) that plays the major role in ensuring that our graduates are well prepared.

In order to make this experiment manageable we are planning to assess the learning exhibited by cohorts of students (rather than by following individual students), and samples of students (rather than all students).

C. Earlier/Current assessment of student learning efforts

A number of us (Olsen, Hallock-Waters and Rogerson) are already experimenting with several American Chemical Society standardized tests (Toledo, First-term and Two-term exams) for measuring learning outcomes in general chemistry. We are assessing skills and knowledge in a number of areas at the beginning and end of CHEM I (single course analysis), or the CHEM I, IV sequence (combined course analysis). In the latter case, we are trying to determine the degree to which students taking CHEM IV have retained any understanding from CHEM I. This work is experimental in nature and aimed at determining whether these instruments are appropriate for basic assessment of learning outcomes in general chemistry.

One critical issue for the Chemistry Program has been freshman performance in CHEM I, the very first chemistry course students take at Stockton, and very likely the one that leaves a lasting impression on students concerning our Program. We have noticed (as others have done at other institutions) a significant withdrawal frequency reflecting a substantial fraction of students struggling with college-level chemistry. Our concern translated into a study that we carried out over several semesters during the 2002 and 2003 academic years involving most of the CHEM I section instructors.

The study was led by Bob Olsen and Brian Rogerson, the results of which were presented at the 2004 Day of Scholarship by Dr. Olsen. We asked the question: Can success in CHEM I be predicted? We attempted to answer this question by administering the Toledo Chemistry
Placement Examination during the first week of class. It is a standardized test designed by the American Chemical Society, which consists of 20 questions on general mathematics, 20 questions on general chemical knowledge and another 20 questions on specific chemical knowledge. Student background is assumed to include one year of high school chemistry and one year of high school algebra. Not surprisingly, students tend to perform better on the general rather than the specific chemical knowledge sections. However, what interested us was their performance in the general mathematics section. When distributions of the student Toledo math scores were plotted versus their final grades for the course, a trend suggesting a link between quantitative skills and success in the CHEM I course became evident. Such a correlation was also evident, but less striking when distributions of student math SAT scores were plotted versus their final grades.

As we proceed with our assessment of student learning plan, it may be possible (with further study) to use the Toledo math scores to identify students at risk in CHEM I. Such early intervention may help put these students on a path that leads to more favorable learning outcomes in CHEM I and future college chemistry courses.

D. Additional learning outcomes we wish to assess

We are also considering assessing student proficiencies at the senior research project/internship level. We would like to develop a common assessment rubric that will measure student understanding of the research experience in their written theses and oral presentations. Among the desired learning outcomes we wish to measure are hypothesis formulation, understanding of project significance, data interpretation, grasp of relevant data, awareness of related literature, and understanding of the application of basic biological/chemical principles in their research projects. We hope this will allow us to introduce some consistency into the research experience particularly when it comes to assessing intramural versus extramural student projects. The plan would be to have research mentors/sponsors meet at the end of each semester to discuss the rubric scores and determine which goals require greater attention. Modifications would then be introduced into our teaching of subsequent research students to remedy any past outcome deficiencies.

There are also non-curricular instructional goals to consider (adapted from Angelo and Cross’ Teaching Goals Inventory and listed in Appendix 4) such as developing a commitment to accurate work and improving oral presentation skills. Some of the listed goals will be readily amenable to assessment if instruments are designed or chosen properly for the qualitative and quantitative goals listed above. Other goals may require their own assessment instruments.

E. How do we define success?

While the Program has not decided what will constitute a “satisfactory” percentage of students in terms of meeting our learning goals (or other measured outcomes), the Middle States assessment booklet “Options and Resources” can serve as a guide. The Teaching Goals Inventory (page 23) suggests a rating scale that could be used for the goals chosen by the Program:

Essential A goal you always/nearly always try to achieve (76% - 100% of the time)
Very Important  A goal you very often try to achieve (51% - 75% of the time)
Important      A goal you sometimes try to achieve (26% - 50% of the time)
Unimportant    A goal you rarely try to achieve (1% - 25% of the time)
Not Applicable A goal you never try to achieve

If writing a good scientific manuscript is identified as an essential program goal, or if a particular concept in the chemistry curriculum is identified as an essential program goal, we could ask if it is being achieved > 75% of the time. The Program, of course, could come up with its own guidelines and definitions of success. Middle States allows for this, and it is our prerogative.

Also, we know that a number of our CHEM and BCMB graduates go on to graduate school. Others get jobs in academia or industry as lab technicians or research assistants. If graduate school acceptance and placement in field-related jobs is identified as an essential program goal, we can ask if it is being achieved > 75% of the time. In those cases where graduate school acceptance requires a good score on an examination, it could be argued that entrance exam performance is connected to what they learned at Stockton. In contrast, gaining employment says little, if anything, about any student learning that may have occurred while at Stockton. Employer satisfaction surveys also do not address what students learned while at Stockton. More direct measures are necessary to determine whether learning is taking place. This is why we are developing the embedded question assessment instrument (described above). If assessment results indicate that certain learning goals are not being met, the program will introduce curricular changes in an attempt to correct any such deficits in future student cohorts.

**F. Obstacles to assessment of non-majors**

It is useful to be reminded of what (and how many) chemistry courses Stockton students take. The list below also highlights the broad student population that we serve (Our majors are underlined). The Chemistry Program teaching responsibilities affect the following numbers of Stockton graduates: ~10 chemistry majors/year, ~15 BCMB majors/year, ~120 biology majors/year, ~30 environmental studies majors/year and ~ 30 marine science majors/year. The challenge we face in assessing student learning in such a broad student population is significant, mostly because non-majors take a limited number of chemistry courses and in many cases, can do so at any time during their tenure at Stockton (i.e. as early as their freshman year or as late as their senior year).

**BCMB (Majors)**
CHEM I, II, III, IV, Biochem, Biochem Lab Meth., BCMB 4800 (Senior research)

**BIOLOGY (Biotech track)**
CHEM I, II, III, IV, Biochem (Survey of Inst. and Biochem. Lab Meth.)

**BIOLOGY (General/Integrative track)**
CHEM I, II, IV, CHEM III or Biochem
BIOLOGY (Pre-med track)
CHEM I, II, III, IV, Biochem (Survey of Inst. and Biochem. Lab. Meth.)

BIOLOGY (Pre-PT, and MPT-accepted)
CHEM I, II

CHEMISTRY (Standard track, ACS) (Majors)

CHEMISTRY (Environmental track) (Majors)
CHEM I, II, III, IV, Envl, Lab. Meth. I, II, Atmospheric, CHEM 4800 (Senior research)

ENVIRONMENTAL STUDIES
CHEM I, CHEM II or CHEM IV

GEOLOGY
CHEM I, CHEM II or CHEM IV

MARINE SCIENCE (Marine Biology, Marine Resource Management tracks)
CHEM I, II

MARINE SCIENCE (Oceanography track)
CHEM I, IV

PUBLIC HEALTH
CHEM I