

2005 Department Teaching Excellence Award
Pre-Proposal Summary of Department Activities
Department of Chemistry & Biochemistry

Section 1. Brief Department Profile and Philosophy

How many adults think back to their old high school or college science classes with a combination of boredom and loathing, simply because science had been presented to them as a rote memorization process, with little connection to the real world? Yet how different that experience might have been if these same students had actually been actively and personally engaged in the majestic enterprise of uncovering new principles about nature, ideas that no human had ever known before.

The teaching/learning mission of the Chemistry & Biochemistry Department centers around the idea that to truly *learn* science, one must *do* science. In other words, it is one thing to learn about scientific principles, definitions, and nomenclature in class, but it is quite another to actually apply all of this to a real situation, as in a research laboratory. It is in the laboratory that these principles are actually used, become real to the student, and transcend what might otherwise be little more than a boring series of facts and numbers that are quickly forgotten.

It is all well and good for a student to learn from a textbook the underpinnings of the scientific method: finding the current status of a scientific problem, the working out of a hypothesis, the development of a strategy to test this hypothesis, the processing of the data measured, and the drawing of conclusions, followed by the writing of a scientific paper to explain all of this to other scientists who work on this problem in a concise, erudite, and convincing manner. But until a student actually *goes through* this entire process for themselves, the true meaning, the very essence, of science remains nebulous and wispy.

Put another way, there are few who would feel comfortable going "under the knife" of an individual who claims to be a brain surgeon, based *solely* on attending classes where the principles of brain surgery were learned from a text book, even if that student had received grades of A in this class. Rather, we seek out an experienced surgeon, one who has learned by doing, who has witnessed first hand all of the pitfalls that can be encountered, and found ways to circumvent each difficulty. Science is much the same. For example, a student may have learned the principles of how to synthesize a particular pharmaceutical molecule from an organic text. But until they have developed the entire synthesis protocol, worked through one step of the process after another, captured the intermediates, discarded the byproducts, and finally achieved success with a pure product, that student has not really "learned" organic synthesis.

Section 2. Department-Sponsored Activities that Promote this Philosophy

It is for this reason that this Department places a great deal of emphasis on engaging our students in the discovery process. While it is generally understood that research is a focus of the education of a graduate student, we extend a similar philosophy to the undergraduate experience. We encourage our chemistry majors to engage in a research project, under the supervision of a faculty member. This project is not simply "make work", or a repetition of what someone else may have done in the past, but is rather an integral component of an ongoing research project, a project considered important enough by the scientific community that it has earned external funding. Our undergraduate students work side by side with graduate students, postdoctoral researchers, and faculty alike.

About the time that students are taking organic chemistry, typically in their sophomore year, they are encouraged to begin undergraduate research. After interviewing a number of different faculty, they choose one in whose lab they begin a research project. With the advice of their faculty sponsor, the student develops a particular research problem which they will attack, and the means by which they hope to solve it. With the help of others in the lab, the student learns the scientific techniques to achieve their goals. During the course of the next year or two, the student works on this research problem as time permits, due to time commitments to their formal coursework. Summers are typically particularly active periods, when each student can more thoroughly engage in their project, with few other diverting commitments. It should be emphasized that, while others in the lab may assist in learning certain lab

techniques and so forth, the project is the *student's*; it is the *student* who must devise the hypothesis, perform the experiments, analyze the results, and ultimately write up a paper explaining and defending their thesis.

Section 3. Assessment

If one had to list the abilities that make for a successful scientist, they would undoubtedly include first being able to read and digest the scientific literature. One must also be able to extract a viable problem from the literature, and propose a means of solving it, using available techniques. Then, a scientist must be able to write a cogent and convincing scientific paper, and to present their results orally in various forums. Both the writing of the paper, and the defense of the oral presentation, require an understanding of a broad set of chemical principles, which have been hopefully learned during the student's entire course of study.

These are *precisely* the skills that are assessed in our capstone course, Chem 4990, in each student's senior year. The student is taught the details of how a paper must be constructed, and a paper is written under the supervision of the instructor of this course. It is expected that each paper represents the equivalent of what one might see in the real scientific journals, and in fact it is a group of these papers which serve as models for the students. The paper provides an important means of assessing the student's acquired competence in critical thinking, as the student must first digest a body of past literature, assess the merits of each previous paper, and place it in the context of the scientific problem. The student is also required to discuss how their own work fits into the broader scheme of this issue, and realistically assess the long-range merits of what they have achieved. Importantly, this paper also provides a means of assessing what the student has learned in their various formal chemistry courses over their undergraduate career, as elements of each course creep into various parts of their paper.

As a final part of this capstone course, each student is required to present their research paper verbally to the Department, both faculty and students. Their presentation assesses their critical abilities to extract what is most crucial in their long written paper. Following their presentation, each student is faced with a number of questions by their audience. Their responses to these questions provide further information about what they have learned in the entire undergraduate experience, and uncovers gaps in their knowledge. For example, we may see from the results that students have not properly learned the important aspects of the spectroscopic properties of molecules, which allows us to beef up this part of our curriculum. Or some might be weak in their understanding of reaction mechanisms. Still another aspect which may show up as weak might be their ability to synthesize different courses into a coherent understanding.

(There is some assessment at earlier stages of the student's career. At the completion of each semester in which a student is registered for Chem 4800 (Undergraduate Research), they must write a scientific paper, a report of their progress to date.)

As one particular example of how this process works, we have recently learned by this process that a segment of our graduating seniors are weak in their understanding of how to prepare a scientific paper. We have consequently developed a new course (Chem 1990) that stresses this important component of their education earlier in their undergraduate career.

This entire process seems to be working rather well by several measures. A number of our undergraduate researchers have received formal recognition for the quality of their research. Several students have been awarded URCO grants, for example, and others have presented at the University's Student Showcase and Posters on the Hill. We have also had national recognition in that one student (Amy Fuller) received an award from the American Chemical Society to attend a National ACS Meeting to present her research and others presented at NCUR. Literally dozens of papers published in peer-reviewed journals, such as the Journal of the American Chemical Society, have contained undergraduates as coauthors, and quite a few students have presented their research at national meetings. Many of these same students have gone on to promising careers at some of the finest graduate schools in the nation.