DEPARTMENTAL PHILOSOPHY OF TEACHING AND LEARNING

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 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 definitions 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 these classes. 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.

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 the focus for graduate education, we extend a similar philosophy to the undergraduate experience. We encourage our 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 original and 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.

In short, our philosophy is centered around the idea that a motivated student is a good student. And what higher level of motivation can there be, than the pioneering discovery of new knowledge? Who wouldn’t work hard, if by doing so, that person would be the first human to learn something heretofore unknown, to discover some new secret of nature, some principle that had not been understood in the entire history of humanity?

Our philosophy is in fact supported by a widespread and growing belief within the educational community at large. For example, the Committee on Professional Training of the American Chemical Society has stated “Research is known to be a powerful pedagogical tool that significantly enhances the quality of undergraduate science education insofar as research more effectively demonstrates the collective intellectual skills needed in practicing scientists better than conventional methods of science education.”

Another aspect of this sort of training has to do with providing direct competitive advantages to our students. A record of past undergraduate research gives our students a leg up in their applications for graduate or other professional schools. For example, many medical schools consider undergraduate research an important component in their evaluation of applicants.

There is still another important, if less obvious, advantage to this approach. A great deal of research over the years has documented that young minds are heavily influenced by effective role models. It is one thing for a student to be exposed to a faculty member who lectures in a classroom situation, and quite another to work closely, side-by-side, on a daily basis in a laboratory. The research participation stressed by our Department fosters the one-on-one contact that is so important in developing personal relationships between faculty and student. The student learns that faculty are human just as they are, but more than that, this program enables each student to directly observe how scientists go about their work. It develops the sort of self-confidence that is part and parcel of a critical thinker. It is thus crucial that our faculty research supervisors be effective role models, people who are highly respected in their field, so that they may be respected, and emulated, by their students. In short, the effectiveness of this entire philosophy rests on the personal reputations developed by our faculty within their research communities. We are thus pleased that several of our own faculty have been recognized locally as well as globally for their research. For example, six of our faculty have received the College of Science's Faculty Researcher of the Year in recent years, one earned the Governor's Medal for Science and Technology in 2002 as well as a nationally competitive Spencer Award in 2004, another represents one of only a small number of USU Trustee Professors, and yet another was designated the USU Professor of the Year in 2002, which recognizes a combination of teaching, research, and student engagement activities. Two of our faculty have received the College of Science's recognition as Undergraduate Advisors of the Year.

NARRATIVE

Due to the philosophy adopted by this Department, the narrative will flow more sensibly if the required Sections are taken out of the usual numerical order.

Section 5. Linking discovery, creative activity, and engagement with teaching and learning for the benefit of students

"Linking discovery, creative activity, and engagement with teaching and learning for the benefit of students" represents the *very heart* of our Department's philosophy. In short, this Department attempts to mold students into scientists. The term "scientist" refers *not* to someone who has simply memorized some facts and numbers in chemistry, physics, or biology. It is much broader than that. There is nothing less satisfying to a scientist than answering a question by "because that's the way it is". They *must* know *why*. A scientist has an unquenchable thirst to understand the fundamental laws of nature. The answer to a question always leads to additional, and deeper, questions. A scientist runs on this treadmill, unlocking one secret after another as they go.

A scientist is a person who has adopted a rigorous discipline of critical thinking. A scientist does not accept statements on face value, but requires proof. A scientist digests facts, data, and observations, and considers a range of interpretations. A scientist can select one interpretation as favored for the time being, but understands that future observations may cause a modification, or perhaps even complete dismissal of this idea. Nothing is sacred, everything is fluid. A scientist will consider all ideas fairly and thoughtfully, letting the facts speak for themselves. This definition of scientist, then, hinges upon the idea of critical and independent thinking. It is through the creative inquiry process that a young person matures into a scientist. It is for this reason that the research experience is the linchpin of this Department's instructional philosophy. All of our majors are strongly encouraged to engage in a research project.

The process begins typically in the student's sophomore year, about the time they are taking organic chemistry. Students will generally interview a number of different faculty concerning the sort of research being conducted in their lab. Upon mutual agreement, the student will be accepted into a lab. The next step is to choose a research project. As students are new to this, the faculty supervisor plays an active role. The project chosen is a genuine scientific project, something new, with clear achievable goals. It might, for example, involve the synthesis of a new molecule, the calculation of the properties of a system that are not measurable, the development of a new analytical technique, or a new mutation of an enzyme. It should be stressed that these projects are deemed important by the entire scientific community, which is to say that each represents a subset of a project that has been subjected to rigorous peer review by expert panels of external agencies such as NSF and NIH, and deemed worthwhile, well designed, and completely new science.

With the project chosen, the student embarks on their research project in Chem 4800 (undergraduate research), or they may be paid a stipend by the faculty member from an external grant. The development of their project requires that the student read the literature so as to understand the current status of their problem. They must develop a protocol to address the problem. As they generate data, they analyze it, and present their work in laboratory group meetings. It is here that they defend their thought processes as other members of the group question the validity of their conclusions, and perhaps propose alternate interpretations. The student then considers ways of testing their earlier conclusions more thoroughly. It is in this way that the student learns first hand the scientific process.

In their senior year, students enroll in our capstone course, Chem 4990, where they write a full and complete paper, in much the same way that a senior scientist prepares a paper for submission to a peer-reviewed journal. In doing so, the student must demonstrate their command of the literature, and how their particular problem fits into the “bigger picture”. They describe their protocol clearly and succinctly, so that others might reproduce it. They present their data, again concisely, and with well-chosen figures and tables to illustrate their points. It is necessary that they discuss the meaning of their data, and how they have arrived at their conclusions, which are well founded and rock solid. It is also expected that they look to the future, and point out other experiments that might answer other questions brought up by their present data. Another component of Chem 4990 is the oral presentation of their paper to an audience of faculty and other students. This experience develops an alternate set of important skills, including verbal communication and the optimal use of visual aids to make their points. At the conclusion of their talk, the student is asked a number of questions by the audience, some of which require the student to think beyond what they have themselves done, to have some knowledge of other work in the field, and to explain some of the details of their experiments.

In addition to instruction of our chemistry majors, this Department performs a major service function for the University, teaching chemistry to large numbers of students from other majors, e.g. biology, engineering, agriculture, etc. While it would be ideal if we could engage our nonmajors in research projects as we do our chemistry majors, this is of course not logistically possible. Nonetheless, these nonmajors are not entirely removed from our Departmental philosophy of discovery and engagement. Our lower-level courses are designed in such a way that students are exposed to the conceptual history of the material, so that they can understand the context of some of the momentous discoveries in science. An example is the development of our current view of the structure of the atom. For many years, it was thought that atoms contained positive and negative charges in a sort of diffuse “jelly”, which occupied the entire volume of the atom. But we discuss in class Rutherford’s experiments that were puzzling at first, so much so that there was some skepticism that the data was even correct. We go on to show how these simple, yet elegant, experiments, primitive by today’s standards, were able to demonstrate that all of the positive charge of an atom, and 99% of its mass, is concentrated in an almost unbelievably small section of the atom, which we now call the nucleus. By incorporating modern computer technology, we are able to show the essence of this experiment in class, and the data obtained. We challenge the students to “be” Rutherford, to go back in time, to consider the data, and propose various alternate interpretations. What does the data tell us? The students’ critical thinking is put to the test. The students themselves “discover” the inescapable, yet astounding discovery of atomic structure, which underlies all of chemistry and atomic physics today.

This same philosophy of engagement in the scientific thought process pervades the laboratory courses that are taught in this Department. In a synthesis lab course, for instance, the student is given the task of synthesizing a given molecule. Exactly *how* to synthesize it becomes a problem for the students to solve for themselves. The student must be able to digest much of their earlier material, and design an entire synthesis procedure of their own accord, analogous to an independent research project, albeit of shorter duration. An analytical laboratory course requires that the student devise an original experiment to solve a chemical problem, the only limitation being the equipment available in the lab. Success therefore is predicated on a full range of critical thinking: the ability of the student to understand the problem, read and digest the original scientific literature, understand the limitations of the equipment, devise an experimental protocol, analyze the data, and critically assess whether the data supports any conclusions. In still another course, students are provided with spectral data and from that and that alone, they must deduce the structure of the molecule. This is again akin to the sort of thought process, the critical thinking skills that would accompany a real research project.

We have extended this philosophy even to our nonmajor GenEd courses. A new text was recently chosen for Chem 1010 which focuses on the concepts of chemistry, to develop better thinking abilities and minimize the amount of memorization required. Technology is fully implemented as well: The Department purchased software from Accelrys and students are encouraged to make use of this visual, graphic tool on an independent basis in the Department's Computer Lab. Nor does the Department limit its efforts to students enrolled in the University, but has been active in outreach efforts to lower grades. For example, Dr. Seefeldt organized a Workshop for High School Students to provide hands-on introduction to modern laboratory methods and concepts of biochemistry. The Department is active also in organizing demonstrations of chemistry to lower grades, including for example USU's Child Development Lab.

There are a number of obvious indications of the success of our program. First, over the last three years, 88 students have participated in research projects, under the supervision of our faculty. (Individuals are listed in Table 1 of the Appendix.) When placed in the context of our total number of declared majors (100-120), and the number of students graduating each year (~20), we believe this to be a strong indication of its popularity amongst students. (Sample projects are listed in Table 2.) Quite a number of students have published their work in peer-reviewed journals, 30 such publications within the last three years (Table 3). A substantial fraction have appeared in the highest prestige journals in chemistry and biochemistry, such as Science, the Journal of the American Chemical Society, Angewandte Chemie, Inorganic Chemistry, Journal of Physical Chemistry, and Biochemistry. Such an accomplishment will add to any student's self-confidence, as well as augur well for their future career. We count 33 papers that have been presented at regional and national meetings by our undergraduate researchers (Table 4).

There have been a number of awards recognizing our students (Table 5). One student was selected for a prestigious Department of Energy Science Undergraduate Research Internship and spent a summer at Lawrence Berkeley National Laboratory; another won a similar competition at PNNL. Two students were winners of ACS Division of Inorganic Chemistry Travel Awards, another won a Barry Goldwater Scholarship, and still another was a recipient of a Chemistry Division of the Council on Undergraduate Research Travel Award. Two students had an outline of their published paper appear in the Sept. 2002 Council on Undergraduate Research Quarterly. Yet another student was recently awarded a Chemistry NSF-REU Leadership Group Travel Award.

With regard to recognition within USU, ten different students have been selected for URCO grants, again within the last three years. One of our students was named the College of Science Valedictorian and another the Scholar of the Year. Four others won COS University Club Scholarships. One was named the College of Science Valedictorian and another the COS Scholar of the Year in 2002. Another important issue relates to what our students do upon graduation. It is indicative that of the seven students doing research in one of our labs, all have gone on to either graduate or medical school.

Our tradition of undergraduate research is far from new, but has been a part of our program for decades. As just one example, Robert Wardle did undergraduate research as a major component of his BS here in 1981. His career accomplishments are impressive: a PhD from Caltech and now Director of Research & Development of ATK Thiokol. He has served as a principal investigator on 22 DoD contracted programs with an aggregate value of more than $30 million, has published more than 110 articles, and holds 37 patents.

A Board of Regents Review of this Department in 2003-04 brought the following recognition from the external reviewers: "The committee noted with approval that undergraduate students are engaged in research in impressive numbers. Clearly, the faculty is mentoring these students in research, not simply using them for menial tasks" and "The committee was particularly impressed by the maturity and interest in chemistry exhibited by the undergraduate students" who "offered compelling anecdotes to support their enthusiasm for majoring in chemistry, providing strong evidence of the devotion of the faculty to undergraduate teaching and research."

Although not the principal focus of this application, we are proud of our graduate students as well, and their success is a supplementary marker of our research programs. Two of our graduate students were USU Graduate Student (PhD) Researchers of the Year recently, and another was the recipient of a Presidential Fellowship. Other awards garnered by our students include the ZoBell Graduate Scholarship, the Piette Graduate Scholarship, a Presidential Fellowship, and an Eccles Fellowship. One student was the winner of a national competition for an Excellence Award from the American Chemical Society and another has won a highly prestigious fellowship from the international Humboldt Foundation.

One may use student retention and graduation rates as another metric. As indicated in Table 6 of the Appendix, the Chemistry Department's 1st year retention rate is 77%, higher than those of both Biology (70%) and Physics (43%), the two most comparable lab science departments, and is significantly higher than both the College of Science (64%) and USU overall (66%) The 6-year graduation rate data is much the same: our rate of 67% is superior to those of Biology (33%) and Physics (40%), and surpasses the College and USU rates of 41% and 43%, respectively.

Section 1. Commitment to sustained excellence in teaching and learning and
Section 4. Provision of resources for students

(It is difficult to separate these two areas, as they both involve a commitment of sorts.)

We put our money where our mouth is, so to speak, with heavy investments in this process, some of which are listed below. In summary, this Department has spent out some **$940,000** over the past three years in support of our mission of education and training of our students, with emphasis on undergraduate research, a very expensive proposition.

Stipends- It is necessary to provide some financial support while students are engaging in research projects, since this represents time where they cannot be working and earning income. These stipends are derived largely from the external research grants generated by their faculty mentors. The expenditure of funds for this purpose demonstrates the faculty "buy in" for this undergraduate research philosophy, as these dollars could easily be spent for other purposes such as research equipment, or expended on more senior researchers. In the last three years, we estimate that **$225,000** has been spent by our faculty in this way.

Supplies- Scientific research is expensive, far more than salaries of personnel. There is a range of supplies and chemicals that must be purchased, samples must be run at expensive facilities elsewhere, etc. We estimate **$450,000** has been spent in this way. In addition, the Department has contributed matching funds to our URCO award winners, which amounts to some **$5,000** to our ten URCO students over the past 3 years.

Summer Program- The summer offers an opportunity for students to concentrate on their research projects. In order to encourage this activity, the Department has developed a summer undergraduate research program, which involves a competition. The winning students are honored at the Department's spring awards ceremony. They also receive an addition to the stipend paid by their faculty advisor, as well as a modest amount of commodities support. With help from the College of Science, we have contributed **$9,000** to this summer program over the last three years. Drs Hevel and Berreau are presently developing plans to further augment this program, so as to improve undergraduate access.

Overload Assignment- In order to integrate undergraduate students more quickly into research, Dr. Berreau is currently teaching a physical sciences section of the Honors 2100 course. This class, which involves first year chemistry, physics, mathematics, and computer science honors students, is designed to provide the students with a guided pathway toward finding an undergraduate research mentor, becoming active in research, and using this experience as a building block toward achieving success in college and beyond.

Outside Visitors Program- The Department considers it important to offer successful role models as examples to our students, in addition to our own faculty. We thus run a program whereby researchers from other institutions are brought to campus for a full day. These external faculty present a seminar describing their research whereby they go through their thought process as they develop one experiment after another. We foster direct contact by making our visitors (25-30 each year) available to meet with students, and provide a relaxed opportunity to get together over lunch. One was a Nobel Laureate, the first such visitor to this campus. Dr. Lipscomb's visit was widely attended and provided an inspiration to many of our aspiring young scientists. The Department has spent approximately **$36,000** on this program over the past three years.

The Visitors program is not limited to researchers *per se*. For example, one of our recent visitors was Madeleine Jacobs, Editor in Chief of C&E News, the weekly newsmagazine of the American Chemical Society. Ms. Jacobs spent a good deal of time with students, discussing not only their individual research projects, but also a full panoply of career options available to students graduating with a degree in chemistry. In some cases, our visitors arrive early and spend extra time with students.

Student Travel- An important component in the development of a young scientist is the ability to attend a meeting, to present their own research results, to interact with other scientists working in the same field. Faculty generally pay student travel costs from their grants, supplemented by contributions from the Department. These costs have totaled approximately **$9,000** over the last three years.

Chemistry Club- It is almost axiomatic that when students enrolled in a similar program socialize with one another, the education of all is enhanced and broadened. It is in part for this reason that the American Chemical Society encourages the formation of "Student Affiliates" within Chemistry Departments. Our Department has encouraged and sponsored a Chemistry Club of chemistry majors which serves a multitude of functions: It provides a forum for students to discuss career issues, like "what happens after graduation?" and "what is graduate school?" Seniors are able to share their collective wisdom with those less advanced in their studies. These students also engage in tutoring services for other students having difficulty in one course or another. It also permits them to test out certain career options, such as high school teaching, by making presentations about chemistry to local high schools. In connection with our goal of fostering undergraduate research, this club offers a means for those students engaged in such research to extol the value of it to those who might not otherwise think seriously about it. The Department has provided an office in our Building to serve as a point of collection, a clubhouse of sorts. We have provided modest amounts of monetary support as well, in the neighborhood of **$1,500** over the last three years. In conjunction with this club, the Department organized a visit of ten of our undergraduates to a pair of pharmaceutical companies on the West Coast, so that they might learn more about this industry and possible careers, and perhaps set up internships for some of them. The Department contributed **$700** to this trip.

Department Tutoring Center- The Department realizes that some students are best served in a one-on-one format, which neither our large lecture classes nor our smaller recitation classes can accommodate. For that reason, we have set up a Department Tutoring Center that provides such one-on-one tutoring for students in a drop-in format. This Center is open four afternoons per week, plus one evening and is staffed by graduate students who have expertise in all of the major areas that we teach. Funding for this Center is supplied entirely by the Department and amounts to **$84,000** over the last three years.

Computer Lab- The Department invested some **$30,000** in the installation of a new computer lab in 2000. This lab contains a dozen computers and a printer, and is dedicated to students who are enrolled in chemistry classes. We have recently purchased and installed state-of-the-art graphics programs to aid students in visualizing some of the larger and more complicated molecules, at a cost of **$4,200**.

Awards and Scholarships- Positive reinforcement can be a powerful tool. This Department has found means of distributing a range of different awards that recognize students for various meritorious activities. More than 15 different types of awards are distributed for outstanding performance in coursework, for excellence in laboratory, and so forth. Important for the theme of our Department, we also grant awards for outstanding research performance, undergraduate as well as graduate. Another award is presented at this ceremony to an alumnus of the Department who has distinguished themselves in their field since their graduation. Some of these awards in the past few years have gone to former students who have won national and international honors for their research. We believe that the display of such former students as role models can act as a powerful inspiration and motivating force for current students, and makes a statement like "Why not you?, You, too, can achieve all this, and may someday be honored just as these former students are being honored today". These awards are presented at a single ceremony, held in April of each year, and attended by the family members of our students, particularly parents and spouses, as well as all faculty in the Department, and the Dean of the College. Each student is individually recognized, and handed their award to the applause of the crowd as photographs are taken. In all, the Department commits on the order of **$30,000** over each three-year period for these awards.

Hosting of a National Meeting- Presentation of their individual research project is an important component in the development of our students. Such a process takes on added value if presented in a venue containing researchers from other institutions. It is for this reason that the Department encourages the travel of our students to national meetings. But not all students can make such a trip. In June 2004, this Department hosted a meeting of the American Chemical Society here at USU. This meeting attracted over 400 chemists, faculty, industrial researchers, and students, to campus to discuss research findings in a broad array of chemical areas, thus providing a forum for our undergraduate students that we could normally only dream of.

Without need of travel, each of our students had the opportunity to present their research results to scores of external researchers, and to observe how others, senior and student alike, present their own research. They were able to meet and network with some of the most well known researchers in this country and abroad. In addition to research *per se*, our students participated in a full-day Career Workshop, run by the career development arm of the ACS, another invaluable reward of this meeting. As one can imagine, the hosting of a meeting of this magnitude represented a truly massive contribution of time and energy by various members of this Department. Any realistic estimate would entail literally hundreds, perhaps thousands, of hours of faculty and staff time.

<u>External Support</u>- The Department has been extremely active in seeking external support for these endeavors:

In concert with the Biology Department, an application was submitted by this Department in 2002 to the Beckman Foundation designed to secure $105,600 solely to foster undergraduate research. While this application passed the first cut and was a finalist, we were not fortunate enough to win an award at that time. A second attempt was made very recently.

Several of our faculty have included a teaching component in proposals they have submitted to the NSF. Dr. Berreau's NSF CAREER grant includes $450 K (this grant was funded), enabling her to pursue some interesting new developments in undergraduate laboratory. In addition, half of the budgeted student support was expended for undergraduate researchers. Dr. Chang has submitted three such grants since 2001, requesting $429,927, $429,927, and $381,083, respectively. He proposed encouraging students to design and assemble their own apparatus for their individual projects, fostering a high level of self-confidence. He is also developing an interdisciplinary short that will develop a cooperative attitude toward research. This course will include components in modern molecular modeling.

Dr Hevel submitted a NSF CAREER application, which centered on providing career guidance to undergraduates, particularly in terms of educating them with regard to industrial positions. Students will perform a variety of tasks in the spring specifically related to the needs of a given partner company, e.g. background work on a particular methodology. This activity will be followed by a summer internship in the industrial environment, after which these interns will present their experiences to more junior students here at USU. She also requested support to involve undergraduates in research at earlier stages in their training. Dr Silva submitted a proposal to this same program in Jan, 05, again with a prime focus on undergraduate issues.

Dr. Kar submitted a proposal to a new program at NSF, the "Discovery Corps". This proposal is aimed toward bringing the rapidly emerging field of nanotechnology into the curriculum of not only the USU Chemistry Department's undergraduate and graduate programs, but into high schools throughout the state as well. This proposal requests $129,000.

NMR spectroscopy is an essential component of much chemical research, including projects of our undergraduates. The deteriorating state of our NMR equipment had thus become a real handicap to progress by these students. The Department thus embarked on a quest to modernize this equipment, knowing that its high cost was going to require the submission of a number of proposals to external agencies, each requiring a good deal of effort on the part of our faculty. Nonetheless, the Department made this commitment, and after a number of attempts, was finally successful with a proposal to NSF which brought **$155,000** toward the purchase. This amount was supplemented by matching funds from the Department and University of **$55,150**, again reflecting the commitment toward undergraduate research in monetary as well faculty time.

A number of our faculty have applied for funding from the **Dreyfus Foundation** that supports undergraduate education in chemistry. Dr. Peters was funded in the amount of $60,000 by this Foundation in 2001 (one of only a dozen in the country). The teaching component of his project involved a package of simple demonstrations appropriate to General Chemistry. These demonstrations were designed to illustrate the fundamental concepts discussed, using materials and procedures with which the students will be somewhat familiar. Dr. Berreau applied to this same agency the next two years. Her project was centered on the notion of further augmenting the mentoring aspect of our undergraduate research, taking students smoothly from the classroom into the research lab. She proposed to set the stage for undergraduate research in a series of meetings, timed so as to dovetail with the students' progress, introducing students already engaged in research, as well as bringing to the students' attention a series of funding opportunities, of which they might not be aware.

Another applicant to the Dreyfus Foundation was Dr. Silva who sought $40,000 to develop an environmental chemistry program for our majors. He proposed to develop first a sophomore-level lab course in environmental chemistry, covering general concepts and issues in environmental chemistry. The next step would be the development of an upper division class in environmental chemistry, a senior level elective, focusing on the quantitative aspects of environmental chemistry. An independent project, chosen, designed, and carried out by each student is an integral part of the laboratory section. Although this proposal was not funded, Dr. Silva has successfully completed the development of these courses, and the Department now has in place an environmental chemistry emphasis, making USU the only institution in the state with this accreditation. Dr. Hevel also submitted a proposal ($40,000) to Dreyfus, intended to develop a graduate level proteomic-based class, promoting learning through research-based problem solving.

Dr. Berreau had a project funded by the Frasch Foundation, one of only 17 nationwide. This Foundation is aimed toward promotion of undergraduate research. Dr. Berreau also used a large portion of her Eccles grant to support undergraduate researchers. She has very recently been awarded a grant in the amount of $208,500, from the AREA program of NIH, experimenting with the concept of starting students off in research in their freshman year. In addition to the scientific research experience itself, the student will develop a support network of fellow students that may encourage their retention in science. The American Heart Association Western Affiliates (which currently funds Dr. Hevel) sponsors summer research by undergraduates, which she uses to support a number of undergraduates.

The Department acquired a rather expensive (>$200 K) atomic force microscopy dip-pen nanolithography system (one of only seven in the entire country) via a grant awarded to Dr. Holz by the AFOSR and DARPA. This system will be of great value in our instructional laboratories, as it enables the use of modern technology to examine systems on an unprecedented small scale. A number of our faculty have been funded by the PRF arm of the ACS. A great deal of this funding has been used to support undergraduate researchers in their labs.

Of course, as indicated above, the lion's share of support for our undergraduate researchers originates in the external research grants won by our faculty. Without the availability of these dollars, many of our efforts would be in vain. It is thus important to summarize Departmental total efforts to secure external research grants. The total Departmental annual contracts and grants funds have been in the $1.9 - 2.3 M range since 1996. On a per-faculty basis, the Department's annual external funding of $137 K is the highest in the College of Science.

<u>Standard Courses</u>

With regard to the teaching of standard courses, our Department is evaluated well by our students. Ratings by students vary from 4.1-4.6 in our lower level general chemistry courses, rise to 4.2-4.8 in sophomore level (organic chemistry), then rise again in the upper level courses, some at 5.0 and higher. This pattern of scores, inversely proportional to enrollment, is typical. All faculty have regular office hours, which students are apprised of. Our faculty are also available outside of these formal office hours and encourage student visits. Many faculty also conduct help sessions in the evening so as to better accommodate their students' schedules.

The quality of faculty teaching has historically been a heavy contributor to faculty merit raises, certainly on a par with research productivity. The potential of each candidate for a new faculty position in our Department is an essential ingredient in deciding on whom to make an offer. The Department involves students in these decisions, asking them to attend presentations by faculty candidates, and spending time with them personally. Students then provide feedback on their impressions of each candidate, which is weighed heavily when the Department makes its final recommendations.

Section 2. Ongoing assessment and improvement of teaching and learning quality

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 (described in detail in Section 5 above). The written paper produced here 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. It also provides a metric of 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. Their oral presentation assesses their critical abilities to extract what is most crucial in their long written paper. Responses to spontaneous 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. (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.)

With regard to individual courses, as required by the University, all courses are subjected to student evaluation each semester. In addition, the Department carries out a similar evaluation of all laboratory and recitation sections. The Head of the Department reads all course evaluation forms (numbering in the thousands each year) so as to glean any themes that might strengthen the courses. In addition to student evaluations, instructors are observed by other faculty on a regular basis. The Department Head observes at least one lecture of each untenured faculty member every semester, and one lecture of tenured faculty once each year. Untenured faculty are regularly observed by members of their T&P Committee, typically one observation every semester. Tenured faculty are observed by other faculty less regularly, with more common observations of Associate Professors (typically one observation each semester). After each observation, whether by the Department Head or some other faculty member, a written memo is given to the instructor with comments, both positive and negative, with a copy going to the instructor's file. The observer and instructor then meet together to discuss the observation, and any suggestions for improvement. These observations extend to other instructors as well. Upon appointment of a Lecturer in this Department, a Mentoring Committee was assembled, consisting of the best instructors. This committee was charged with monitoring the instructional style of the Lecturer, and providing constructive feedback on a regular basis, as well as advice about matters in which they had previous experience.

<u>Assessment Committee</u>- The Department has a committee that bears direct responsibility for assessment issues, and with curriculum as well. This committee has been leading this Department's efforts in upgrading our assessment procedures. As one example, the Department has begun to use standardized exams that are prepared by the American Chemical Society as final exams in many of our courses. This change permits us to compare our students' performance to national norms. The breakdown in the test results will also facilitate the identification of course topics that are not being learned as well as we would like, so that we can augment the related part of the curriculum.

<u>General Chemistry</u> - The Department has a standing General Chemistry Steering Committee that is responsible for regularly assessing the success of our lower level course offerings and making recommendations for improvements. This Committee has made recommendations concerning changes in textbook when they had reason to believe a superior text was available. This committee also works toward a certain degree of uniformity, so that students receive similar training regardless of the particular instructor assigned to the course.

<u>Advising</u>- Rather than use a staff member as advisor to undergraduates, or a single faculty member, this Department carries out its advising with a small group of faculty. The use of faculty provides a level of expertise about career options, graduate schools, etc that would be beyond the ability of a staff member. Making use of several faculty permits us to customize our advising according to the interests of each student. For example, those students interested in biochemistry or medical school are assigned to a biochemistry faculty member, while those interested in the use of analytical instrumentation are assigned to a faculty member knowledgeable of this area. Each student sticks to their advisor during their entire undergraduate

career, providing a continuity that is conducive to development of a trusting, personal relationship. Along the theme of this Department's interest in undergraduate research, our advisors encourage students to become involved in this activity as soon as they believe would be appropriate.

It might be added at this point, that the student's research advisor, once chosen, serves as a second advisor of sorts to this student. In addition to monitoring and supervising the actual research, this faculty member develops a particularly intimate relationship with the student, which fosters important advice involving future careers, choice of professional school, and so on. The nature of this interaction is also conducive to long-term contacts, so that the research advisor typically remains in communication with the student long after they have graduated. The information received is valuable in our attempts to assess the long-term success of our program. We are able to find out the student's impressions of whether our program has stood them in good stead over their entire career. If the student has gone into industry, we are able to glean the impressions of their employer as to the level of training on the part of the student.

Both types of advisors, the primary who takes on the student at an early stage, and the research advisor, provide an important means of assessment. The primary advisor is concerned not only with the success that each student has in their courses, but also how the student views their courses: what they feel they have learned, how effectively the material was communicated, the manner in which the various courses relate to one another, and a range of other issues. The research advisor is in a position to observe how well the student is able to apply their course material in order to engage in their research. This advisor can pinpoint which aspects of their training has been effective and which have not "sunk in", how well the student can integrate an entire program of courses and diverse material. This advisor can also assess the student's critical thinking skills, and communication, both written and verbal.

OUTCOMES

As a first example of how our assessment process works, we have recently learned that a segment of our graduating seniors are weak in their understanding of how to prepare a scientific paper, modern literature-searching skills, and use of computer software. We have consequently developed a new course (Chem 1990) that stresses these important components of their education much earlier in their undergraduate career. This course is also intended to instill in these beginning students an awareness of possible career options, via field trips to industry and internships, in addition to providing a more formal introduction into the benefits of undergraduate research. Additionally, chemistry demonstrations were developed for use in a middle school visit event on the USU campus run by the 1990 students. Student evaluations indicated this course to be highly successful, with scores at the 5.4 level.

With respect to undergraduate research, as a response to input from students, we have added renewed emphasis to our efforts to recruit undergraduates into research. The Department created a new faculty role as Coordinator of Undergraduate Research, assumed by Dr Hevel. She has added a renewed emphasis to this part of our curriculum on the homepage not only of the Department, but of the College of Science as well.

Responding to strong demand on the part of students, the Department has approved a biochemistry major, and only awaits approval at the state level. When activated, this major will be the only accredited biochemistry major offered in the state of Utah and will add to the job opportunities of these majors. As students had exhibited a strong interest in environmental issues, the Department has developed a new emphasis in Environmental Chemistry, designed along the guidelines of the ACS.

Students had habitually commented that the two-semester organic chemistry sequence (2310/20) required a great deal of work for 3-credit courses, a point echoed by the faculty teaching them. We have consequently expanded them to 4-credit courses, consistent with many other universities, and designed to allow more in-depth training in what has become an increasingly broad and important discipline.

For those students who are not science majors, the GenEd chemistry course, Chem 1010, has been modified. Its old format covered standard general chemistry but at a lower level. Students commented that they found this uninteresting and irrelevant to their lives. Topics now include important societal issues, such as global warming, pollution, ozone depletion, and energy issues, introducing the basic chemical concepts as they are needed to understand these issues.

With regard to our general chemistry program, the Department has been considering whether the present recitation sections, which meet once a week under the supervision of a graduate student in a small group, might be better replaced by an additional lecture class, under the supervision of the faculty instructor. This discussion was engendered in part by student comments about perceived weaknesses in the recitations in their current form, and inconsistencies from one section to the next. Experiments are underway in one of our classes to evaluate the merits of this new idea.

Advances in Course Instruction Techniques- Many in our field have come to believe that the level of student comprehension in General Chemistry could be enhanced if students were encouraged to work additional practice problems, more than just a selection of those in the back of each chapter of the text. WebCT allowed us to construct a series of quizzes that students can take online, whenever is most convenient for them. When logged on, the student is given 10 questions, dealt out randomly from a large database. After completing the quiz, and a first grade recorded, the student is given immediate feedback as to the correct answer to each question. They may then go back to the text and class notes, look over the relevant material where they were in error, and then retake the quiz, with another 10 random questions. The student is motivated to take the quiz a number of times so as to improve their grade, and by doing so, continuously build their comprehension via this feedback loop. And indeed, it was noted that some students were taking each quiz quite a number of times, learning from literally hundreds of questions from each chapter of the text. Monitoring of the quiz grades showed steady improvement from one day to the next, along with student understanding of the material. And the merits of this system were apparent too on the exam grades, which were 7-10 points higher on average than those of comparable exams from years past. Following the conclusion of this successful experiment, this approach is spreading to other segments of our curriculum, e.g. organic chemistry.

Online quizzing is in the process of being incorporated into the laboratory classes as well. In order to take maximal advantage of an experiment, a student must be prepared in advance: they should have read the experiment, understood what they are to do, and how they are to analyze their data. But in common with our sister Departments around the country, our lab classes have suffered from the lack of such preparation on the part of the students. In order to counter this detriment, quizzes are being constructed that pertain directly to each particular experiment, regarding procedures, analysis of data, and overall comprehension. Before coming to class, each student will have to demonstrate preparedness and understanding of the lab by taking and passing the relevant quiz.

Advances in computer technology have been channeled into our biochemistry curriculum as well. Biochemistry faculty have added computer technology to permit students to visualize very large and complicated molecules, both in lecture class and in laboratory.

Diversity - This Department is committed to diversity. In the field of chemistry, women correspond to an underutilized resource. We have made efforts to recruit and retain females in our programs at both the undergraduate and graduate levels. It begins perhaps with providing positive role models. Three of our Department's current eighteen tenure-track faculty are women, which places us above the national norm for chemistry. Our female faculty teach courses at all levels, varying from general chemistry to advanced graduate courses. All three female faculty are engaged in externally funded, nationally visible research programs, and welcome student participation. Our collection of undergraduate advisors contains one of these female faculty, and students are free to choose her as their primary advisor. Female graduate students are frequently utilized as laboratory and recitation teaching assistants, so undergraduates can utilize young female scientists as role models throughout their coursework. Some of the leaders of our undergraduate Chemistry club are female as well, providing yet another level of reinforcement to the idea that women can be every bit as successful as men in this field.

Our Department has exerted a great deal of effort in tracking the careers of our graduates. This information is listed in Tables 7 and 8 of the Appendix in a general sense. As one would expect, we have learned it is far easier to maintain contact with those students who have engaged in undergraduate research, adding another dividend to our emphasis in this area. We list in Table 9 some typical information we have gleaned from our recent former students. We track our graduate students as well. Table 10 reports our findings in the biochemistry segment of our graduates.

Section 3. Faculty development for teaching

Faculty development and improvements in our course offerings have already been dealt with in earlier sections of this application. We mention here only a few other items:

As mentioned elsewhere, new faculty are carefully monitored in their probationary phase for teaching effectiveness. In addition to classroom observation by the Department Head each semester, members of the T&P Committee make regular observations as well. All observations are documented and discussed for constructive critique and recommendations. As an example of how this process works effectively, it had been noted that one of our young faculty had received less than desirable teaching evaluations. Some suggestions provided by the Department Head resulted in some improvement. This was augmented by the assignment of a "teaching mentor" to this faculty member, a more experienced instructor who had taught this same course very successfully in the past. The final result was that this young faculty member is now receiving scores as high as anyone else in the entire Department and is a sought after instructor by the students.

Due to the large number of laboratory sections offered by this Department (nearly 100 each year), as well as numerous recitation sections (45), it is impossible for faculty to instruct all of these directly without graduate student participation as teaching assistants (TAs). Prior to the beginning of the semester, all TAs are subjected to a rigorous course of orientation and training. The Department supplements the general training sessions provided by the Graduate School with our own training with particular relevance to our discipline. TAs are trained in how to handle both recitation and lab sessions, including lab safety and hygiene procedures. During the semester, TAs hold weekly meetings with faculty members whose primary responsibility is that particular course, in addition to the Department's Lab Manager, to discuss instructional issues. Moreover, TAs are observed in class by the faculty instructor, augmented by visits from the Department Head. The performance of each TA is carefully assessed at the conclusion of each class, in part by the administration of an evaluation which parallels the University-sponsored evaluations of all faculty. In addition, faculty relay their assessment of each TA to the Department Head; TAs with unsatisfactory ratings are ineligible for continued TA positions. This TA experience is a valuable component in the training of future chemistry teachers, one which nearly all American faculty have undergone prior to their first academic appointment.

During faculty retreats held in late summer, one of the primary issues revolves around our instructional program. Faculty bring up innovative ideas, past problems, etc which are discussed first by a committee, and then by the entire faculty at large.

As the success of our undergraduate research program is predicated on a core of faculty who can serve as effective role models, it is important to assess the level of achievement of our faculty in their own research programs. In summary, the Department faculty have solid national and international reputations. Summaries of some of their accomplishments are included in Table 11 of the Appendix.