

Proposal from the Department of Chemistry and Biochemistry to the Science Education Initiative

Introduction

Chemistry has a central role in science education providing the molecular alphabet for science. Chemistry interacts and overlaps with math, physics, biology, geology, environmental science, engineering, and other disciplines. At the University of Colorado, there are more than a hundred chemistry majors per class; in addition, more than 7000 undergraduate students are enrolled in chemistry courses and labs each year. The teaching of chemistry provides unique challenges, in addition to those it shares with other scientific disciplines.

The Faculty of the Department of Chemistry and Biochemistry devoted a portion of their meeting on November 16, 2005 to a discussion of a major initiative in innovative undergraduate education, as facilitated by the opportunity to submit a proposal to the Science Education Initiative program led by Professor Carl Wieman. In this discussion, it became apparent that our faculty members are deeply interested in better educating the current generation of students and believe that the traditional lecture format in its present form is not producing the full educational result that we would hope to see. While there may be many reasons for this result, we recognize that it is essential to explore new methods to work effectively to educate our current students. The Science Education Initiative (SEI) affords us both the resources and a unique opportunity to explore such changes, to study and document results of teaching experiments, and to preserve the results of this exploration for future use. At the end of this discussion, the chemistry faculty directed a small group of faculty members to prepare a proposal for Professor Wieman.

With this faculty endorsement, we have prepared a proposal for a five-year program to evaluate and transform our undergraduate instruction, aiming to work towards a testable, more effective curriculum and educational experience for our students. While we recognize that there may well not be major new resources continuously available to the Department at the conclusion of this program, those resources provided by the five-year funding will be absolutely essential to the redevelopment of our undergraduate program.

Proposed teaching experiment

Over the next five years, we expect to institute major changes in essentially all of our undergraduate courses. Initially, however, the major focus will be on the introductory chemistry classes (CHEM 1011, 1021, 1031, 1071, 1111, 1131, 1151, and 1171), sophomore organic chemistry (CHEM 3351 and 3371), upper level physical chemistry courses (CHEM 4511, 4521, and 4531), and upper level biophysical courses (CHEM 4411 and 4431). The initial phase of this development will be based upon a careful, faculty-driven, assessment of the key conceptual goals for each class, carried out by faculty teaching the course and others who have taught it with assistance provided by SEI personnel. Faculty may choose to team-teach some of the courses being redeveloped. The SEI personnel will be instrumental in helping faculty with new technology and materials. The implementation will initially follow the process used in CHEM 4511 and in selected introductory courses (CHEM 1111 and 1131). Over the last few years, a

number of programmatic and technology-related innovations were implemented in CHEM 1111 and 1131. Some of the improvements, issues, and resulting suggestions are described in the Appendix; these innovations provide a strong foundation upon which to build the proposed program.

It will be essential that we continue to evaluate and modify our approach to teaching innovation, as well as document and provide materials to enable these course materials to be available in the future. As we gain experience, this approach will be extended to essentially all of our undergraduate courses. While the use of this approach to undergraduate instruction will not be mandatory for individual faculty, it is our expectation that the results of this change will prove sufficiently compelling as to ensure broadly their continued development and usage.

Institutional structures proposed

It is essential that the Department of Chemistry and Biochemistry develop and implement institutional structures to accomplish and sustain these educational initiatives.

1) We propose to hire a full-time Program Coordinator, who possesses a Ph.D. in chemistry or chemical education, and who has considerable teaching experience in a university setting. The Program Coordinator would consult frequently with an Advisory Board, consisting of faculty representatives from physical chemistry, biochemistry, organic chemistry, analytical chemistry, and inorganic chemistry, as well as the Director of the General Chemistry Program and the Department Chair. With the guidance of this group, the Program Coordinator will develop the overall integrated plan of action, as well as specific and immediate goals and tasks. The PC will be actively involved in the recruitment, interviewing, and selection of the Teaching Fellows. The PC will coordinate the identification of specific learning goals for classes undergoing transformation as well as the development of valid assessments of student learning. The PC will supervise the development of technology, materials, and practices for the course transformations. The PC will serve as a resource for innovations in chemical education; these include the use of Concept Tests, collaborative tutorials, and textbooks, as well as the wealth of materials and approaches developed by the National Science Foundation through four systemic initiatives for undergraduate chemistry education reform. The PC will organize a workshop or series of seminars for chemistry faculty to educate our department about the current status of chemical education research and of the availability of innovative practices. The PC will assist in the archiving of all teaching and assessment materials for ongoing utilization and improvement. We believe that the position of Program Coordinator will be extremely attractive to a dedicated and experienced chemical educator. By the conclusion of the five-year SEI grant, the Department of Chemistry and Biochemistry plans to have the position institutionalized as an integral part of the departmental staff. We believe that the position of Program Coordinator is essential to the success of the Science Education Initiative in chemistry, as we currently do not have tenure-track faculty in chemical education, or the necessary departmental infrastructure for education reform.

2) We propose to hire a 50% web master to work with the PC and faculty to generate web tools for undergraduate courses and to disseminate the materials developed. The Department

would find additional resources for the 50% position to develop the Departmental web page and link the teaching activity into this page.

3) We propose to hire a programmer with IT expertise to work with the PC, faculty, TAs and SEI personnel to develop illustrations for concepts, animations, and computer programs.

4) Another major component of program development relates to the background and training of our Teaching Assistants. It has been our experience that new graduate students are not well prepared to serve as teaching assistants in our undergraduate introductory classes, and they certainly have no background in the interactive, collaborative form of instruction envisioned in this program. We believe it is essential to have a period of intensive training for our new graduate students, if they are to be effective in this program. We propose that, under faculty supervision, new Teaching Assistants be given the opportunity to receive one week of paid instruction, covering both content and methodology, prior to beginning their TA activities. It would be most valuable if SEI personnel were able to play a major role in the methods portion of this program. Our experience suggests that this training alone would have a significant impact on the education of our students. The additional workload for TAs involved in courses being redesigned will be covered by hiring of additional TAs for these courses so as to not place an added burden on TAs during the semester.

An obvious incentive for faculty participation in this program is the opportunity for improvement of our curriculum. The SEI personnel, Program Coordinator, web and IT staff, Teaching Fellows, and trained TAs will make it possible for faculty to perform educational experiments and analyze and document the findings. However, the proposed activities will require additional faculty time. Faculty involved may wish to team-teach a course under development. A redistribution of the teaching effort of faculty involved in this teaching experiment will be necessary. We propose internally funded "course development" semesters be made available to faculty involved in the SEI. These fellowships would be funded from endowments in the Department and continue beyond the five-year time frame of the grant. In addition, the assessment of effective teaching will continue to be an integral component of faculty evaluation for reappointment, tenure, promotion, and financial remuneration.

The Faculty of the Department of Chemistry and Biochemistry recognize that the Science Education Initiative offers a unique opportunity for comprehensive evaluation and dramatic improvement of our educational program. We look forward to participating in this venture.

Course Objectives, Learning Goals, and Assessment

A variety of general chemistry courses are offered including introductory chemistry, environmental chemistry, general chemistry for science majors, general chemistry for engineers, honors general chemistry, and introductory organic and biochemistry for allied-health fields. The objectives and learning goals for each course will be evaluated in light of the needs of students in the 21st century; formative and summative assessment tools will be evaluated or developed as necessary, building from the foundations established in the SEI. The Program Coordinator mentioned earlier will be key to successful implementation, evaluation and documentation of these proposed changes.

CHEM 1111/1131 Lectures

Large lecture sections of CHEM 1111 and CHEM 1131 have been transformed from traditional lectures to student-centered teaching and learning environments that facilitate active learning and peer interaction. The use of ConcepTests and IR clickers since Fall 2003 has placed a formative assessment tool in the hands of the instructors. Misconceptions are addressed quite effectively and new solid state models were developed to facilitate visualization of cubic unit cells. The SEI initiative will allow us to continue and enormously extend these initial steps, and to coordinate these changes with the advanced level courses.

The use of discipline-specific examples that relate to real life applications can make chemistry more exciting and enjoyable. Unfortunately, CHEM 1111 and CHEM 1131 are offered to students in a variety of disciplines as if they were all potential chemistry majors. We could conceivably allow instructors more flexibility to focus on biological applications in one section of CHEM 1111; chemical, physical, geological, and environmental applications could be the focus in a second section; and the third section could use a variety of chemistry in everyday life examples. All three sections would have many similar learning goals but the exams would no longer be common exams. This approach would limit section options that are currently available to students, but they would receive the same foundation required for sequence chemistry courses. In addition, it would become necessary to offer these options in CHEM 1131, which currently has only two sections in the Spring.

Improvements in TA Preparation

The lab performance of TAs improved significantly after we required all CHEM 1111 and CHEM 1131 TAs to perform the experiments scheduled for the course. They also write detailed lab reports that are graded and feedback is provided. However, the performance of some TAs on the hour exams show weaknesses that concern us about the quality of instruction provided during recitations and in the Help Room. Attendance at lecture is mandatory for inexperienced teaching assistants, but it is clear that some of them do not attend many of the lectures.

To address these concerns, we would bring new graduate students a week earlier in August and pay them a stipend to participate in TA training activities. These would include training in effective teaching, short presentations on chemistry topics presented in general chemistry, electronic homework assignments, and assessment of readiness to teach using our general chemistry final exams. Both Chemistry faculty and SEI personnel would take part in this training. We will ensure that there are effective assessment mechanisms in place, so that the training can be improved in future years.

Summary

1. To evaluate/develop learning goals and assessment tools in a variety of general chemistry courses to better prepare CU-Boulder students for the challenges of the 21st century.
2. To pilot new approaches to teaching freshman general chemistry with a focus on discipline-specific examples and real life applications.
3. To integrate lecture demonstrations and multimedia in a more efficient way without increasing the workload of students.
4. To focus on the scholarship of teaching and learning by enhancing our TA training program.